EFFECTS OF THE VARIABLE FLOW REGIME ON THE ECOLOGY OF THE BLACK CANYON OF THE BEAR RIVER, IDAHO

Prepared for PacifiCorp
&
the Environmental Coordination Committee

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ACRONYMS AND ABBREVIATIONS

AFDW	Ash-Free Dry Weight
AI	Autotrophic Index
ANOVA	Analysis of Variance
APHA	American Public Health Association
BF	Bankfull
BMI	Benthic macroinvertebrate
BWD ratio	Bankfull width / bankfull water depth
CFS	Cubic Feet per Second
CL	Confidence Level
cm^2	square centimeters
CPUE	Catch per Unit Effort
ECC	Environmental Coordination Committee
FERC	Federal Energy Regulatory Commission
g	Grams
ID DEQ	Idaho Department of Environmental Quality
m^2	square meters
mg	Milligrams
MSE	Mean square error
NZMS	New Zealand mud snail
R	Reach
RBT	Rainbow Trout
ΔT	Temperature Difference
T	Transect
μG	Micrograms
WP	Wetted Perimeter
Wr	Relative Weight
WY	Water Year

1. INTRODUCTION

The effects of flow regulation on stream ecology and fish populations have been and will continue to be widely studied throughout the world (Petts 1984; Naiman and Bilby 1998). Many studies have been and will be conducted in conjunction with the relicensing of hydroelectric projects. These studies are designed in part to evaluate operational effects on downstream water quality and quantity, aquatic biota and habitats, channel structure and stability and on recreational activities such as rafting and fishing.

In December 2003 PacifiCorp received a new operating license for the Bear River Hydroelectric Project (FERC No. 20) located in southeast Idaho. The new license includes a condition requiring PacifiCorp to implement and study a variable flow regime at the Grace Hydropower Facility in the 6.2 mile reach known as the Black Canyon between Grace Dam and the Grace powerhouse. PacifiCorp, in collaboration with the Environmental Coordination Committee (ECC), developed a monitoring plan for the Black Canyon of the Bear River to characterize the aquatic biota and habitat responding to the new minimum instream flow regime and compare those results with the aquatic biota and habitat resulting from the variable flow regime associated with recreational whitewater boating flows.

This study plan focuses specifically on the effect of the variable flow regimes on aquatic biota and habitat in the Black Canyon of the Bear River in southeast Idaho. The study is designed to evaluate and quantify changes in the abundance, composition and distribution of aquatic biota and habitat longitudinally across sites and through time as well as compare post-disturbance conditions to a reference reach.

In years 2005-2007 Phase I monitoring studies were conducted to characterize the aquatic biota and habitat present under the new minimum instream flow conditions in the FERC license. In years 2008-2010, the FERC license requires PacifiCorp to provide periodic whitewater boating flows below Grace Dam. The objective in the 2008-2010 Phase II study is to characterize the aquatic biota and associated habitat exposed to variable flow regimes resulting from whitewater releases. Data from the 2005-2007 Phase I study (baseline conditions) will be compared to results from the 2008-2010 Phase II study (variable flow conditions) to determine the effects of whitewater releases from Grace Dam on fisheries, macroinvertebrates, periphyton and aquatic habitat at three study reaches located in the 6.2 mile bypass reach.

Specifically the Black Canyon Monitoring Plan includes investigation of: 1) Macroinvertebrates—population trends, diversity and community indices; 2) Organic Matter Ash-Free Dry Weight (AFDW); 3) Periphyton—chlorophyll concentration and biomass; 4) Fisheries—population trends, community composition, fish condition; 5) Filamentous Algae—density; and 6) Channel Morphology—shape and substrate composition.

The Black Canyon Monitoring Plan includes a reference reach located upstream of Soda Reservoir and three experimental reaches within the Black Canyon. The reference reach is not subjected to the flow fluctuations associated with the whitewater releases but is partially regulated by Bear Lake. Field sampling occurred once annually in October. Field sampling was initiated in October 2005 and will conclude in October 2010.

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2. STUDY AREA

The Bear River originates in Summit County, Utah in the northern Uinta Mountains in the Wasatch National Forest. From an aerial perspective, the Bear River is a giant three state loop originating in Utah, traversing north into Wyoming then curving west into southeast Idaho before bending in a southerly direction back into Utah and emptying into the Great Salt Lake. This circuitous route is dictated by the north-south orientation of mountain chains and corresponding valleys. In the higher elevation zones, snow is the dominant form of precipitation. Accordingly, the majority of the annual hydrograph occurs during spring snowmelt.

Since European settlement in the 1850's numerous water diversion dams and storage reservoirs have been constructed on the Bear River for irrigating agricultural lands. The most notable storage was the diversion of water into the formerly closed basin Bear Lake via Stewart Dam and an associated canal system. This canal system greatly increased the storage capacity in the Bear River basin and consequently altered the annual hydrograph significantly below this diversion point. In the 1900's, additional dams and diversions were constructed for hydropower generation and irrigation.

This study encompasses four study reaches (Figure 2-1). Reach 1 located upstream of Soda Reservoir serves as the reference reach for this study. Reaches 2, 3, and 4, located downstream of Grace Dam, serve as the experimental reaches. This 6.2 mile section of the Bear River below Grace Dam is known as the Black Canyon named after the basalt walls of the incised canyon. Approximately 0.5 miles downstream of Grace Dam, the Bear River cuts through a basalt bedrock layer into the Black Canyon. The river gradient in the Black Canyon is considerably steeper relative to upstream and downstream reaches. In the Black Canyon the character of the Bear River alternates between steep cascades, plunge pools, riffles and runs. Channel shape and structure is dominated by bedrock ledges and large boulders. In contrast, reach 1 upstream of Soda Reservoir has a flatter gradient and more closely resembles an alluvial channel with alternating erosion and deposition zones.

2.1 REACH 1: UPSTREAM OF SODA RESERVOIR

Reach 1 was located approximately 1 mile upstream of Soda Reservoir. Five transects were sampled in a 0.25 mile reach directly upstream of Bailey Road. This section of the Bear River was located in a broad alluvial valley. The reach was a Rosgen C type channel. The predominant habitat type was alternating riffles and runs with clearly demarcated scour and deposition zones exhibited by the gravel/cobble point bars above the wetted perimeter. Bankfull zones were clearly delineated by grasses and woody vegetation. The substrate was highly embedded with fine silt and sand. In higher velocity riffle areas substrate was less embedded. In lower velocity runs a thick mat of periphytic algae blanketed cobbles and gravels further trapping fine sediments.

Reach 1 served as the reference reach for comparison with reaches 2, 3 and 4 which were scheduled for periodic spring flow fluctuations required in the new FERC license for the Grace hydropower project. Instream flows in reach 1 were partially regulated by a combination of upstream dams and reservoirs. The peaks in the spring snowmelt hydrograph were buffered by upstream reservoir storage. Instream flows remained above normal through August and early September to meet downstream irrigation needs. Discharge averaged 118 cfs during the October sampling effort in 2007.

2.2 REACH 2: DOWNSTREAM OF GRACE DAM

Reach 2 was located directly downstream of Grace Dam just west of the Highway 34 bridge and the power canal viaduct. Instream flows were relatively stable year-round regulated by releases from Grace Dam. Discharge averaged 82 cfs during the 2007 October sampling effort. Transects A through E spanned approximately 800 meters from upstream to downstream. Transects A through C were indicative of the scour and deposition found in alternating pool and riffle stream habitat types with the exception that the pool areas are largely filled in with sand and silt. This reach was a Rosgen Type C channel. Transects D and E were distinctly different than transects A, B and C. The gradient increased slightly and the substrate shifted to larger particle sizes including extensive bedrock shelves in transect D. Transects D and E were located at the nick point where the Bear River begins cutting through the basalt shelf into the Black Canyon.

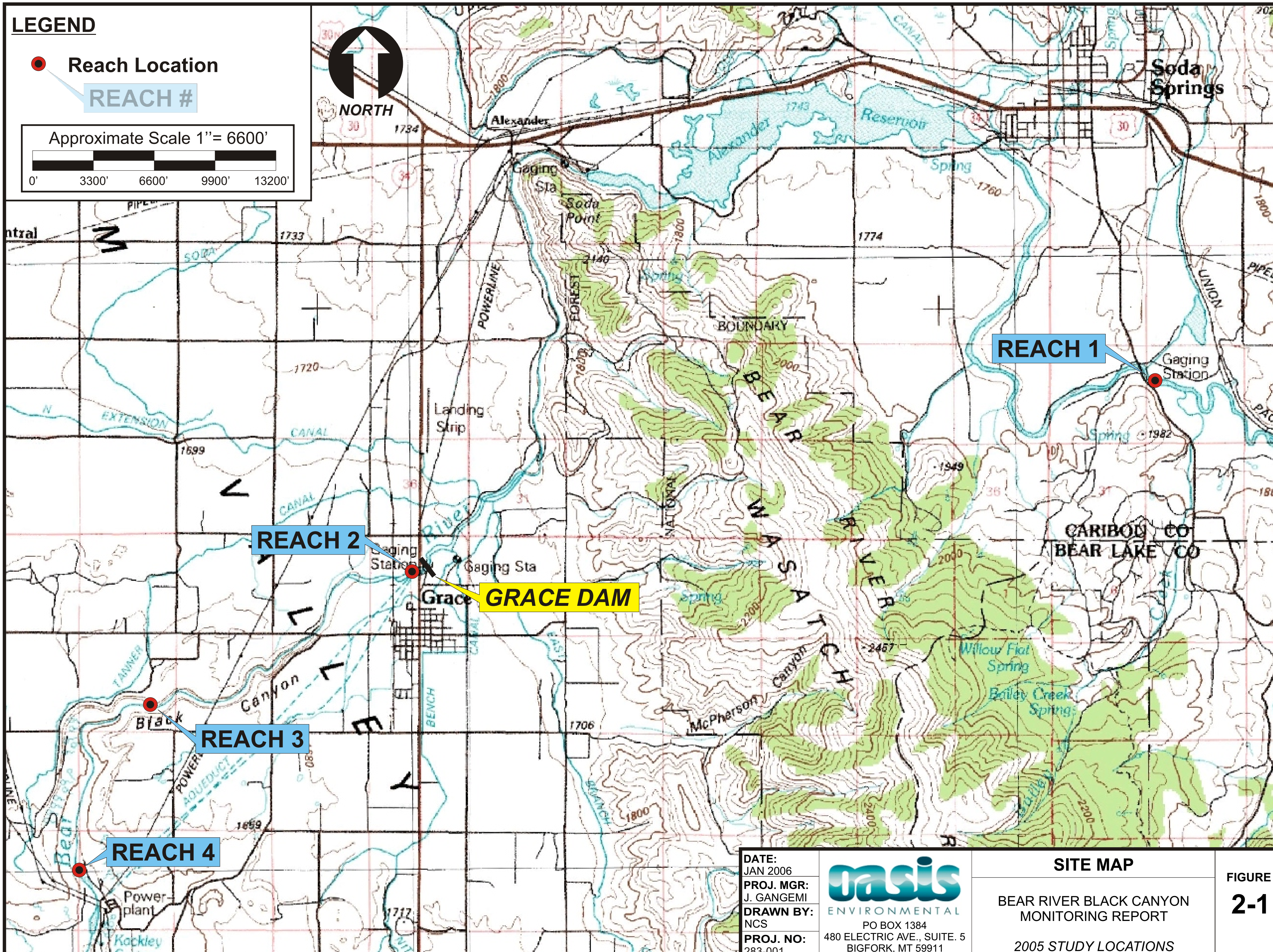
2.3 REACH 3: BLACK CANYON

Reach 3 was located in the incised canyon of the Bear River known as the Black Canyon. Instream flows were relatively stable year-round regulated by releases from Grace Dam. Discharge averaged from 82 cfs during the 2007 October sampling effort. Mladenka and Van Every (2004) established five transects in an ascending order from downstream to upstream, starting with transect 6 and ending with transect 10. For the six-year Black Canyon monitoring study the transects in reach 3 were re-labeled to A, B, C, D and E in descending order from upstream to downstream for consistency with naming conventions in reaches 1, 2 and 4.

Reach 3 was approximately 400 meters long. The reach began 100 meters upstream of a sweeping left hand turn and continued through the turn, ending approximately 25 meters below it. This section of river channel was constrained and defined by the basalt bedrock of the Black Canyon. The outside of the bend (right bank) was defined by the edge of a talus slope stretching down from the top of the canyon walls, 180 ft in elevation above the stream. Much of reach 3 was run type habitat with the exception of Transect A which was riffle habitat. Transect E was located at the start of a 300 meter long pool. Scour around boulders on the right bank formed “pocket water” adjacent to the boulders. Deposition of gravel and sand material formed point bars on the river left bank heavily vegetated with perennials and in some cases woody shrubs. Reach 3 resembled a Rosgen Type C channel.

2.4 REACH 4: BEAR RIVER ABOVE GRACE POWER PLANT

Reach 4 was located at the downstream end of the Black Canyon, approximately 6.2 miles downstream of Grace Dam. This reach was just upstream of the Grace power plant. Discharge averaged 112 cfs during the 2007 October sampling period. Discharge in reach 4 was approximately 30 cfs greater than reaches 2 and 3 due to inflows from spring sources just upstream of reach 4. This reach resembled a Rosgen Type B channel. The channel consisted of high velocity laminar flow over basalt bedrock ledges with corresponding plunge pools. Basalt bedrock ledges were the dominant substrate type. Large mats of filamentous algae clung to a significant percentage of the bedrock substrate.



DATE: JAN 2006	OASIS ENVIRONMENTAL	SITE MAP	FIGURE
PROJ. MGR: J. GANGEMI	PO BOX 1384	BEAR RIVER BLACK CANYON MONITORING REPORT	2-1
DRAWN BY: NCS	480 ELECTRIC AVE., SUITE. 5		
PROJ. NO: 283-001	BIGFORK, MT 59911	*2005 STUDY LOCATIONS*	

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3. METHODS

Field and laboratory methods used for the six-year Black Canyon monitoring study are described for each discipline. Hydrology data for reach 1 and reach 2 was obtained from PacifiCorp. Temperature data for reaches 1, 2 and 4 was obtained from the Idaho Department of Environmental Quality (ID DEQ).

3.1 CHANNEL SURVEY

Channel shape and substrate type were surveyed in October at two of the four study areas. The two reaches surveyed were reach 2 and reach 3, located below the Grace Dam and in the middle of Black Canyon respectively. Five transects were surveyed in each reach. The locations of transects were pre-selected by staff from the Idaho Department of Environmental Quality (Mladenka and Van Every 2004). Each transect was marked with 18" rebar stakes located on both banks, perpendicular to stream flow. The stakes located on the river right bank were labeled with stamped metal tags describing the transect number and location.

In 2005, surveys were conducted with a CST/Berger precision autolevel and metric stadia rod. The 2006, 2007 and 2008 surveys were conducted with a Leica Total Station and rod mounted prism. Surveyed elevations for each cross section included right and left bank pins, bankfull, wetted perimeter and channel elevations. The latter elevations were taken at major elevation changes or in one meter increments, whichever occurred first. Substrate type was recorded with each elevation point.

Surveys of both reaches started with shooting benchmark elevations established in 2004 by Idaho DEQ. These elevations were re-set to 100 meters for calculation purposes.

Bankfull features were difficult to identify in reaches 2 and 3 due to the effects of flow regulation, grazing in reach 2 and vegetation encroachment in reach 3. Deposition zones and scour common in stream systems with fluctuating flow regimes were not evident in reaches 2 and 3. The field crew conducting channel surveys in 2005, 2006, 2007 and 2008 consisted of the same individuals each year for consistency identifying bankfull features in these reaches.

3.2 SUBSTRATE SURVEY

Wolman pebble counts were conducted on reaches 2 and 3. The pebble count for reach 2 started at a randomly selected point in transect TD (ID DEQ T4). The pebble count for reach 3 started at a randomly selected point in transect TD (ID DEQ T7). Standard procedures for conducting Wolman pebble counts were followed (Wolman 1954). Particles were classified into six categories: Fines (0-0.062 mm), Sand (0.062-2.0 mm), Gravel (2.0-64 mm), Cobble (64-256 mm), Boulder (256-4096 mm), and Bed Rock. Pebble counts were conducted in an upstream direction due to the high amount of fine sediment mobilized in the water column.

3.3 PERIPHYTON

Periphyton was sampled in all four study reaches using natural substrate material. Cobble substrate was randomly selected in each transect of the four study reaches. After removal from the stream, a 4 cm by 4 cm surface area was immediately scraped with a razor blade and the dislodged material rinsed with deionized water into a Nalgene filtering apparatus containing a 47 mm Gelman A/E glass-fibre filter. Two samples were scraped and filtered from each rock substrate for paired analysis of AFDW and chlorophyll concentrations. Filtered material was stored on dry ice in dark containers to prevent pigment degradation. Periphyton samples were analyzed for the concentration of chlorophyll a, b and c according to the methods described in the Standard Methods for Examination of Water & Wastewater (American Public Heath Association, 20th ed., 1999). Periphyton samples were homogenized and extracted with 90 percent acetone. Chlorophyll concentration was determined using a spectrophotometer correcting for degraded materials within the sample.

3.4 FILAMENTOUS ALGAE

Filamentous algae and macrophyte coverage was quantified along five transects in each of the four study reaches. Researchers deployed a 50 cm by 50 cm pvc square sampler further divided into quarter sections by an intersecting grid at 25 cm. The algal coverage for each quarter cell in the grid was recorded as a percentage per cell. The cumulative percent coverage per 0.25 m^2 was summed and expressed as filamentous algal coverage per m^2.

3.5 FISHERIES

Electrofishing was used to sample three designated study reaches and one upstream reference reach of the Bear River. For the 2009 sampling event, all sampling was conducted from October 6, 2009 to October 8, 2009 under similar stream flow conditions. In October 2007, 2008, and 2009, a Halltech model HT-2000 electrofishing unit was used to sample 100-meter long sections of each reach. For the October 2005 and 2006 sampling events, a Smith-root model 12-B backpack electrofishing unit was used. In each section, a three person crew conducted two consecutive upstream electrofishing passes, collecting all fish possible with dip nets. All captured fish were anesthetized, identified by species, weighed in grams, and total length was measured in millimeters. All rainbow trout captured were checked for freeze-brands and the location and orientation of the freeze-brand was recorded.

For each reach, relative species composition was determined by taking the total number of fish caught of each species, dividing by the total catch of all species, and multiplying by 100 (% of catch). In addition, relative biomass by species was determined for each reach by taking the total weight of each species, dividing by the total weight of all species, and multiplying by 100 (% of biomass). Catch per unit effort (CPUE) was calculated by dividing the total number of fish collected in two passes by the total electrofishing effort in minutes.

Relative weight (Wr) was used to assess the condition of rainbow trout and common carp according to the methods described by Anderson and Neumann (1996). The condition (relative weight) of the other species collected was not determined because the relative weight equations have not been developed for those species or they were not within the applicable length for the equations.

3.6 BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrates were sampled in October at all four study reaches. In each reach, five transects were sampled. In 2005, eight BMI samples were combined into a single composite sample for each transect. In total, forty BMI subsamples were collected for each study reach. Individual subsamples were randomly located laterally along each transect encompassing a variety of microhabitats.

In 2006, 2007, 2008 and 2009 BMI samples were divided into two jars per transect to test the variance in single surber samples verses composite samples. The first surber sample was collected in the thalweg of the transect and preserved in a separate reference jar referred to as the single surber (SS) sample. The remaining seven surber samples were collected laterally along the same transect in a random fashion and combined in the field to become a composite. These seven surber samples were referred to as the composite sample (CS).

Samples were collected using a 400 cm^2 surber sampler with 500 µm mesh. The substrate was disturbed to a depth of 10 cm. Individual substrate was scrubbed clean of attached material and organisms. The effort used per collection of each individual sample was consistent throughout all the study reaches. Samples were preserved in 90 percent isopropyl alcohol in the field then decanted in the laboratory and preserved in 95 percent ethanol for long-term storage.

Identification and enumeration was performed by EcoAnalysts in Moscow, Idaho. In 2005, macroinvertebrates were processed according to Idaho DEQ standards. These standards include the identification of 500 organisms to the genus/species-level (or the lowest possible level) for all groups of organisms.

In 2006, 2007, 2008 and 2009 the laboratory sorting procedure was modified to account for differences in the size of the samples and allow comparisons of the within-site variability between SS samples and CS samples. The SS sample (1/8 of the transect) was sub-sampled to 200 organisms. In the event that the sample contained fewer than 200 organisms, the entire sample was sorted. The CS (7/8 of the transect) was sub-sampled to 500 organisms.

3.7 ORGANIC MATTER ASH-FREE DRY WEIGHT

Organic Matter present in BMI samples was quantified using American Public Health Association (APHA) Standard Methods (1999) for Ash-Free Dry Weight (AFDW). A subsample of each composite BMI sample was homogenized, filtered, weighed after drying at 100 ºC and re-weighed again after being placed in the muffle furnace at 500 ºC to measure the amount of organic material expressed as AFDW. The data was standardized to represent the amount of organic material per square meter in grams.

3.8 STATISTICAL ANALYSIS

Statistical analysis was carried out using a single factor ANOVA (α = 0.1) to compare differences among the four study reaches within a sample year. Statistical comparisons between the four sample years within an individual study reach were undertaken with the single factor ANOVA (α = 0.1) and the non-parametric Kruskal-Wallis H-Test. Baseline conditions for sample years 2005 through 2007 were compared to variable flow conditions within individual study reaches using the single factor ANOVA (α = 0.1) and the non-parametric Kruskal-Wallis H-Test.

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4. RESULTS

The October 2005, 2006, 2007, 2008 and 2009 monitoring results are organized into the seven resource parameters. Histograms were used to present descriptive statistics (averages and confidence levels, alpha = 0.1) organized by respective reaches and sample years as well as comparisons between baseline conditions (2005-2007 sample years) with variable flow conditions (2008 and 2009 sample years). Statistical analysis using the parametric single factor ANOVA ($\alpha = 0.1$) and the non-parametric Kruskal-Wallis H-Test were used to compare results within an individual site over the four sample years and between baseline and variable flow conditions. Non-parametric tests were used in cases where sample variance was significant (Bartlett-Test for homogeneity of variances) thereby violating use of the single factor ANOVA.

4.1 HYDROLOGY

The 2009 sampling effort occurred from October 6 – 8 under MIF conditions regulated by PacifiCorp's Grace Dam. Discharge in reach 1 was partially regulated by flows from the Lifton Pump Station at Bear Lake. Discharge varied annually during the annual October sampling events due in part to regulation from Grace Dam and partial regulation from Lifton Pump Station (Figure 4.1-1).

In reach 1, the annual hydrograph was largely shaped by irrigation withdrawals from Bear Lake during the summer months. This partial regulation from Bear Lake affects the annual timing, magnitude and duration of peak flows in reach 1 (Figure 4.1-2). Discharge during the summer irrigation delivery period (generally July 1 to September 1) resulted in prolonged high flows later in the summer season. In 2005, daily average discharge was greater than 1000 cfs from July 1 to August 1. In 2006, daily average discharge remained less than 1000 cfs from July 1 through September 1. In 2007, daily average discharge in reach 1 exceeded 1000 cfs from June 19th through August 4th with additional peak discharges greater than 1000 cfs between August 1 and September 1 2007. In 2008, daily average discharge was typically greater than 1000 cfs from August 1 through September 3. In 2009, daily average discharge greater than 1000 cfs occurred from July 12 through 26. During the baseline sampling period, the highest peak discharge was 1610 cfs on July 8th, 2007. During the period for variable flows, peak flows in reach 1 occurred on November 8, 2007 and October 20, 2008 (1460 and 1290 cfs respectively).

In reach 2, discharge was controlled by flow regulation at Grace Dam. The average annual discharge during the baseline period for respective water years was 102 cfs in 2004-2005, 83 cfs in 2005-2006 and 93 cfs in 2006-2007. Releases above the minimum instream flow (MIF) occurred during each of the three baseline study years. Only one of these releases was substantially greater than the MIF, a spring pulse flow of 863 cfs on April 17, 2005. No other releases of this magnitude occurred during the three-year baseline monitoring period. The average annual discharge during the variable flow period (2008 and 2009) was 92 cfs in 2007-2008 and 95 cfs in 2008-2009.

Variable flow releases from Grace Dam were conducted in 2008 and 2009 affecting reaches 2, 3 and 4. In 2008, a total of five releases were made from Grace Dam (Table 4.1-1). Flows ranged from 940 to 1344 cfs spanning April to mid-July. In 2009, eight variable flows occurred ranging from an instantaneous peak of 869 cfs to 1140 cfs between April and mid-July.

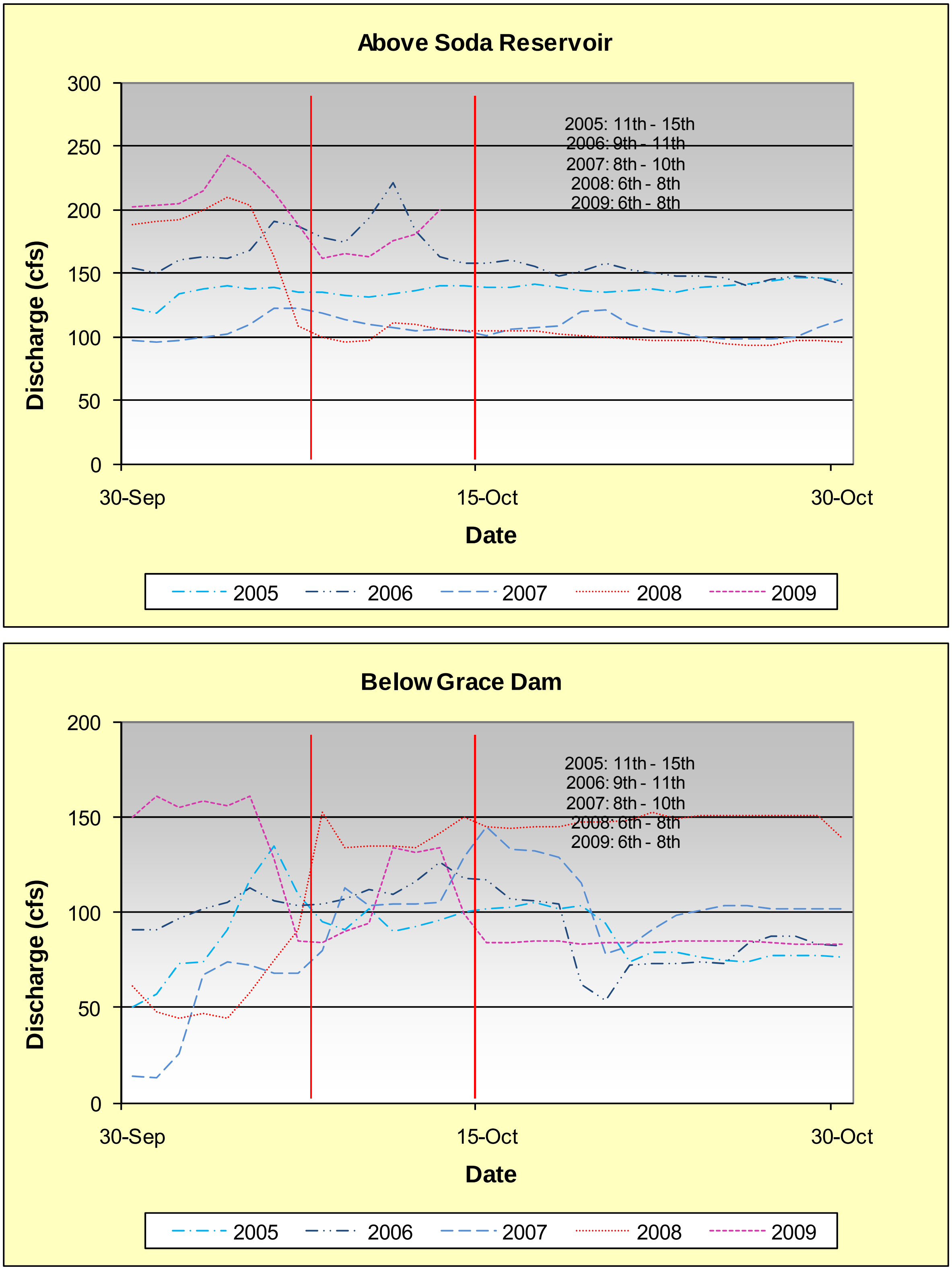
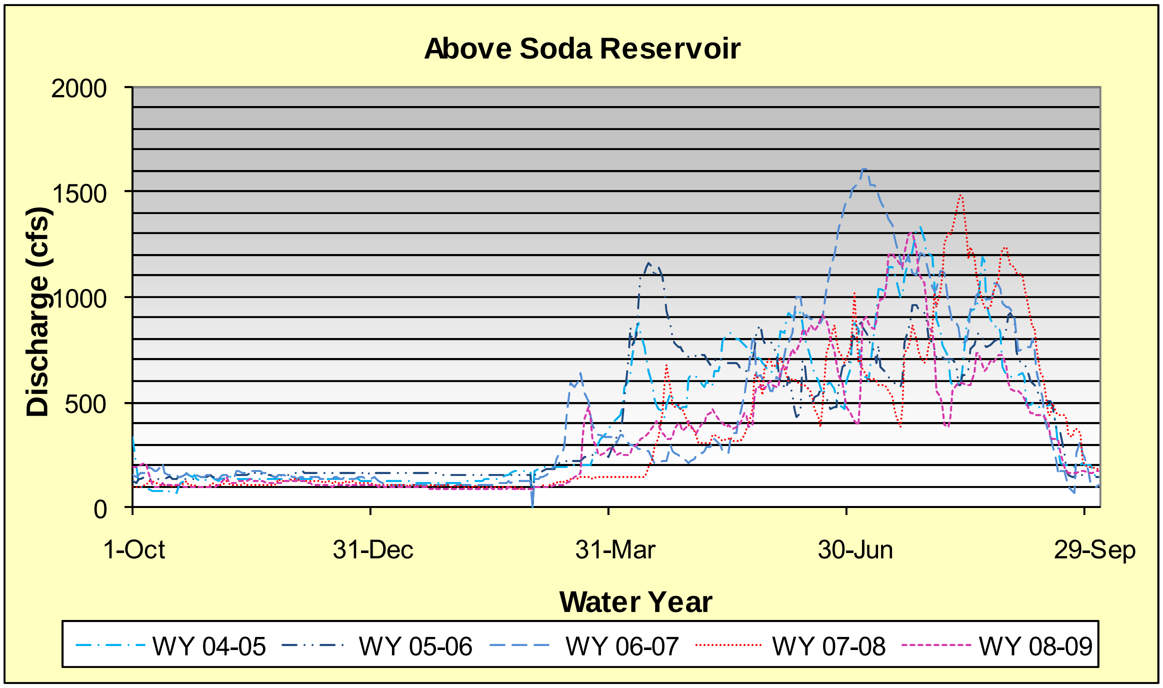


Figure 4.1-1: Discharge, October sampling period, 2005 through 2009



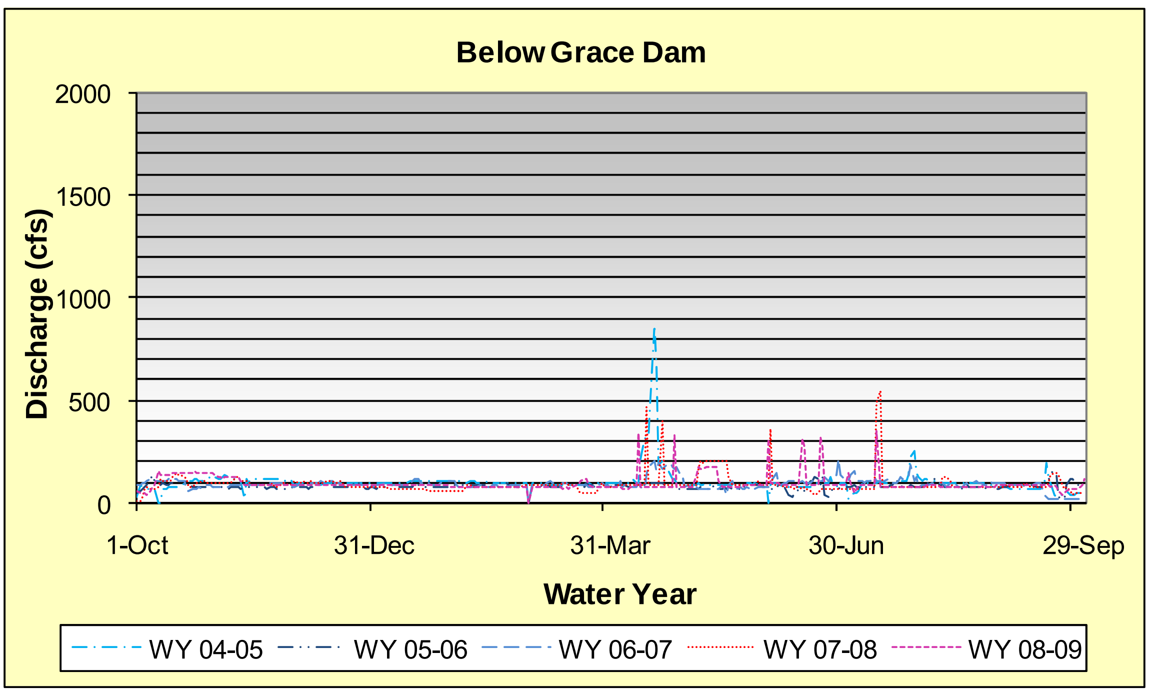


Figure 4.1-2: Annual daily average discharge for reaches 1 and 2 on the Bear River

Reach 3 did not have a staff gage and corresponding rating curve for measuring discharge. It was assumed that discharge in reach 3 was roughly equivalent to that measured in reach 2. Reach 4 also lacked a staff gage. Previous studies estimated that discharge in reach 4 was approximately 30 to 60 cfs greater than reach 2 flows (Connelly Baldwin, personal communication). The additional discharge was from groundwater inflows located at the bottom end of the Black Canyon. For this study we assumed flows in reach 4 were 30 cfs greater than discharge measured in reach 2.

The annual instantaneous peak discharge during the three-year baseline monitoring period for reaches 1 and 2 was lower than annual peaks recorded between 1976 and 2005 (Figure 4.1-3). For the period 1976 to 2004 the average annual peak flow in reach 1 was 1884 cfs. During the three-year baseline monitoring period annual instantaneous peak discharges were 1350 cfs, 1200 cfs and 1610 cfs in 2005, 2006 and 2007 respectively. In 2008 and 2009, the instantaneous peak discharge for reach 1 above Soda Reservoir was 100 and 1300 cfs respectively.

In reach 2, the annual peak discharge for the period 1976 to 2005 was 1012 cfs compared to an annual instantaneous peak discharge of 965 cfs, 222 cfs, and 218 cfs in 2005, 2006 and 2007 respectively. The peak below Grace dam in 2005 was the result of spring run-off in the Bear River watershed. In 2006 and 2007 spring run-off did not result in spill from Grace Dam. In 2006, pulse flows over Grace dam less than 500 cfs instantaneously occurred in September to assist with channel restoration efforts associated with Cove Dam decommissioning. Instantaneous annual peak discharges during the variable flow period in 2008 and 2009 were 1344 and 1140 cfs respectively.

Table 4.1-1: Variable flow events in the reach below Grace Dam in 2008 and 2009.

Year	Date	Description	Sustained Discharge (cfs)	Instantaneous Discharge (cfs)	Downramp Rate
2008	4/14/2008	Scheduled Varial Mapping Event	1290	1344	.25 FT / HR
	4/20/2008	Scheduled Stranding Test	930	940	.25 FT / HR
	6/1/2008	Scheduled Stranding Test	940	980	.25 FT / HR
	7/12/2008	In Flow Dependent Event	1270	1344	.25 FT / HR
	7/13/2008	Scheduled Stranding Test	1280	1310	.25 FT / HR
2009	4/11/2009	Scheduled Stranding Test	889	931	.25 FT / HR
	4/25/2009	Scheduled Stranding Test	898	939	.43 FT / HR
	5/31/2009	Scheduled Stranding Test	954	954	.40 FT / HR
	6/13/2009	In Flow Dependent Event	839	869	.49 FT / HR
	6/14/2009	In Flow Dependent Event	854	877	.53 FT / HR
	6/20/2009	In Flow Dependent Event	858	885	.50 FT / HR
	6/21/2009	In Flow Dependent Event	845	869	.52 FT / HR
	7/12/2009	Scheduled Stranding Test	1118	1140	.46 FT / HR

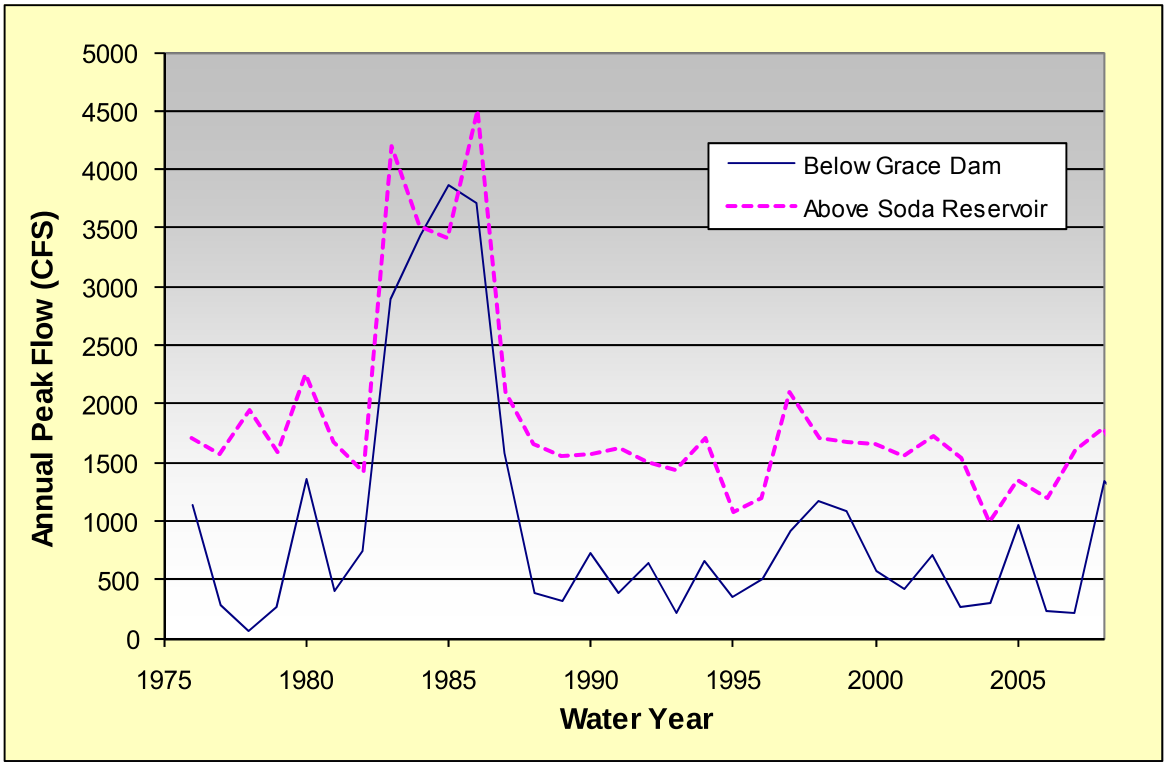


Figure 4.1-3: Annual peak discharge (1976-2009), Bear River, ID

4.2 CHANNEL SHAPE AND SUBSTRATE

Reach 2 transects were surveyed on October 6, 2009 between 0830 and 1430 hours. Discharge was greater than the previous sampling years. Reach 3 transects were surveyed on October 8, 2009 between 0800 and 1130 hours. The flow appeared to be similar to previous sampling years in reach 3. The flows recorded for the Bear River during the previous sampling events in reach 2 were 89 cfs in 2005, 104 cfs in 2006, 65 cfs in 2007, XX cfs in 2008 and XX cfs in 2009. In reach 3 instream flows were 101 cfs in 2005, 107 cfs in 2006, 107 cfs in 2007, XX cfs in 2008 and XX cfs in 2009.

In 2009, reach 2 had a mean bankfull width of 63.34 meters (Table 4.2-1). The mean bankfull widths for reach 2 in 2005, 2006, 2007 and 2008 were 63.04, 62.71, 62.88 and 62.51 meters respectively. In 2009, the bankfull widths were narrowest at transect TE, 48.61 meters, and widest at transect TD, 78.81 meters. Compared to the mean bankfull width during the baseline study period (2005 – 2007), bankfull widths during the variable flow conditions (2008 - 2009) were greater in transect TA, TC and TD; 1.91, 0.36and 1.86 meters respectively. In contrast, mean bankfull widths in transect TB and TE were greater during the baseline period compared to the bankfull width measured under variable flow conditions; 3.11, 0.79 and 0.30 meters respectively.

The mean water depths associated with the bankfull elevation in 2009 were between 0.31 meters at transect TD and 0.62 meters at transect TA. In 2009, the mean water depth based on bankfull elevations was 0.46 meters compared to 0.34, 0.40, 0.43 and 0.38 meters in 2005, 2006 2007, and 2008 respectively. Mean bankfull water depths were similar between the baseline study period and the variable flow conditions for all five transects TB in reach 2.

Beaver activity continues in transect TA altering the left channel and bankfull indicators substantially. Channel cross section profiles for the respective transects exhibit similar shape for the five sample years (Figure 4.2-1).

In 2008, reach 3 had a mean bankfull width of 23.99 meters. The bankfull widths ranged from 19.17 meters at TE to 31.83 meters at TA. The mean bankfull widths for reach 3 in 2005, 2006 and 2007 were 21.78 meters respectively and 20.19 meters in 2008. Mean bankfull widths in transect TA, TC and TE were greater under the variable flow conditions compared to the bankfull width measured under baseline flow conditions; 1.05, 1.14 and 0.75 meters respectively. In 2009, pins were difficult to find in transects TE (right bank pin), TD (right bank pin), TC (left bank pin) and TA (left bank pin) due to a combination of vegetation growth encroaching to low flow channel and deposition of organic material along the base of the woody growth. Despite the increases in bankfull width, channel cross section profiles for the respective transects remained similar in shape for the across the five sample years (Figure 4.2-2).

The mean water depths associated with the elevation of the bankfull indicators were between 0.84 meters at TA and 1.24 meters at TE. The mean bankfull water depth was 1.01 meters in 2009 compared to 0.77, 0.78 0.81 and 0.62 in 2005, 2006, 2007 and 2008 respectively. Compared to the bankfull mean water depths in the baseline study period, the bankfull water depths during the variable flow period were deeper for transects TB, TC and TD, 0.15, 0.10, and 0.19 respectively. Mean bankfull water depth in Transect TA decreased 0.30 meters under variable flow conditions compared to the baseline period. Mean bankfull water depths in transect TE were similar between study periods.

Rosgen (1994, 1996) uses the bankfull width to water depth ratio (BWD ratio) to characterize streams in the Level II stream classification system. The BWD ratio for reach 2 in 2009 ranged from 83.03 at TA to 254.23 at TD. The mean BWD ratio for reach 2 in 2009 was 149.55. The BWD ratio for reach 2 was 241.41in 2005, 185.28 in 2006, 167.09 in 2007, and 182.41 in 2008. Rosgen's stream classification system ranks these BWD indices "very high".

The BWD ratio for reach 3 ranged from 15.46 at TE to 37.89 at TA, and the mean was 24.58. The mean BWD ratio for reach 3 was 29.12 in 2005, 31.95 in 2006, 31.40 in 2007 and 33.64 in 2008. Rosgen ranks these BWD ratios in the "moderate to high" range. ."

Substrate composition in reach 2 during the 2009 sampling period continued to exhibit the dramatic reduction in fines observed during the 2008 sampling period compared to much higher percentage of fines observed under the baseline period (Figure 4.2-3). In 2009, Wolman pebble counts indicated that fines composed only 9% of the substrate composition compared to a mean of 40% during the baseline period. In fact, in the baseline period, fines comprised more than double the amount of any other class size in reach 2. Sand also composed a substantially lower percentage in 2009 compared to the baseline period; 8% compared to 14%. Gravel, cobble, boulder and bedrock were greater in 2009 compared to the baseline period; 19%, 17%, 12% and 31% respectively.

In reach 3, Wolman pebble counts in 2009 indicated an absence of fines similar to that observed in 2008 (Figure 4.2-4). In contrast, fines comprised 7.7% of the substrate in reach 3 during the baseline period. Sand comprised 15% in 2009 similar to the mean of 15.3% during the baseline period. Gravel was 67% of the substrate in 2009 compared to 54.3% in the baseline. Cobble was 17% of the substrate in 2009 compared to 18% in the baseline period.

Table 4.2-1: Channel survey data for reaches 2 and 3; October 2005 through 2009

Reach	Transect	Bankfull Width (m)					Average Bankfull Depth (m)					Bankfull Width/Depth Ratio				
		2005	2006	2007	2008	2009	2005	2006	2007	2008	2009	2005	2006	2007	2008	2009
2	TA	48.85	48.85	49.34	50.36	51.48	0.57	0.58	0.64	0.46	0.62	86.46	84.06	77.38	109.14	83.03
2	TB	67.22	67.22	69.19	64.26	65.28	0.48	0.45	0.48	0.42	0.53	140.97	150.74	145.12	154.80	123.17
2	TC	71.30	71.50	70.79	70.61	72.51	0.31	0.27	0.29	0.31	0.41	226.42	267.65	247.44	225.33	176.85
2	TD	76.57	76.57	76.13	77.75	78.81	0.16	0.25	0.30	0.25	0.31	483.48	312.19	252.06	309.02	254.23
2	TE	51.28	49.42	48.95	49.58	48.61	0.19	0.44	0.43	0.44	0.44	269.73	111.77	113.46	113.76	110.48
Reach 2 Mean		**63.04**	**62.71**	**62.88**	**62.51**	**63.34**	**0.34**	**0.40**	**0.43**	**0.38**	**0.46**	**241.41**	**185.28**	**167.09**	**182.41**	**149.55**
3	TA	28.80	28.80	28.80	27.88	31.83	0.73	1.21	1.33	0.74	0.84	39.34	23.81	21.66	37.57	37.89
3	TB	20.70	20.70	20.70	20.47	20.56	0.63	0.65	0.67	0.57	1.02	33.09	31.95	30.86	35.91	20.15
3	TC	17.10	17.10	17.10	17.09	19.40	0.62	0.65	0.63	0.62	0.85	27.37	26.45	27.21	27.57	22.82
3	TD	24.80	24.80	24.80	18.20	29.00	0.86	0.41	0.41	0.41	1.09	28.77	60.12	59.81	44.34	26.60
3	TE	17.50	17.50	17.50	17.33	19.17	1.03	1.00	1.00	0.76	1.24	17.03	17.44	17.47	22.78	15.46
Reach 3 Mean		**21.78**	**21.78**	**21.78**	**20.19**	**23.99**	**0.77**	**0.78**	**0.81**	**0.62**	**1.01**	**29.12**	**31.95**	**31.40**	**33.64**	**24.58**

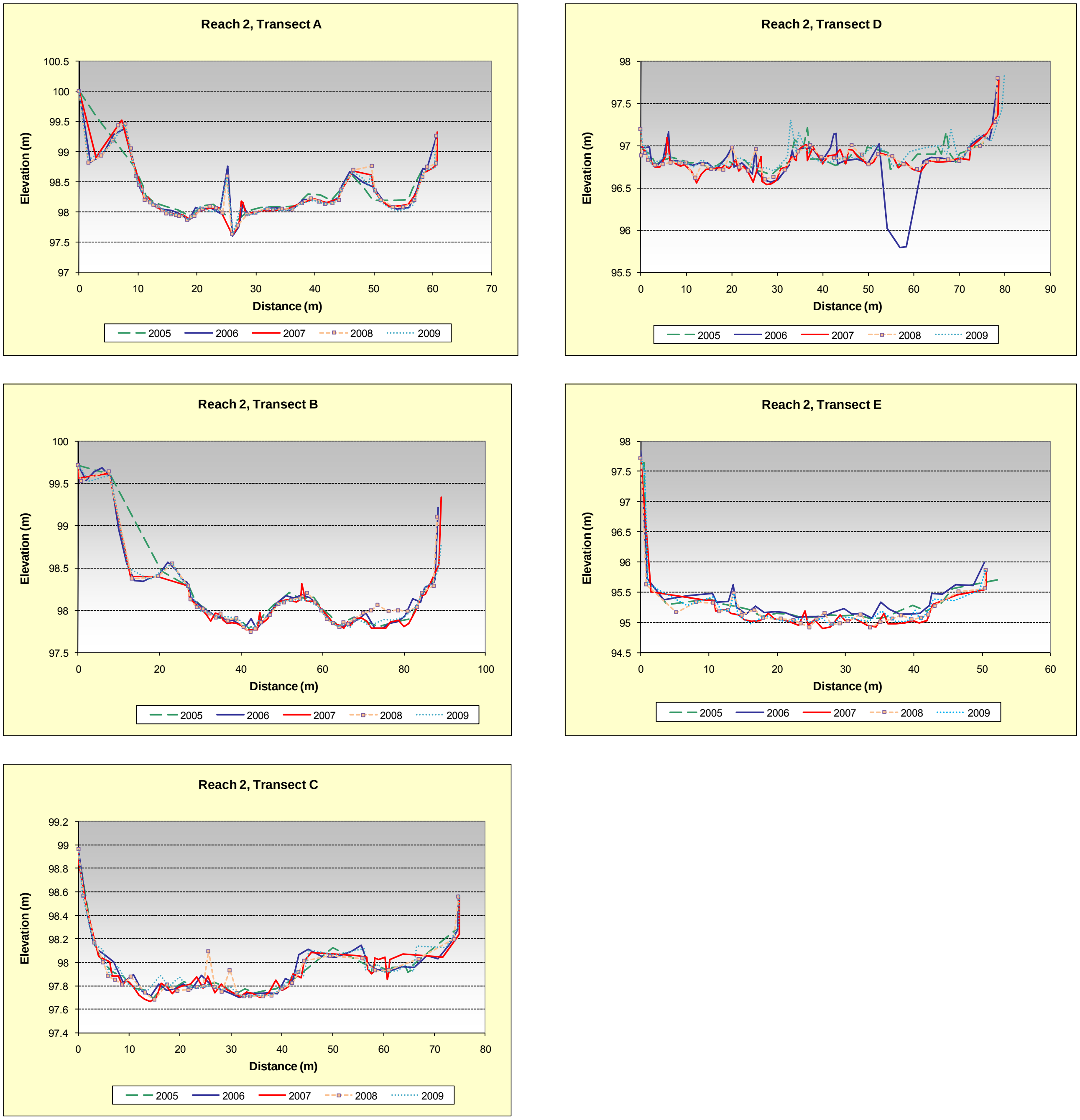


Figure 4.2-1: Reach 2 channel cross sections over the five-year study period.

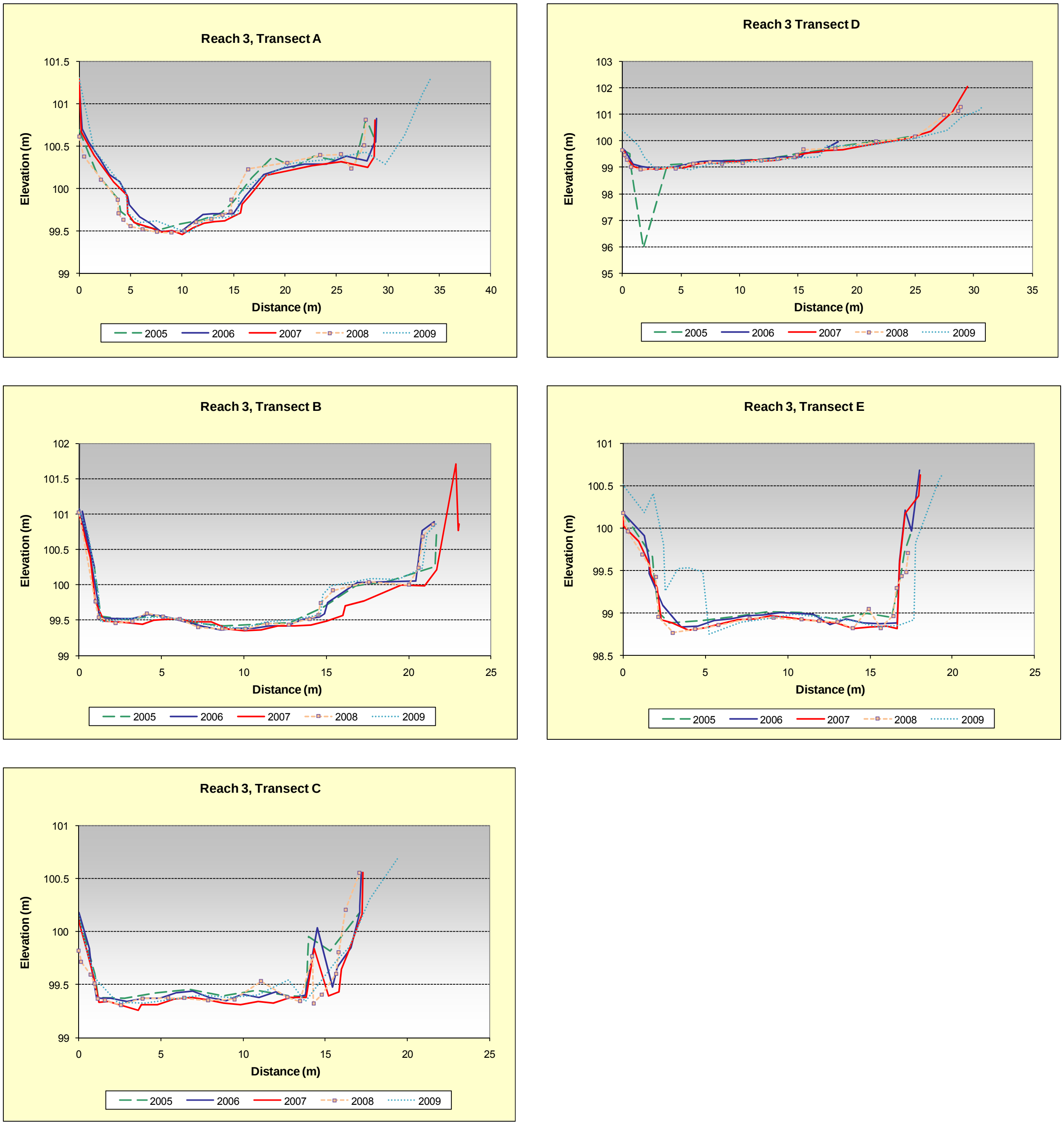


Figure 4.2-2: Reach 3 channel cross sections over the five-year study period.

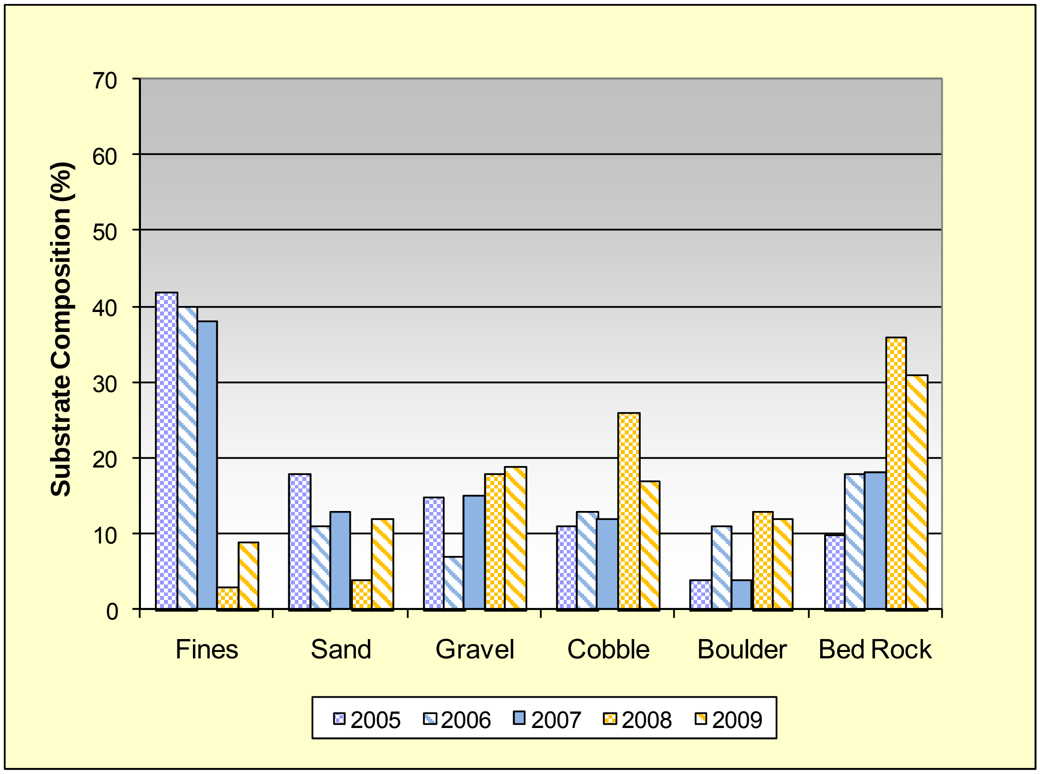


Figure 4.2-3: Substrate composition over five-year study period in reach 2.

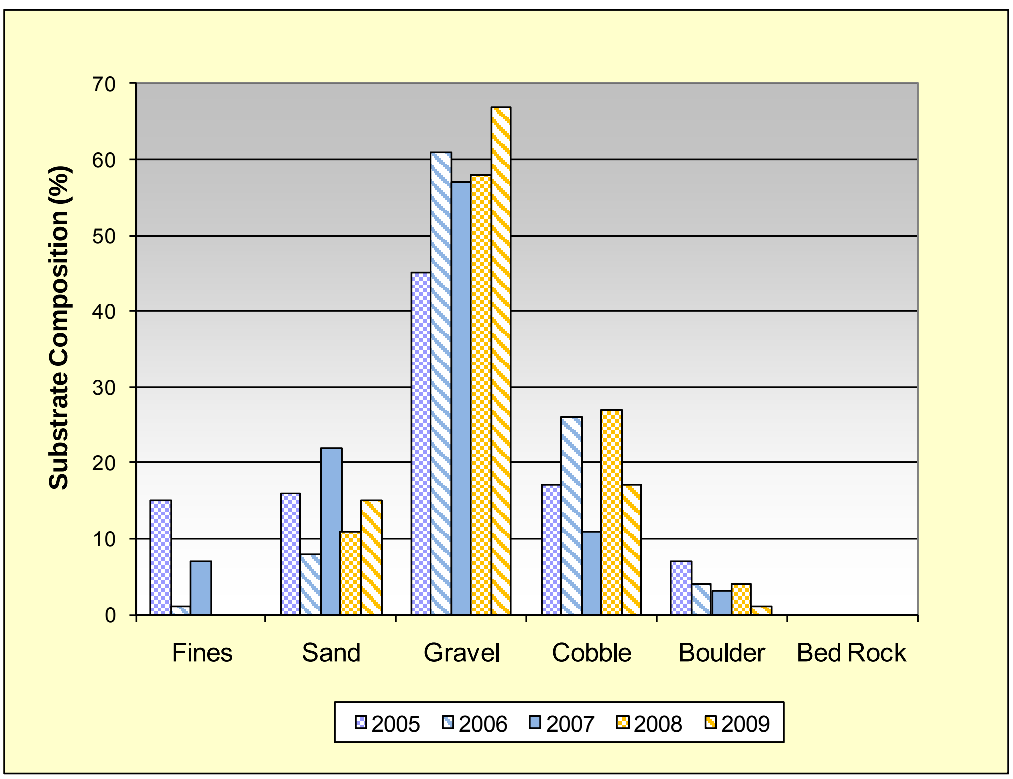


Figure 4.2-4: Substrate composition over five-year study period in reach 3.

4.3 PERIPHYTON— ASH-FREE DRY WEIGHT AND CHLOROPHYLL

Periphyton AFDW in 2009 was similar in reaches 1, 2 and 3 but substantially greater in reach 4 (Figure 4.3-1). The AFDW average in 2009 for each reach was 92.0 g/m^2 100.4 g/m^2, 67.7 g/m^2 and 191.4 g/m^2 for reaches 1, 2, 3, and 4 respectively. Periphyton AFDW was significantly greater in reach 4 (p=0.02, ANOVA) than reaches 1, 2 and 3 in 2009.

Periphyton AFDW comparisons indicate significant differences between sample years within individual study reaches. Sample variance required the use of non-parametric statistics in some reaches. In reach 1, AFDW was significantly lower in the 2005 and 2006 sampling years compared to 2007, 2008 and 2009 sample years (p=0.08, ANOVA). Reach 1 AFDW in 2009 (92.0 g/m^2) was nearly four times greater than the 2008 mean (24.3 g/m^2). In Reach 2, periphyton AFDW was significantly lower in the 2005 and 2008 sampling years compared to 2006, 2007 and 2009 sample years (p=0.002, H-test). In Reach 3, periphyton AFDW exhibited significant differences between sample years using non-parametric statistics (p=0.10, H-test) but was not significant using parametric computations (p=0.11, ANOVA). Samples years 2005 and 2007 exhibited similarities whereas sample years 2006, 2008 and 2009 were more similar in reach 3. In reach 4, periphyton AFDW was significantly greater in 2009 compared to the other four study years (p=0.01, ANOVA). AFDW was more than double in 2009 than any previous sampling year in reach 4. 2009 marked the first year a significant difference in periphyton AFDW was detected in reach 4.

Periphyton AFDW means for the three-year baseline period were higher in reach 1 compared to the two-year variable flow conditions. In contrast, in reaches 2, 3 and 4, AFDW means were lower for the three-year baseline period compared to the two-year variable flow conditions. The differences between the baseline period and variable flow period were significant in reaches 2 and 4 only (p=0.07 and p=0.02 respectively, ANOVA). Reaches 1 and 3 did not exhibit significant differences between the three-year baseline sampling period and two-years of the variable flow regime. The high degree of sample variance during the baseline period in reach 1 makes it difficult to detect differences between sample years.

Periphyton chlorophyll a in 2009 was highest in reach 4 (Figure 4.3-3). The chlorophyll a average for reach 4 was 270.4 mg/m^2 compared to 124.3 mg/m^2, 191.9 mg/m^2 and 116.08 mg/m^2 for reaches 1, 2 and 3 respectively. In the five sample years, reach 4 has had the highest chlorophyll a values each year.

Periphyton chlorophyll a comparisons within individual reaches indicate significant differences between sample years in reaches 1 and 3 only (p=0.007 and p=0.02, H-test and ANOVA respectively). Comparisons between the baseline sampling period and the variable flow regime were significant in reach 3 only (Figure 4.3-4). In reach 3, mean chlorophyll a was significantly higher during the three-year baseline period compared to the variable flow period; 179.7 versus 113.8 mg/m^2 (p=0.02, ANOVA). This difference between the baseline and variable flow periods was observed in reach 3 during the 2008 comparisons as well. No significant differences between the baseline sampling period and the variable flow regime were observed in reaches 1, 2 and 4.

In 2009, the Autotrophic Index (AI) varied between the four study sites(Figure 4.3-5). Reach 1 had the highest AI, 791.6, followed by reach 4, 723.6, reach 2, 622.4 and, lastly, reach 3, 577.8. Periphyton AI comparisons across the five sample years within a single study reach indicate significant differences in study reaches 2, 3and 4 (p=0.04, p=0.03 and p=0.03 respectively, H-test). In reach 4, periphyton AI values were substantially higher compared to the levels observed in the previous four sample years. In reach 2, 2009 AI values were similar to those observed in 2007 and 2008 but higher than 2005 and 2006.

Periphyton AI was greater in reaches 2, 3 and 4 during the variable flow regime conditions compared to the baseline period (Figure 4.3-6). In contrast, reach 1 periphyton AI was greater during the baseline period. These differences between the baseline and variable flow periods was significant in reaches 3 and 4 only (p=0.04 and p=0.01 respectively, H-test).

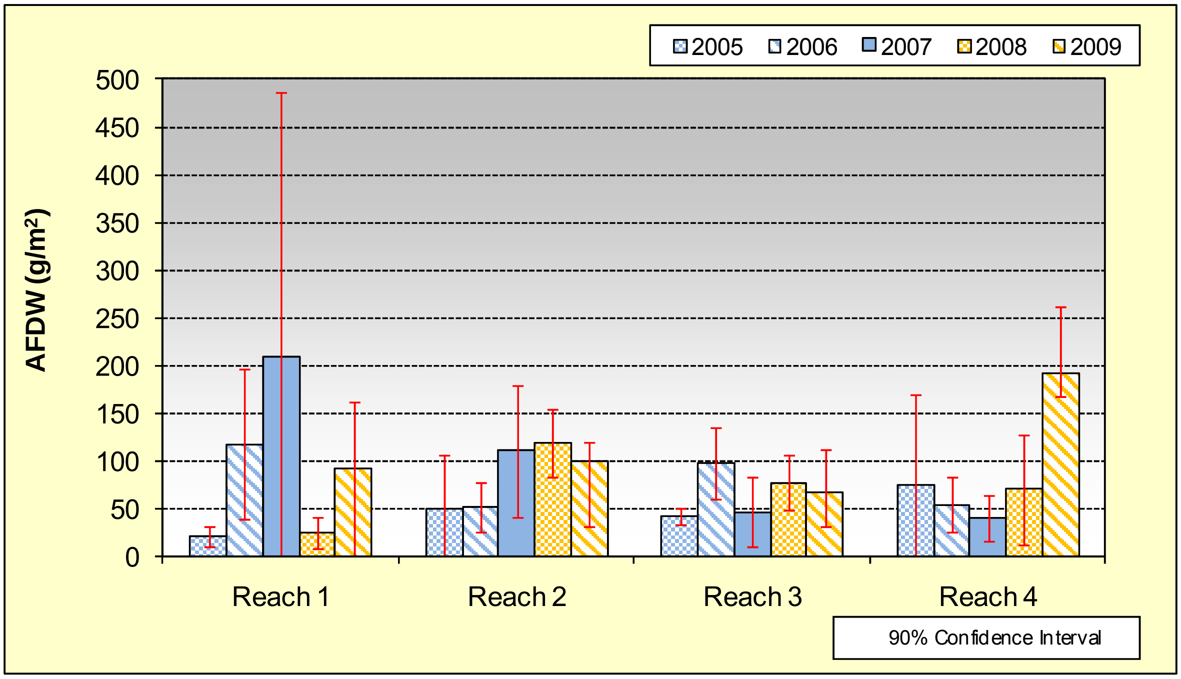


Figure 4.3-1: Periphyton mean AFDW, October 2005 through 2009.

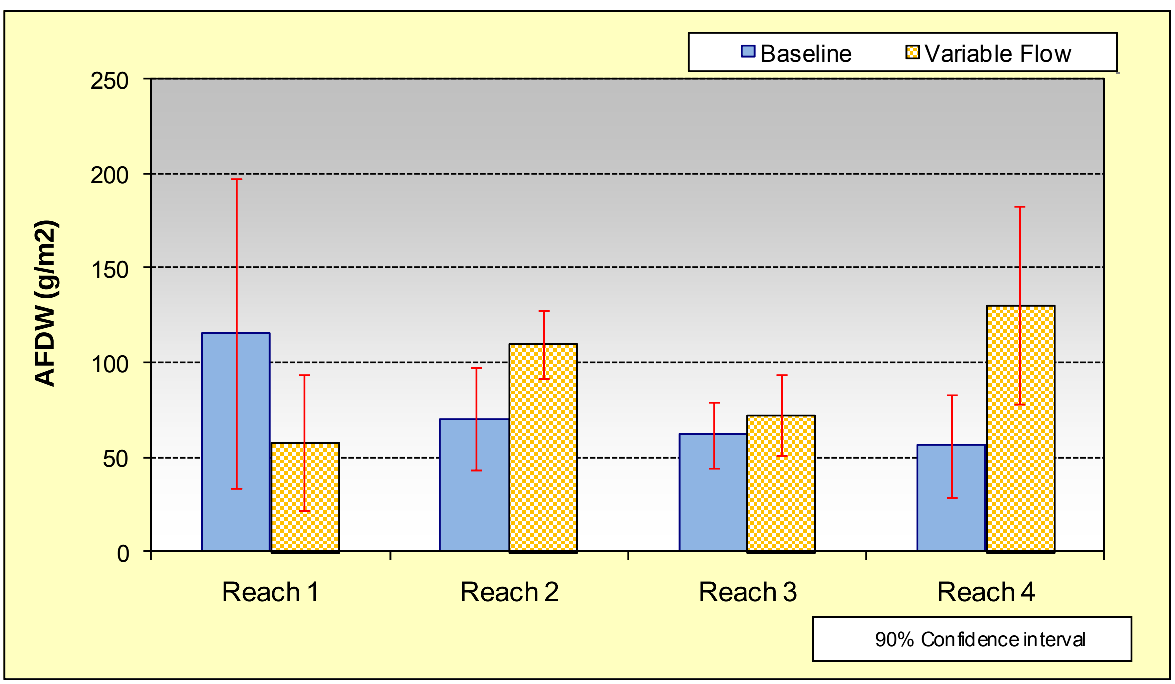


Figure 4.3-2: Periphyton mean AFDW, baseline period versus variable flow.

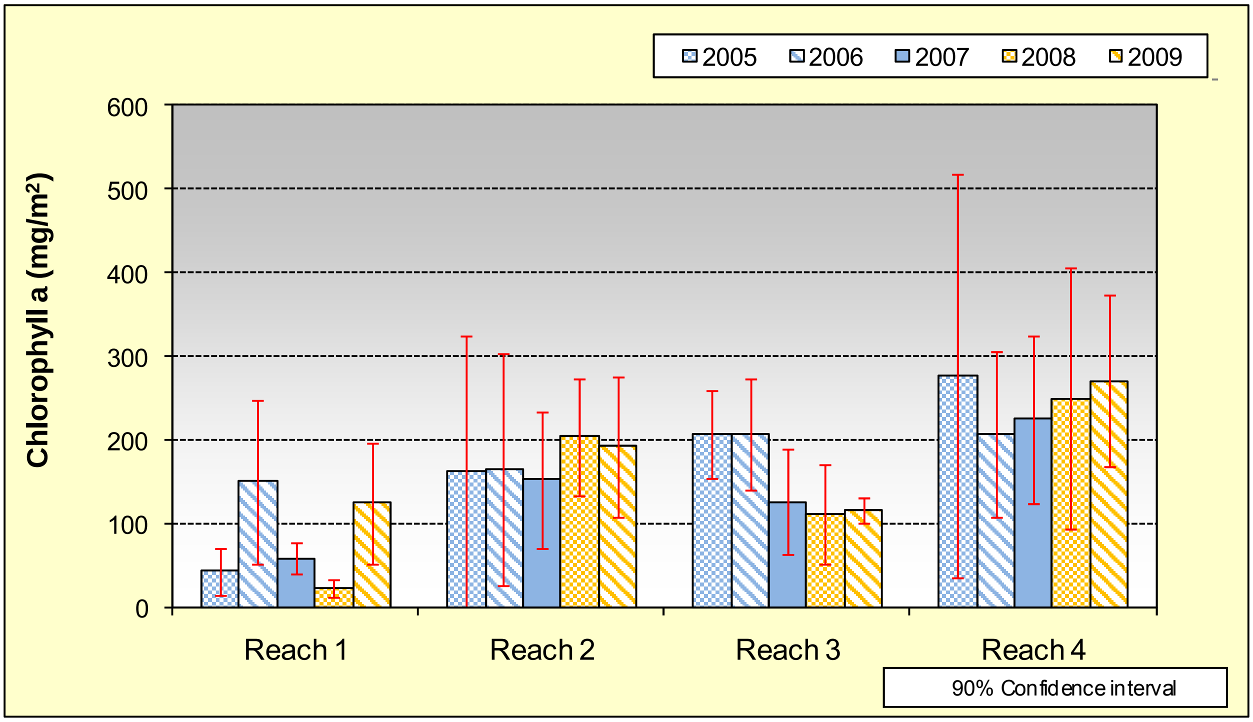


Figure 4.3-3: Periphyton mean chlorophyll a concentration, October 2005 through 2009.

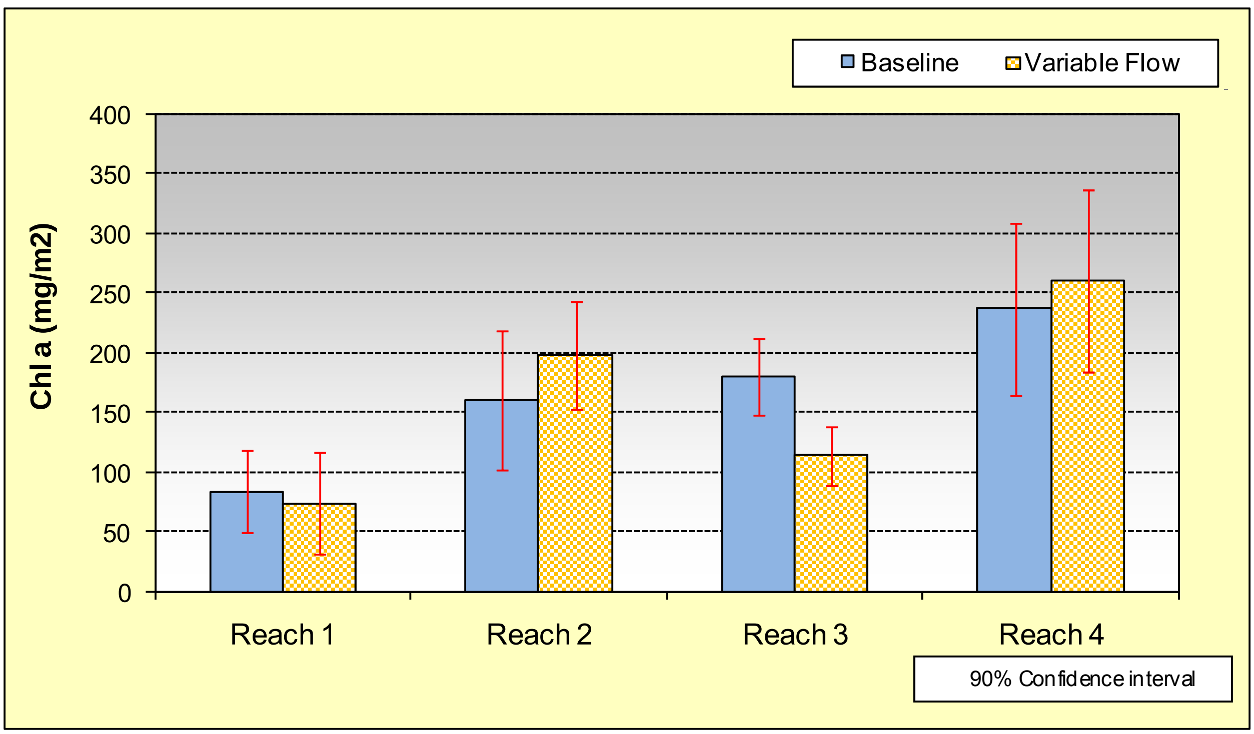


Figure 4.3-4: Periphyton mean chlorophyll a, baseline period versus variable flow.

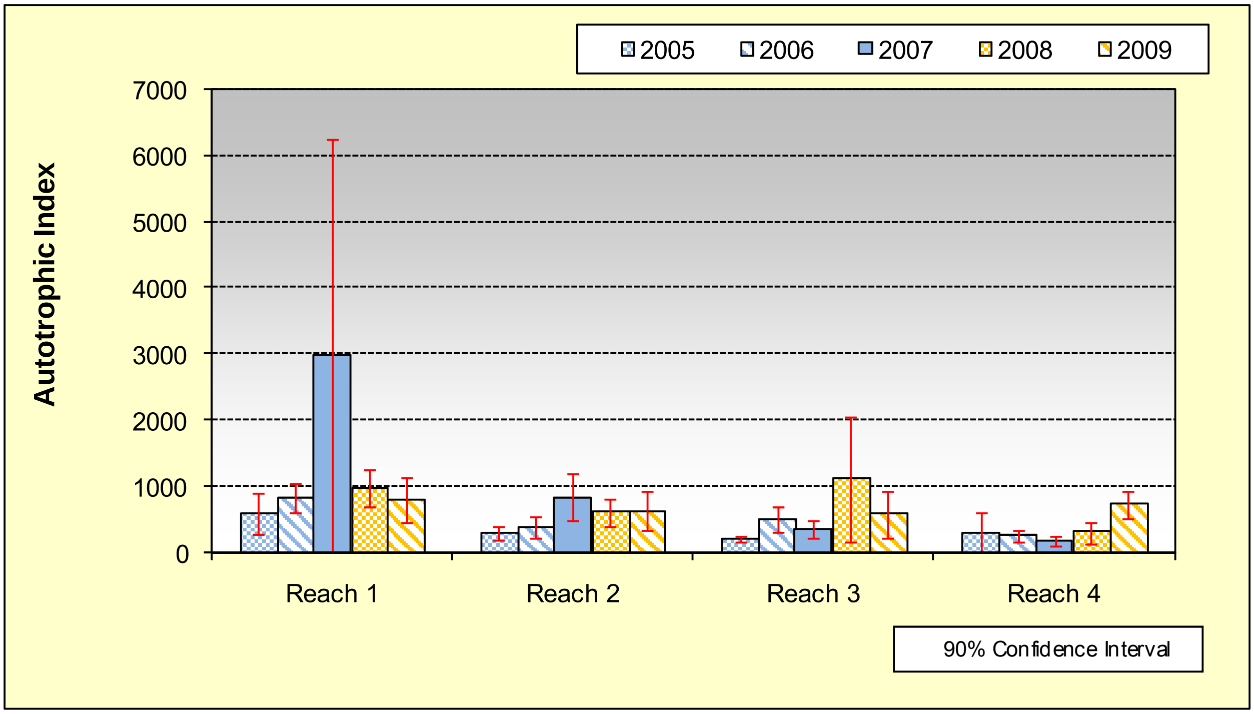


Figure 4.3-5: Periphyton mean autotrophic index, October 2005 through 2009.

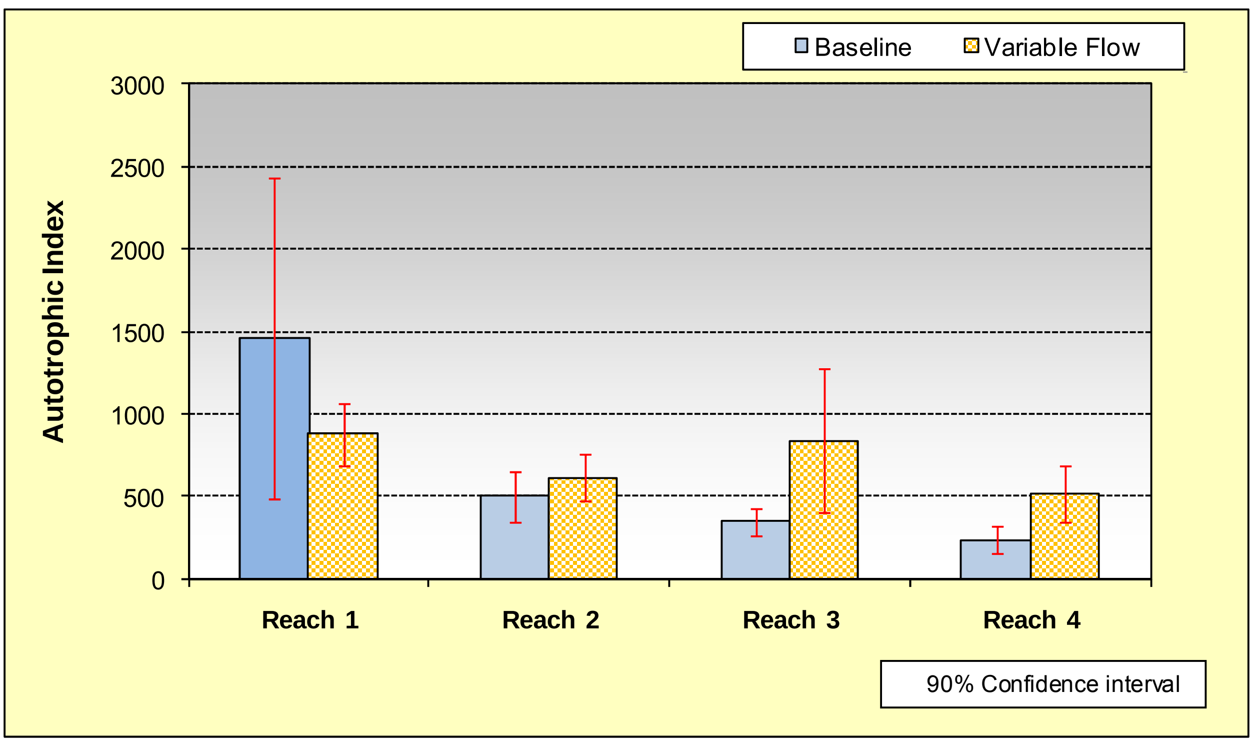


Figure 4.3-6: Periphyton mean AI, baseline period versus variable flow.

4.4 FILAMENTOUS ALGAE

In 2009, filamentous algae cover (Figure 4.4-1) was highest in reach 1 (78%) followed by reach 2 (64%), reach 43 (62%) and, lastly, reach 3(12%). 2009 marks the first year that the percent of filamentous algae coverage was not highest in reach 4. In reach 4, filamentous algae coverage decreased relative to the four previous sample years. Significant differences in filamentous algae coverage was observed within reaches 2, 3 and 4 between sample years (p=0.005, p=0.006 and p=0.06 respectively, H-test). Filamentous algae comparisons within individual reaches indicate significant differences between the baseline sampling period and the variable flow regime in reaches 2 and 3 (Figure 4.4-2). In reaches 2 and 3, mean percent filamentous algae cover was significantly higher during the variable flow conditions than the three-year baseline period; 77% versus 39% m^2 in reach 2 and 32% versus 8% in reach 3 (p=0.003 and p=0.02 respectively, ANOVA). In reaches 1 and 4, filamentous algae cover was higher during the baseline conditions compared to the variable flow period but not significant.

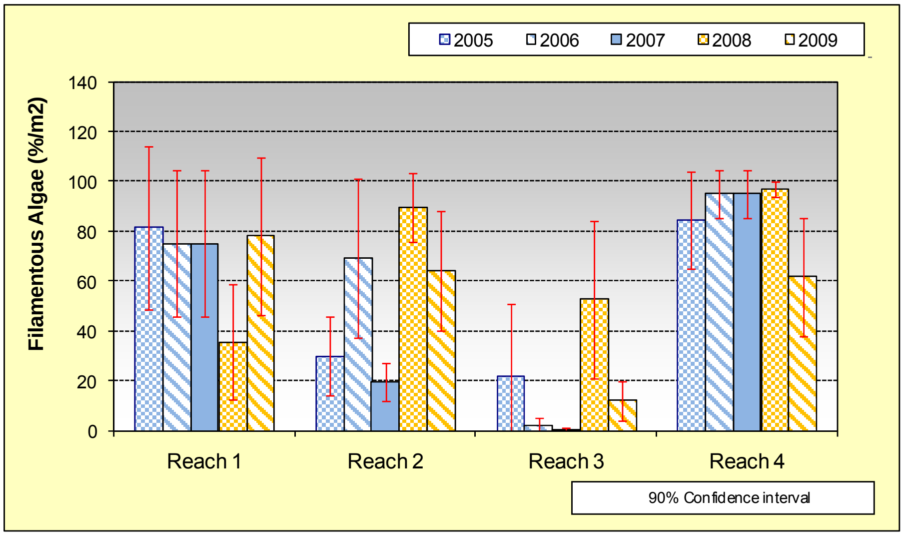


Figure 4.4-1: Filamentous algae cover, October 2005 through 2009.

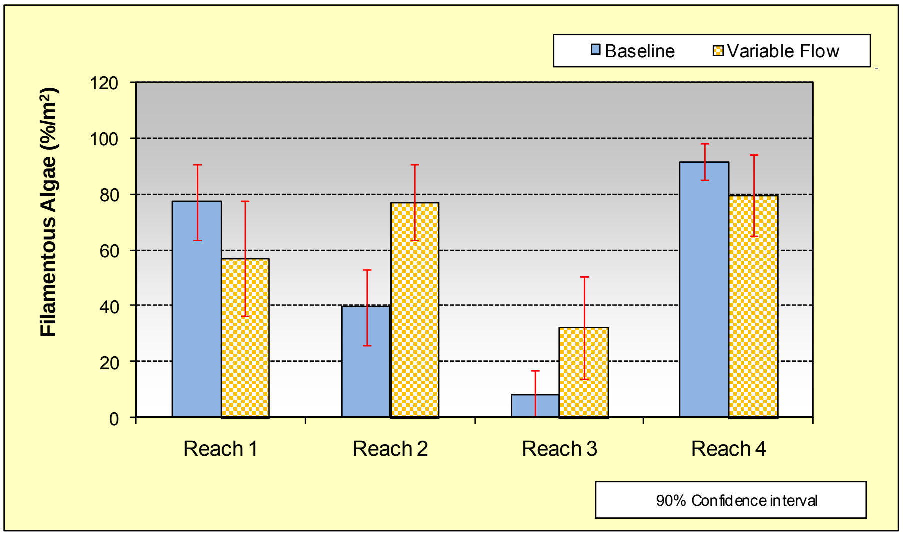


Figure 4.4-2: Filamentous algae cover, baseline period versus variable flow.

4.5 FISHERIES

Fisheries data was analyzed to determine species abundance, biomass and relative weight. Relative weight is a measure of fish condition. Catch per unit effort (CPUE) was calculated for each reach for comparison purposes within and between sample study years. Six species total were collected in this sampling effort but not all species were present in each study reach. The analysis was divided into results for each respective study reach.

4.5.1 Reach 1—Above Soda Reservoir

Three species were collected in reach 1 for a total catch of 5 fish and biomass of 0.036 kg (Table 4.5-1). Longnose dace and mottled sculpin were the most abundant (2 fish; 40% of the catch) followed by redside shiner (1; 20%). Mottled sculpin comprised a majority of the biomass at 78% (28 g), followed by longnose dace (17%; 6 g), and redside shiner (6%; 2 g) (Figure 4.5-2).

Catch per unit effort (CPUE) was highest for longnose dace and mottled sculpin at 0.10 fish/minute, followed redside shiner (0.05 fish/minute) (Figure 4.5-3).

Table 4.5-1: Fish density and biomass per 100 meters in reach 1, October 2009

Species	N	Weight (g)	CPUE (fish / minute)
Longnose Dace (*Rhinichthys cataractae*)	2 (40%)	6 (17%)	0.10
Small Mouth Bass (*Micropterus dolomieu*)	0	0	0
Mottled Sculpin (*Cottus bairdi*)	2 (40%)	28 (78%)	0.10
Common Carp (*Cyprinus carpio*)	0	0	0
Redside Shiner (*Richardsonius balteatus*)	1 (20%)	2 (6%)	0.05
Utah Sucker (*Catostomus ardens*)	0	0	0
Rainbow Trout (*Oncorhynchus mykiss*)	0	0	0
Cutthroat Trout (*Oncorhynchus clarki*)	0	0	0
Total	5	36	0.25

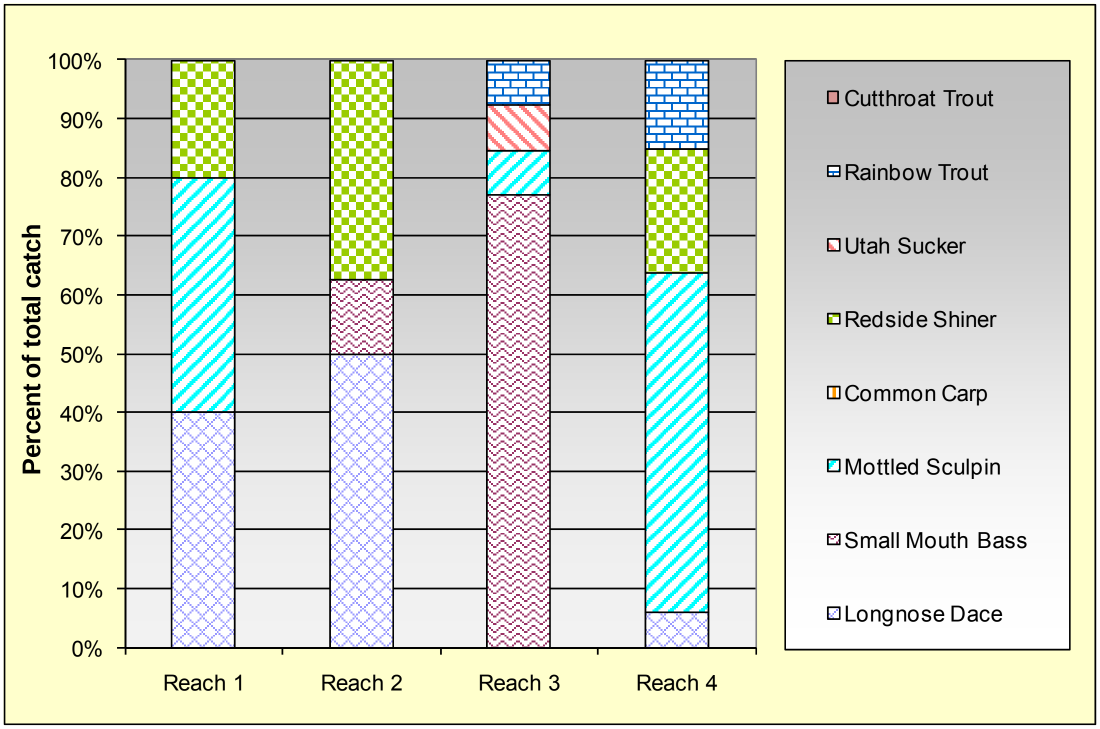


Figure 4.5-1: Fish species composition, October 2009

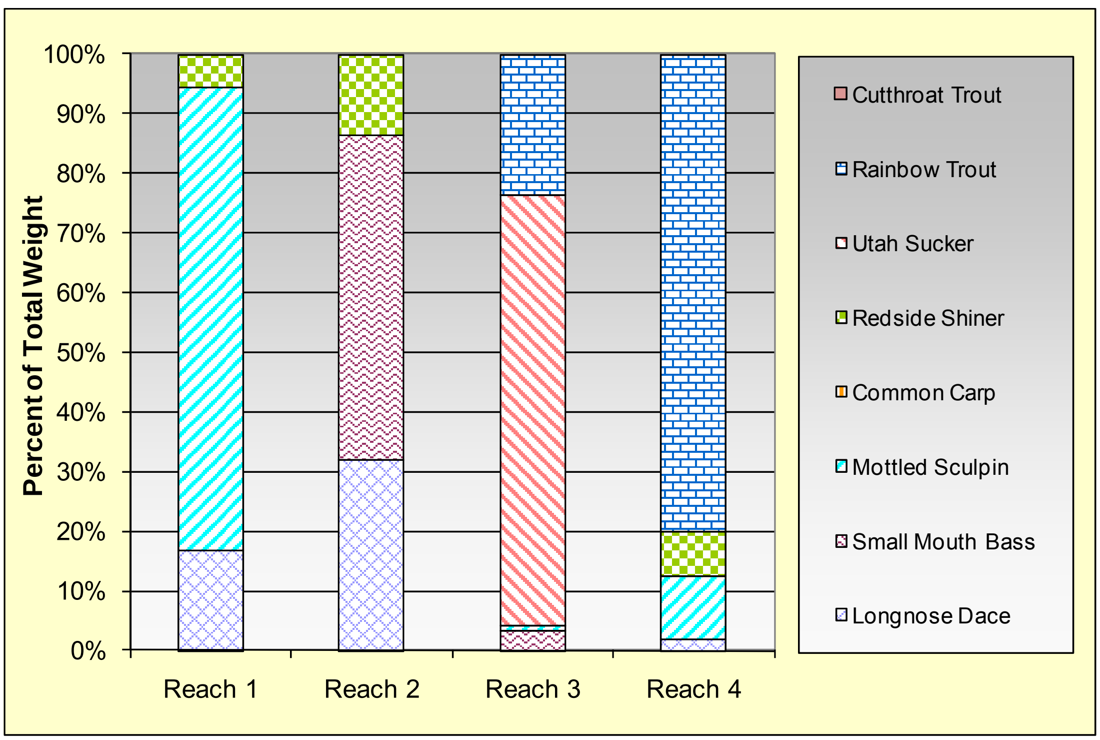


Figure 4.5-2: Fish species biomass, October 2009

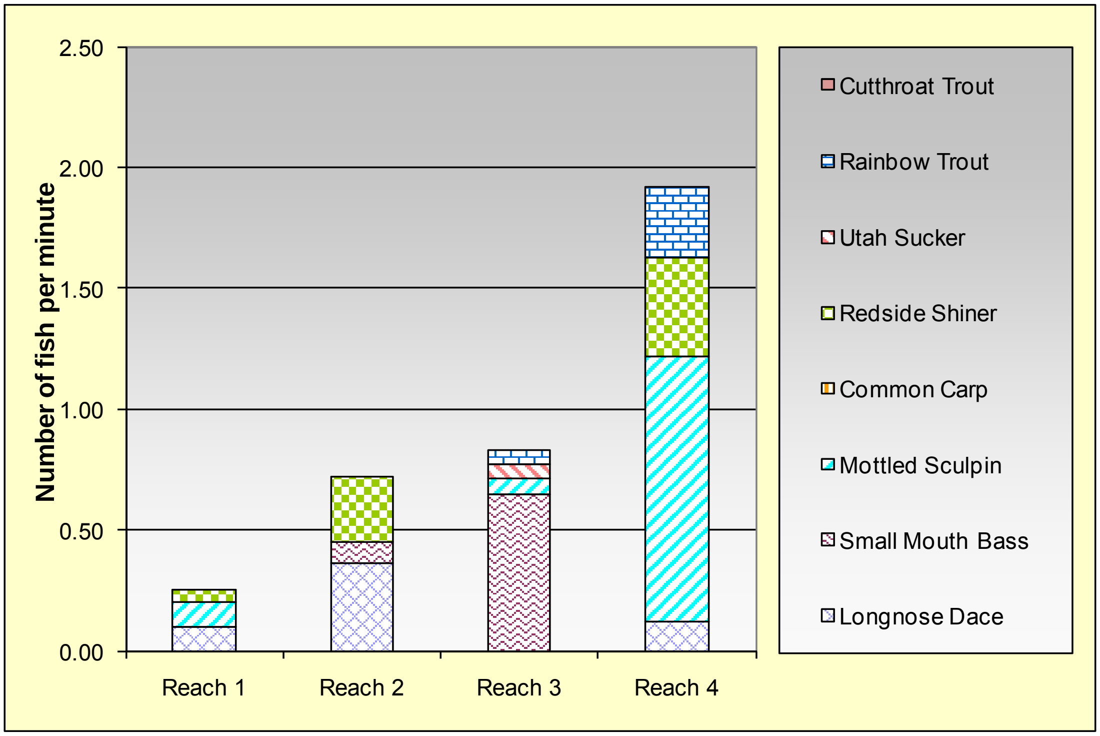


Figure 4.5-3: Catch per unit effort for reaches 1, 2, 3 and 4, October 2009

4.5.2 Reach 2— Below Grace Dam

Three species were collected in reach 2 for a total catch of 16 fish and biomass of 0.088 kg (Table 4.5-2). Longnose dace were the most abundant as they accounted for 8 of the 16 fish collected (50% of the catch) followed by redside shiner (6; 38%), and small mouth bass (2; 13%) (Figure 4.5-1). Smallmouth bass comprised a majority of the biomass at 55% (48g) followed by longnose dace (32%, 28 g), and redside shiner (14%; 12 g) (Figure 4.5-2).

Table 4.5-2: Fish density and biomass per 100 meters in reach 2, October 2009

Species	N	Weight (g)	CPUE (fish / minute)
Longnose Dace (*Rhinichthys cataractae*)	8 (50%)	28 (32%)	0.36
Small Mouth Bass (*Micropterus dolomieu*)	2 (13%)	48 (55%)	0.09
Mottled Sculpin (*Cottus bairdi*)	0	0	0
Common Carp (*Cyprinus carpio*)	0	0	0
Redside Shiner (*Richardsonius balteatus*)	6 (38%)	12 (14%)	0.27
Utah Sucker (*Catostomus ardens*)	0	0	0
Rainbow Trout (*Oncorhynchus mykiss*)	0	0	0
Cutthroat Trout (*Oncorhynchus clarki*)	0	0	0
Total	16	88	0.72

Catch per unit effort was greatest for longnose dace at 0.36 fish / minute followed by redside shiner (0.27 fish/minute), and small mouth bass (0.09 fish/minute) (Figure 4.5-3).

4.5.3 Reach 3— Black Canyon

Four species were collected in reach 3 for a total catch of 13 fish and a biomass of 2.59 kg (Table 4.5-3). Smallmouth bass dominated in abundance (10 fish; 77% of catch) followed equally by Utah sucker (1; 8%), rainbow trout (1; 8%) and mottled sculpin (1; 8%) (Figure 4.5-1). The Utah sucker collected accounted for 72% of the biomass (1872 g), followed by rainbow trout (24%; 608 g), small mouth bass (3%, 84 g) and mottled sculpin (<1%; 22 g) (Figure 4.5-2).

Table 4.5-3: Fish density and biomass per 100 meters in reach 3, October 2009

Species	N	Weight (g)	CPUE (fish / minute)
Longnose Dace (*Rhinichthys cataractae*)	0	0	0
Small Mouth Bass (*Micropterus dolomieu*)	10 (77%)	84 (3%)	0.65
Mottled Sculpin (*Cottus bairdi*)	1 (8%)	22 (1%)	0.06
Common Carp (*Cyprinus carpio*)	0	0	0
Redside Shiner (*Richardsonius balteatus*)	0	0	0
Utah Sucker (*Catostomus ardens*)	1 (8%)	1872 (72%)	0.06
Rainbow Trout (*Oncorhynchus mykiss*)	1 (8%)	608 (24%)	0.06
Cutthroat Trout (*Oncorhynchus clarki*)	0	0	0
Total	13	2586	0.83

Catch per unit effort was greatest for smallmouth bass at 0.65 fish/minute, followed equally by Utah sucker (0.06 fish/minute), rainbow trout (0.06 fish/minute), and mottled sculpin (0.06 fish/minute) (Figure 4.5-3).

The one rainbow trout collected in reach 3 was not marked with a freeze brand. This rainbow trout was 376 mm in length, weighed 608 g, and had a relative weight of 105.

4.5.4 Reach 4—Above Grace Power Plant

Four species were collected in reach 4 for a total catch of 33 fish with a biomass of 0.948 kg (Table 4.5-4). Mottled sculpin were the most abundant (19 fish; 58% of the catch) followed by redisde shiner (7; 21%), rainbow trout (5; 15%), and longnose dace (2; 6%) (Figure 4.5-1). Rainbow trout accounted for a large majority of the biomass at 80% (758g). The remaining 20% of the biomass was comprised of mottled sculpin (11%; 100 g), redside shiner (8%; 72g), and longnose dace (2%; 18 g) (Figure 4.5-2).

Table 4.5-4: Fish density and biomass per 100 meters in reach 4, October 2009

Species	N	Weight (g)	CPUE (fish / minute)
Longnose Dace (*Rhinichthys cataractae*)	2 (6%)	18 (2%)	0.12
Small Mouth Bass (*Micropterus dolomieu*)	0	0	0
Mottled Sculpin (*Cottus bairdi*)	19 (58%)	100 (11%)	1.10
Common Carp (*Cyprinus carpio*)	0	0	0
Redside Shiner (*Richardsonius balteatus*)	7 (21%)	72 (8%)	0.41
Utah Sucker (*Catostomus ardens*)	0	0	0
Rainbow Trout (*Oncorhynchus mykiss*)	5 (15%)	758 (80%)	0.29
Cutthroat Trout (*Oncorhynchus clarki*)	0	0	0
Total	33	948	1.92

Catch per unit effort was greatest for mottled sculpin (1.10 fish/minute) followed by redside shiner (0.41 fish/minute), rainbow trout (0.29 fish/minute), and longnose dace (0.12 fish/minute) (Figure 4.5-3).

A total of 5 rainbow trout were collected in reach 4. None of the 5 fish were marked with a freeze-brand, however they are no longer freeze-branding the fish at the Grace Hatchery prior to release in the river. The 5 rainbow trout collected in reach 4 ranged in length from 231 mm to 267 mm and had a mean length of 246 mm (Table 4.5-5). They ranged in weight from 118 g to 182 g with a mean weight of 152 g. The length-frequency distribution of the 5 rainbow trout collected in reach 4 is shown in figure 4.5-4.

Table 4.5-5: Rainbow Trout lengths and weights in reach 4, October 2009

Number	Freeze brand	Length (mm)	Weight (g)	Relative Weight
1	None	267	170	82
2	None	258	182	98
3	None	233	118	86
4	None	239	166	112
5	None	231	122	92
	Average	246	152	94

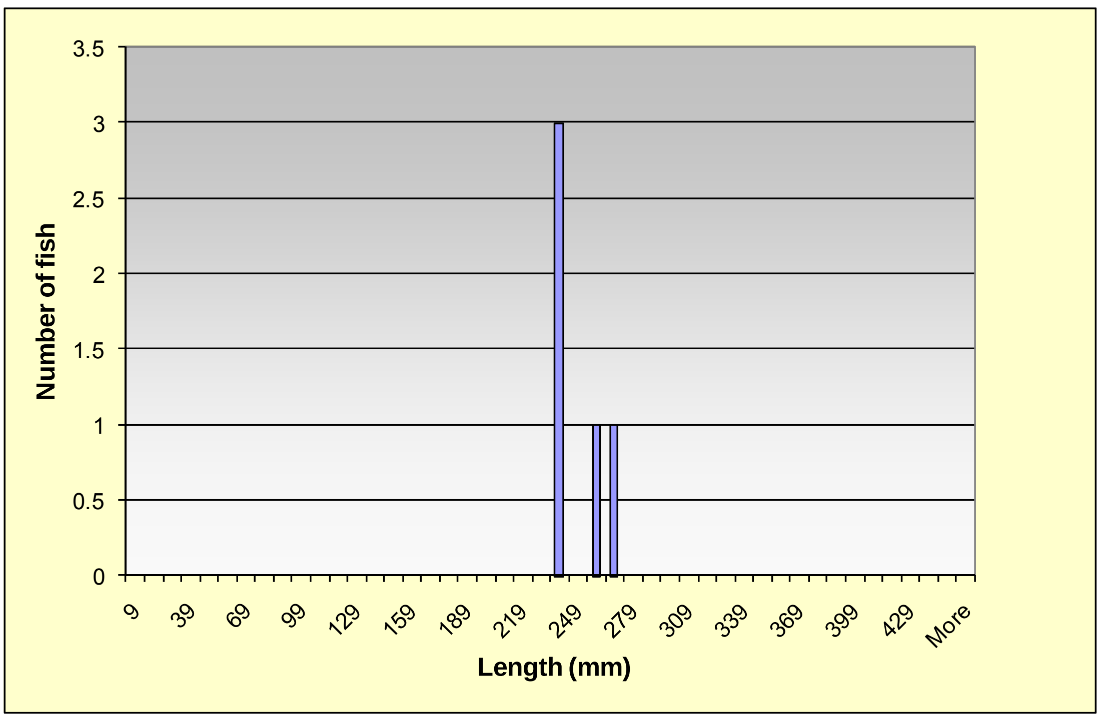


Figure 4.5-4: Length frequency distribution for RBT in reach 4, October 2009

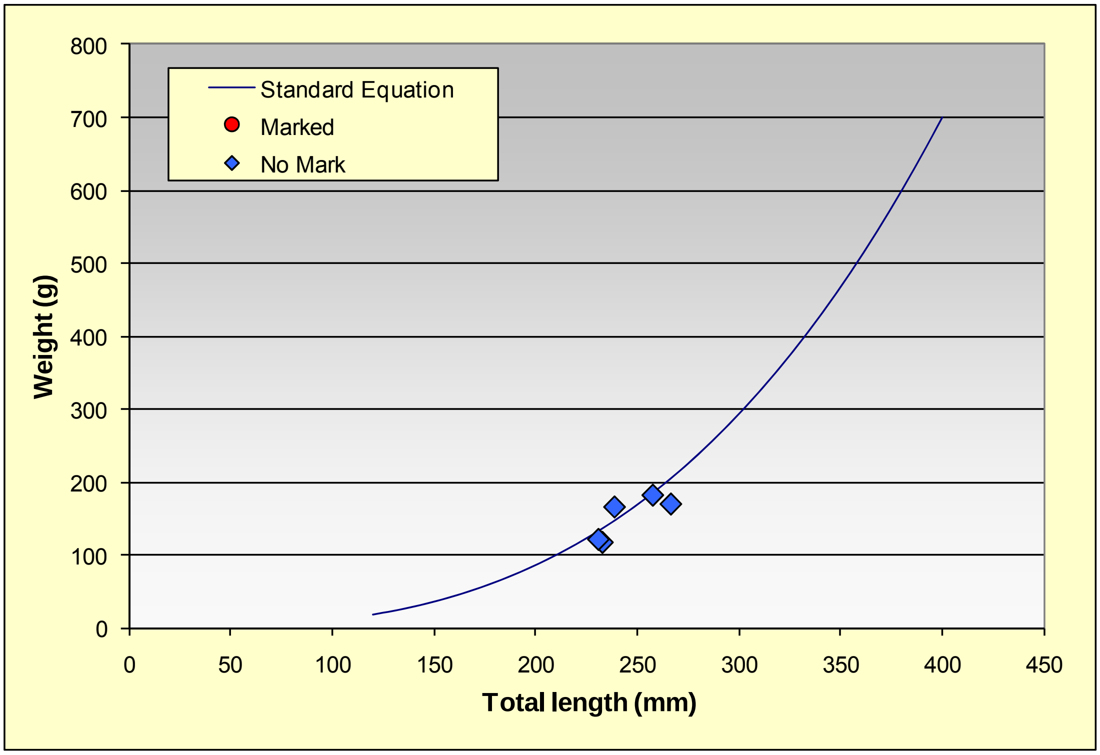


Figure 4.5-5. Length-weight relationship for rainbow trout in reach 4, October 2009

The relative weight of 1 of the 5 rainbow trout collected in reach 4 fell above the standard weight-length curve (Wr = 100) while 4 of the 5 rainbows had relative weights that fell below the curve (Figure 4.5-5). The mean relative weight (Wr) for all 5 rainbows was 94 and ranged from 82 to 112 (Table 4.5-5).

4.5.5 Within Reach Comparisons—2005, 2006, 2007, 2008 and 2009

In reach 1, species richness was greatest in 2006 and 2008. Five species were collected in reach 1 in 2006 and 2008 compared to four species in 2005 and 2007 and three species in 2009 (Table 4.5-6). Longnose dace and mottled sculpin were collected in all 5 years, and common carp were collected in 3 of the 5 years. One juvenile Utah sucker was collected in 2006 and one redside shiner was collected in both 2007 and 2009. One rainbow trout and one cutthroat trout were collected in reach 1 in 2008, but no trout were collected in any other years.

In reach 2, species richness was greater in 2006, 2007, and 2008 than in 2005 or 2009 (Table 4.5-7). Four species were collected in 2006, 2007, and 2008, three species were collected in 2009, and only 2 species were collected in 2005. Longnose dace and small mouth bass were present all years, redside shiner were collected in 4 of 5 years (2006, 2007, 2008, and 2009), Utah sucker were collected in 2006 and 2007, and common carp were collected only in 2008.

Table 4.5-6: Fish density and biomass for reach 1, October 2005, through 2009

	Species	2005			2006			2007		
		N	Weight (g)	CPUE	N	Weight (g)	CPUE	N	Weight (g)	CPUE
Before Whitewater Flows	Longnose Dace	55 (65%)	362 (5%)	3.29	14 (36%)	78 (29%)	0.83	35 (59%)	186 (48%)	1.97
	Small Mouth Bass	1 (1%)	30 (<1%)	0.06	9 (23%)	40 (15%)	0.53	0	0	0
	Mottled Sculpin	26 (31%)	260 (4%)	1.56	12 (31%)	94 (35%)	0.71	20 (34%)	172 (44%)	1.13
	Common Carp	2 (2%)	6654 (91%)	0.12	3 (8%)	48 (18%)	0.18	3 (5%)	28 (7%)	0.17
	Redside Shiner	0	0	0	0	0	0	1 (2%)	4 (2%)	0.06
	Utah Sucker	0	0	0	1 (3%)	10 (4%)	0.06	0	0	0
	Rainbow Trout	0	0	0	0	0	0.00	0	0	0
	Cutthroat Trout	0	0	0	0	0	0	0	0	0
	Total	84	7306	5.03	39	270	2.31	59	390	3.33

	Species	2008			2009			2010		
		N	Weight (g)	CPUE	N	Weight (g)	CPUE	N	Weight (g)	CPUE
After Whitewater Flows	Longnose Dace	9 (56%)	40 (5%)	0.49	2 (40%)	6 (17%)	0.10	N/A	N/A	N/A
	Small Mouth Bass	2 (13%)	6 (1%)	0.11	0	0	0	N/A	N/A	N/A
	Mottled Sculpin	3 (19%)	38 (4%)	0.16	2 (40%)	28 (78%)	0.10	N/A	N/A	N/A
	Common Carp	0	0	0	0	0	0	N/A	N/A	N/A
	Redside Shiner	0	0	0	1 (20%)	2 (6%)	0.05	N/A	N/A	N/A
	Utah Sucker	0	0	0	0	0	0	N/A	N/A	N/A
	Rainbow Trout	1 (6%)	250 (28%)	0.05	0	0	0	N/A	N/A	N/A
	Cutthroat Trout	1 (6%)	568 (63%)	0.05	0	0	0	N/A	N/A	N/A
	Total	16	902	0.86	5	36	0.25	N/A	N/A	N/A

Table 4.5-7: Fish density and biomass for reach 2, October 2005 through 2009.

	Species	2005			2006			2007		
		N	Weight (g)	CPUE	N	Weight (g)	CPUE	N	Weight (g)	CPUE
Before Whitewater Flows	Longnose Dace	33 (97%)	257 (97%)	1.52	29 (88%)	206 (84%)	1.28	32 (82%)	338 (66%)	1.55
	Small Mouth Bass	1 (3%)	8 (3%)	0.05	1 (3%)	8 (3%)	0.04	1 (3%)	8 (2%)	0.05
	Mottled Sculpin	0	0	0	0	0	0	0	0	0
	Common Carp	0	0	0	0	0	0	0	0	0
	Redside Shiner	0	0	0	2 (6%)	20 (8%)	0.09	5 (13%)	30 (6%)	0.24
	Utah Sucker	0	0	0	1 (3%)	12 (5%)	0.04	1 (3%)	140 (27%)	0.05
	Rainbow Trout	0	0	0	0	0	0.00	0	0	0.00
	Cutthroat Trout	0	0	0	0	0	0	0	0	0
	Total	34	265	1.57	33	246	1.45	39	516	1.89

	Species	2008			2009			2010		
		N	Weight (g)	CPUE	N	Weight (g)	CPUE	N	Weight (g)	CPUE
After Whitewater Flows	Longnose Dace	19 (26%)	150 (33%)	0.95	8 (50%)	28 (32%)	0.36	N/A	N/A	N/A
	Small Mouth Bass	6 (8%)	64 (14%)	0.3	2 (13%)	48 (55%)	0.09	N/A	N/A	N/A
	Mottled Sculpin	0	0	0	0	0	0	N/A	N/A	N/A
	Common Carp	16 (22%)	138 (30%)	0.8	0	0	0	N/A	N/A	N/A
	Redside Shiner	33 (45%)	108 (23%)	1.65	6 (38%)	12 (14%)	0.27	N/A	N/A	N/A
	Utah Sucker	0	0	0	0	0	0	N/A	N/A	N/A
	Rainbow Trout	0	0	0	0	0	0	N/A	N/A	N/A
	Cutthroat Trout	0	0	0	0	0	0	N/A	N/A	N/A
	Total	74	460	3.7	16	88	0.72	N/A	N/A	N/A

In reach 3, species richness was greater in 2007 and 2008 than in 2005, 2006 and 2009 (Table 4.5-8). Five species were collected in 2007 and 2008 while four species were collected in 2005, 2006, and 2009. Utah sucker were the only species collected all 5 years, redside shiner and smallmouth bass were collected 4 of 5 years, and Longnose dace were collected 3 of 5 years. One large adult common carp was collected in 2007 and 2 juvenile carp were collected in 2008. One mottled sculpin was collected in reach 3 in both 2008 and 2009, and one rainbow trout was collected in this reach in 2006 and in 2009.

Table 4.5-8: Fish density and biomass for reach 3, October 2005 through 2009.

	Species	2005			2006			2007		
		N	Weight (g)	CPUE	N	Weight (g)	CPUE	N	Weight (g)	CPUE
Before Whitewater Flows	Longnose Dace	5 (4%)	22 (5%)	0.43	3 (3%)	12 (2%)	0.23	5 (7%)	24 (<1%)	0.30
	Small Mouth Bass	1 (1%)	4 (<1%)	0.09	0	0	0	3 (4%)	30 (<1%)	0.18
	Mottled Sculpin	0	0	0	0	0	0	0	0	0
	Common Carp	0	0	0	0	0	0	1 (1%)	4960 (54%)	0.06
	Redside Shiner	101 (85%	392 (83%)	8.71	73 (82%)	240 (31%)	5.48	52 (75%)	198 (2%)	3.13
	Utah Sucker	12 (10%)	56 (12%)	1.03	12 (13%)	234 (30%)	0.09	8 (12%)	3920 (43%)	0.48
	Rainbow Trout	0	0	0	1 (1%)	294 (38%)	0.08	0	0	0
	Cutthroat Trout	0	0	0	0	0	0	0	0	0
	Total	119	474	10.26	89	780	5.88	69	9132	4.15

	Species	2008			2009			2010		
		N	Weight (g)	CPUE	N	Weight (g)	CPUE	N	Weight (g)	CPUE
After Whitewater Flows	Longnose Dace	0	0	0	0	0	0	N/A	N/A	N/A
	Small Mouth Bass	10 (20%)	64 (2%)	0.65	10 (77%)	84 (3%)	0.65	N/A	N/A	N/A
	Mottled Sculpin	1 (2%)	14 (<1%)	0.07	1 (8%)	22 (1%)	0.06	N/A	N/A	N/A
	Common Carp	2 (4%)	20 (1%)	0.13	0	0	0	N/A	N/A	N/A
	Redside Shiner	35 (70%)	146 (4%)	2.29	0	0	0	N/A	N/A	N/A
	Utah Sucker	2 (4%)	3330 (93%)	0.13	1 (8%)	1872 (72%)	0.06	N/A	N/A	N/A
	Rainbow Trout	0	0	0	1 (8%)	608 (24%)	0.06	N/A	N/A	N/A
	Cutthroat Trout	0	0	0	0	0	0	N/A	N/A	N/A
	Total	50	3574	3.27	13	2586	0.83	N/A	N/A	N/A

Reach 4 had 5 fish species collected in 2005 and 2006 but only four in 2007, 2008, and 2009 (Table 4.5-9). Longnose dace, mottled sculpin, redside shiner, and rainbow trout were all collected in all 5 years of the study, while Utah suckers were collected in small numbers in 2005 and 2006 only.

In reach 1, longnose dace accounted for the largest proportion of the relative species composition in all 5 years (65%, 36%, 59%, 56%, and 40% of catch) (Table 4.5-6). Mottled sculpin were the next most abundant in all years at 31%, 31%, 34%, 19%, and 40% of the catch. In all years, other species comprised less than 10% of the catch except in 2006 and 2008, when small mouth bass accounted for 23% and 13%, respectively, and in 2009 redside shiner comprised 20% of the catch.

In reach 2, longnose dace were the most abundant in 2005, 2006, 2007, and 2009 (97%, 88%, 82%, 50%), however redside shiner were the most abundant in 2008 at 45% while longnose dace accounted for just 26% (Table 4.5-7). Redside shiner accounted for relatively small proportions of the catch in 2006 (6%) and 2007 (13%) and were not collected in 2005, however in 2009 they comprised 38% of the catch. Common carp accounted for 22% of the catch in 2008 but were not collected in reach 2 in any other years. Small mouth bass comprised 3% to 13% of the catch over the 5 sample years. Utah sucker accounted for only a small proportion of the catch (3%) in 2006 and 2007, and were not collected in this reach in 2005, 2008, or 2009.

In reach 3, redside shiner were the most abundant species in the first four sample years (85%, 82%, 75% and 70%), however none were collected in 2009 (Table 4.5-8). In 2005, 2006, and 2007 Utah sucker were the next most abundant at 10%, 13%, and 12% respectively, while it was small mouth bass accounting for 20% of the catch in 2008. In 2009, smallmouth bass were by far the most abundant (77%) while mottled sculpin, Utah sucker, and rainbow trout each accounted for less than 8%. Longnose dace, common carp, mottled sculpin, and rainbow trout also accounted for small proportions of the catch in reach 3 during other years of this study.

Table 4.5-9: Fish density and biomass for reach 4, October 2005 through 2009.

	Species	2005			2006			2007		
		N	Weight (g)	CPUE	N	Weight (g)	CPUE	N	Weight (g)	CPUE
Before Whitewater Flows	Longnose Dace	39 (39%)	263 (4%)	2.59	27 (57%)	134 (7%)	1.10	35 (37%)	225 (10%)	1.77
	Small Mouth Bass	0	0	0	0	0	0	0	0	0
	Mottled Sculpin	27 (27%)	180 (3%)	1.80	7 (15%)	66 (3%)	0.29	30 (32%)	252 (12%)	1.52
	Common Carp	0	0	0	0	0	0	0	0	0
	Redside Shiner	10 (10%)	92 (1%)	0.67	6 (13%)	58 (3%)	0.25	24 (26%)	238 (11%)	1.21
	Utah Sucker	2 (2%)	58 (1%)	0.13	1 (2%)	52 (3%)	0.04	0	0	0
	Rainbow Trout	22 (22%)	6308 (91%)	1.46	6 (13%)	1600 (84%)	0.25	5 (5%)	1460 (67%)	0.25
	Cutthroat Trout	0	0	0	0	0	0	0	0	0
	Total	100	6901	6.65	47	1910	1.93	94	2175	4.75

	Species	2008			2009			2010		
		N	Weight (g)	CPUE	N	Weight (g)	CPUE	N	Weight (g)	CPUE
After Whitewater Flows	Longnose Dace	18 (38%)	164 (7%)	1.04	2 (6%)	18 (2%)	0.12	N/A	N/A	N/A
	Small Mouth Bass	0	0	0	0	0	0	N/A	N/A	N/A
	Mottled Sculpin	18 (38%)	106 (4%)	1.04	19 (58%)	100 (11%)	1.10	N/A	N/A	N/A
	Common Carp	0	0	0	0	0	0	N/A	N/A	N/A
	Redside Shiner	2 (4%)	26 (1%)	0.12	7 (21%)	72 (8%)	0.41	N/A	N/A	N/A
	Utah Sucker	0	0	0	0	0	0	N/A	N/A	N/A
	Rainbow Trout	9 (19%)	2198 (88%)	0.52	5 (15%)	758 (80%)	0.29	N/A	N/A	N/A
	Cutthroat Trout	0	0	0	0	0	0	N/A	N/A	N/A
	Total	47	2494	2.72	33	948	1.92	N/A	N/A	N/A

In reach 4, longnose dace accounted for the majority of the relative species composition in the first four years of this study at 39%, 57%, 37% and 38% of the catch, however in 2009 they comprised only 6% of the total catch (Table 4.5-9). Mottled sculpin were the next most abundant in the first 4 years (27%, 15%, 32%, and 38%), while they made up a majority of the catch in 2009 at 58%. Rainbow trout accounted for 22% of the catch in 2005, 13% in 2006, 5% in 2007, and 19% in 2008, and 15% in 2009. Redside shiner comprised a small to moderate amount of the catch all 5 years at 10% in 2005, 13% in 2006, 26% in 2007, 6% in 2008, and 21% in 2009.

In reach 1, the total biomass was 7.31 kg in 2005, but was only 0.27 in 2006, 0.39 in 2007, 0.90 in 2008, and 0.04 in 2009 (Table 4.5-6). The large difference in total biomass was largely the result of collecting two large adult common carp in 2005 while only small juvenile carp were collected in 2006 and 2007 and no carp were collected in 2008 or 2009. Accordingly, common carp accounted for 91% of the biomass in 2005 at 6.65 kg while in 2006 and 2007 they accounted for only 18% and 7%, respectively (Table 4.5-6). Despite only 2 trout being collected, Cutthroat trout accounted for a majority of the biomass at 63% (0.57 kg) in 2008 followed by rainbow trout at 28% (0.25kg). In 2006 and 2009, mottled sculpin accounted for the largest proportion of the biomass at 35% and 78%, respectively, while longnose dace comprised 29% and 17% in these years. In 2007 longnose dace accounted for the highest proportion of the biomass at 48% (0.19 kg) followed closely by mottled sculpin at 44% (0.17kg).

Total biomass in reach 2 lowest in 2009 at 0.09 kg, but was very similar in 2005 and 2006 at 0.27 and 0.25 kg, respectively, and in 2007 and 2008 biomass was greater at 0.52 kg and 0.48 kg (Table 4.5-7). The increase in biomass in 2007 was due mainly to the capture of one 0.14 kg Utah sucker (27% of biomass) however in 2008 the increased biomass resulted from collecting larger numbers of juvenile carp and redside shiners. Longnose dace comprised a majority of the biomass in the first 4 years (97% in 2005; 84 % in 2006, 66% in 2007, and 33% in 2008) while in 2009 smallmouth bass was the majority at 55% and longnose dace comprised 32%. In 2005 through 2007, the remaining biomass was typically comprised of small proportions of small mouth bass and redside shiner (Table 4.5-7) but in 2008 common carp accounted for 30%.

In reach 3, total biomass was much greater in 2007 (9.13 kg), 2008 (3.57 kg), and 2009 (2.59 kg) than in 2006 (0.78 kg) or 2005 (0.47 kg) (Table 4.5-8). For 2007, a majority of the total biomass can be attributed to the collection of one large adult common carp (4.96 kg, 54% of total biomass) while large adult Utah suckers were collected in 2008 and 2009, accounting for a majority of the total biomass. No carp were collected in reach 3 in 2005 or 2006 and only 2 juvenile carp were collected in 2008. Redside shiner comprised a majority of the biomass in 2005 (83%, 0.39 kg) while rainbow trout made up a majority of the biomass in 2006 at 0.29 kg (38%). Common carp accounted for the highest proportion of the biomass in 2007 at 54% (4.96 kg), and Utah sucker made up the majority of the biomass in 2008 and 2009 at 93% and 72%, respectively (Table 4.5-8).

Total biomass in reach 4 was considerably greater in 2005 (6.90 kg) than in 2006 (1.91 kg), 2007 (2.18 kg), 2008 (2.49 kg), or 2009 (0.95 kg) (Table 4.5-9). This decrease in total biomass was consistent with a decrease in the number of rainbow trout collected in 2006 (6), 2007 (5), 2008 (9), and 2009 (5) verses the 22 collected in 2005. Rainbow trout accounted for a large majority of the biomass during all five years of this study at 91% in 2005, 84% in 2006, 67% in 2007, 91% in 2008, and 80% in 2009 (Table 4.5-9). The remainder of the biomass in reach 4 was typically comprised of small proportions of longnose dace, mottled sculpin, redside shiner, and Utah sucker.

In reach 1, total catch and CPUE varied considerably between the five study years. Total catch was highest in 2005 at 84 fish, followed by 59 fish in 2007, 39 fish in 2006, 19 fish in 2008, and just 5 fish in 2009 (Table 4.5-6). Likewise, catch per unit effort (CPUE) was also highest in 2005 at 5.03 fish/minute, lesser at 3.33 fish/minute in 2007, 2.31 fish/minute in 2006, 0.86 fish/minute in 2008, and was lowest in 2009 at just 0.25 fish/minute.

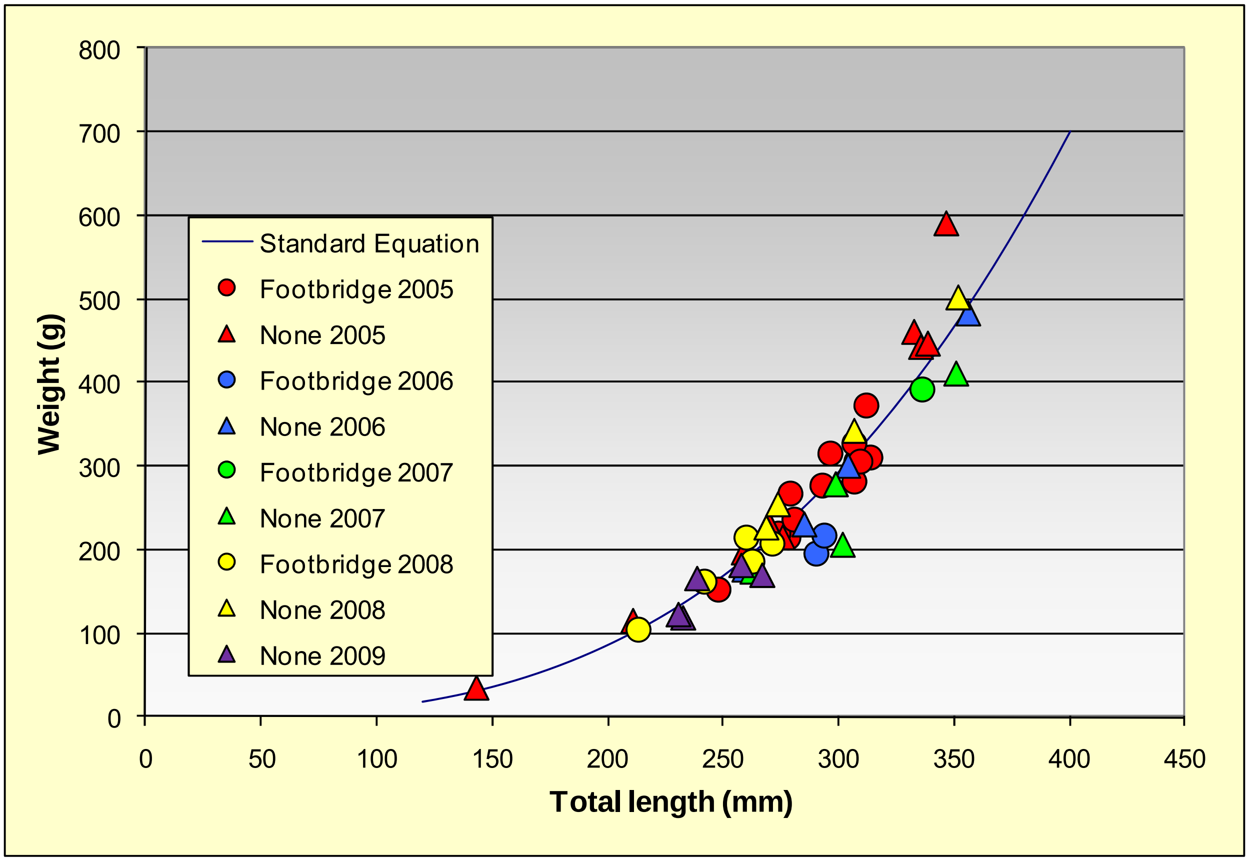
Total catch in reach 2 was similar between 2005, 2006, and 2007 with 34, 33, and 39 fish, respectively. However, total catch increased considerably in 2008 to 74 fish and then decreased to 16 in 2009 (Table 4.5-7). Correspondingly, CPUE was also similar during the first 3 years with a rate of 1.57 fish/minute in 2005, 1.45 fish/minute in 2006 and 1.89 fish/minute in 2007, and then increased to 3.70 fish/minute in 2008 and subsequently decreased to 0.72 in 2009.

Total catch in reach 3 decreased each year of the study. In 2005, total catch was highest at 119 fish, decreased to 89 fish in 2006, to 69 in 2007, to 50 fish in 2008, and finally down to just 13 in 2009 (Table 4.5-8). Following the same trend as total catch, CPUE was highest in 2005 at 10.26 fish/minute then decreased to 5.88 fish/minute in 2006, 4.15 fish/minute in 2007, 3.27 fish/minute in 2008, and 0.83 fish/minute in 2009.

In reach 4, total catch was much higher in 2005 (100 fish) and 2007 (94 fish) than in 2006 (47 fish), 2008 (47 fish), and 2009 when only 33 fish were collected (Table 4.5-9). Similarly, CPUE was also considerably greater in 2005 (6.65 fish/minute) and 2007 (4.75 fish/minute) than in 2006 (1.93 fish/minute), 2008 (2.72 fish/minute), and 2009 (1.92 fish/minute).

Overall, the condition (relative weight) of rainbow trout in reach 4 was highest in 2008 with a mean of 105 (Figure 4.5-8). Mean relative weight of all rainbow trout collected was 104 in 2005, 89 in 2006, 87 in 2007, and in 2009 the mean was 95. The mean relative weight of freeze-branded hatchery released fish was highest in 2008 at 102 compared to 95 in 2007, 76 in 2006, and 100 in 2005. The mean relative weight of rainbow trout without freeze-brands was 109 in 2008 and 2005, 95 in 2006, and 85 in 2007. No rainbow trout with freeze-brands were collected in 2009 in reach 4.

Figure 4.5-6: Length-weight relationship for rainbow, reach 4, 2005 through 2009



4.6 TEMPERATURE

Water temperature can be a critical factor limiting the distribution and abundance of aquatic species particularly coldwater fishes. Releases from Grace Dam have the potential to cause thermal loading to surface waters in reaches 2, 3 and 4. Over the three-year monitoring period discharge has remained relatively stable in the regulated reach below Grace Dam reflecting the MIF requirement in the FERC license. On several occasions, spills from Grace Dam have occurred to pass water downstream to meet irrigation demands. In 2005, the maximum summer flow below Grace Dam was 255 cfs on July 26, 2005. In 2006, several small discharge spikes occurred in the summer time frame; 128 cfs on June 21; 122 cfs on July 22, 115 cfs on August 4 and 152 cfs on September 18. In 2007, the maximum flow below Grace Dam was 218 cfs on June 27th. During that release maximum temperatures in reach 4 reached 20.8 ºC, equivalent to the highest temperature recorded in reach 4 in 2007.

The absence of substantial changes in discharge in the summer season during the three-year baseline monitoring period made it difficult to detect if there was an interaction between changes in discharge at Grace Dam and stream temperatures in reaches 2, 3 and 4 (Figure 4.6-1). In 2006, daily maximum stream temperatures in reach 4 increased approximately 1 ºC from the previous day on June 21 and July 19 corresponding to discharge increases from Grace Dam. In 2007, daily maximum stream temperature on June 27 was approximately 2 ºC higher than the day prior or after the release.

The variable flows released from Grace Dam in 2008 and 2009 provide an opportunity to track potential changes in stream temperatures induced by releases from Grace Dam in reaches 2, 3 and 4. Surface water releases from Grace Dam have the potential to increase stream temperatures above the Idaho water quality standards established for the Bear River. Idaho DEQ staff deploy and retrieve hobo temps in study reaches 1, 2, 3 and 4 annually. The temperature data should be analyzed to determine the magnitude of the temperature changes, if any, associated with releases from Grace Dam. The temperature changes are likely to vary seasonally.

Constraints on the project budget have prevented analysis and reporting of the temperature data for years 2008 and 2009 under the variable flow treatment. Previous analysis and reporting of temperature data has been outside the original scope of work. OASIS has provided this analysis to the ECC to provide a thorough assessment of habitat and water quality conditions in the reference and treatment reaches. Further analysis of this data is recommended to assess compliance with water quality standards and evaluate potential for thermal impacts to salmonids. Temperature is considered one of the primary factors influencing the longitudinal distribution of aquatic organisms (Ward and Stanford 1979).

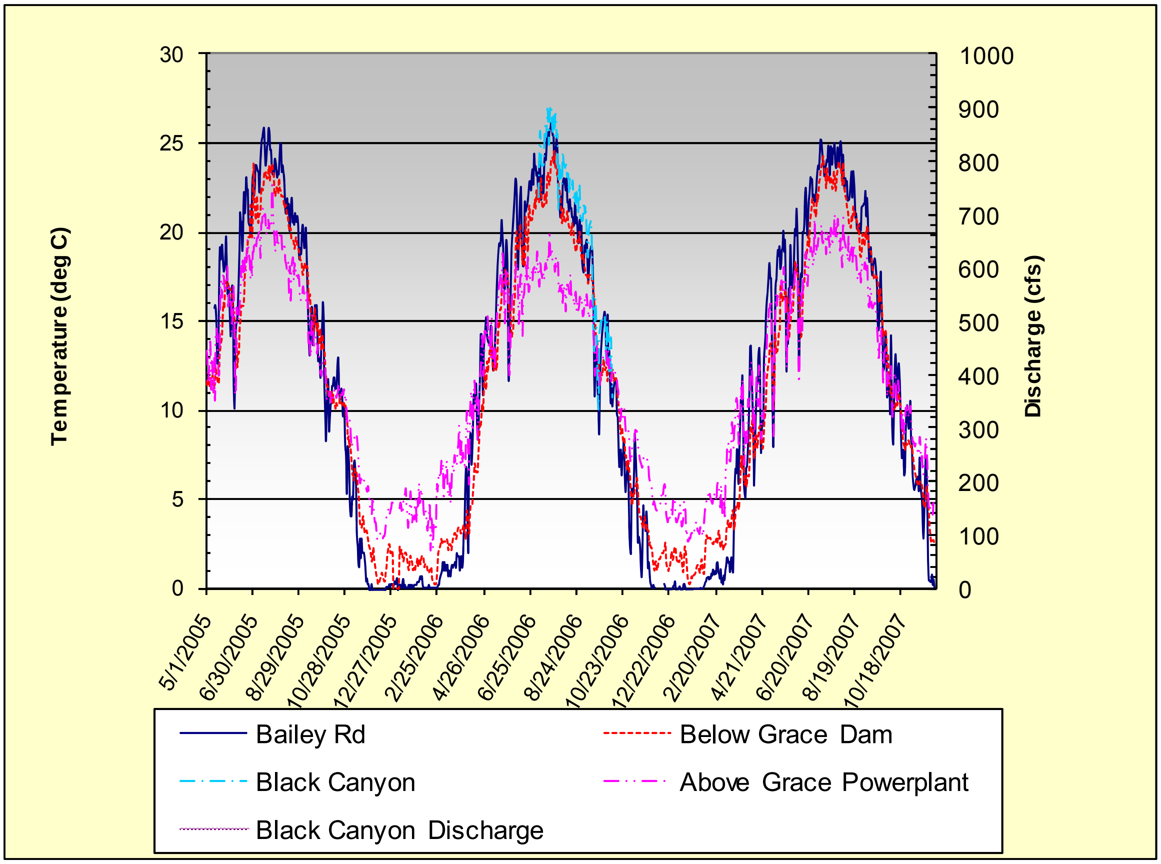


Figure 4.6-1: Maximum water temperatures in reaches 1, 2, 3 and 4, 2005 through 2007

4.7 BENTHIC MACROINVERTEBRATES

BMI density in 2009 exhibited patterns between study reaches similar to the four previous study years (Figure 4.7-1). Reach 4, once again, contained the highest BMI density (95,107 organisms/m^2) of all four study reaches (Table 4.7-1). The 2009 BMI density in reach 4 was similar to densities observed in 2005, 2006 and 2007. In 2008, BMI density in reach 4 was was less than half (44,008 organisms/m^2) the mean measured in 2009 as well as the other three sample years. BMI density in study reaches 1, 2 and 3 was 17,444, 21,802 and 5,884 organisms/m^2 respectively. As in the previous four years, reach 3 contained the lowest BMI density for the 2009 sampling effort.

Comparisons across all four sample years within a single study reach indicate BMI densities were similar over time at each reach (single factor ANOVA and Kruskal-Wallis H-test). BMI density comparisons between the three-year baseline sampling period and two years of the variable flow regime found no significant differences within any of the study reaches (Figure 4.7-2).

Table 4.7-1: Average BMI density in October at four reaches; 2005 through 2009.

	BMI										EPT									
	2005		2006		2007		2008		2009		2005		2006		2007		2008		2009	
Study Reach	Density	No. taxa	Density	No. taxa	Density	No. taxa	Density	No. taxa	Density	No. taxa	Density	No. taxa	Density	No. taxa	Density	No. taxa	Density	No. taxa	Density	No. taxa
Reach 1	25,144	39	21,190	39	14,367	28	15,696	30	17,444	36	14,836	14	13,415	16	10,544	13	9,665	14	10,628	16
Reach 2	16,402	37	31,929	39	16,151	25	25,750	35	21,802	36	595	5	1,244	5	124	3	1,164	5	722	5
Reach 3	5,390	45	8,621	39	3,645	35	8,750	38	5,884	38	826	11	2,125	10	727	9	3,531	10	1,622	12
Reach 4	86,048	25	104,430	34	80,589	20	44,008	35	95,107	17	412	2	2,310	5	238	2	2,171	5	1,435	3

Reach 1 contained the highest EPT density (10,628 organisms/m^2) of all four study reaches in 2009 (Figure 4.7-3). EPT density in study reaches 2, 3 and 4 was 722, 1,622 and 1,435 organisms/m^2 respectively. In reach 1, EPT comprised 63 percent of the overall BMI density compared to 4 percent, 28 percent and 1 percent in reaches 2, 3 and 4 respectively.

Comparisons across all five sample years within a single study reach indicate EPT densities were similar over time in reaches 1 and 3 but differed in reaches 2 and 4 ($p=0.04$ and $p=0.007$ respectively, H-test). EPT density comparisons between the three-year baseline sampling period and two years of the variable flow regime found no significant differences in reach 1 but significant increases in EPT density in study reaches 2, 3 and 4 under the variable flow conditions (Figure 4.7-4). In reaches 2, 3 and 4, EPT density was significantly higher under the variable flow conditions compared to the three-year baseline period ($p=0.01$, $p=0.05$ and $p=0.04$ respectively, H-test). EPT density under variable flow conditions in reach 3 was double the mean for the baseline period (2,576 compared to 1,226 organisms/m^2). EPT density in reach 3 under the variable flow conditions comprised 35% of the BMI community compared to 20% during the three-year baseline period.

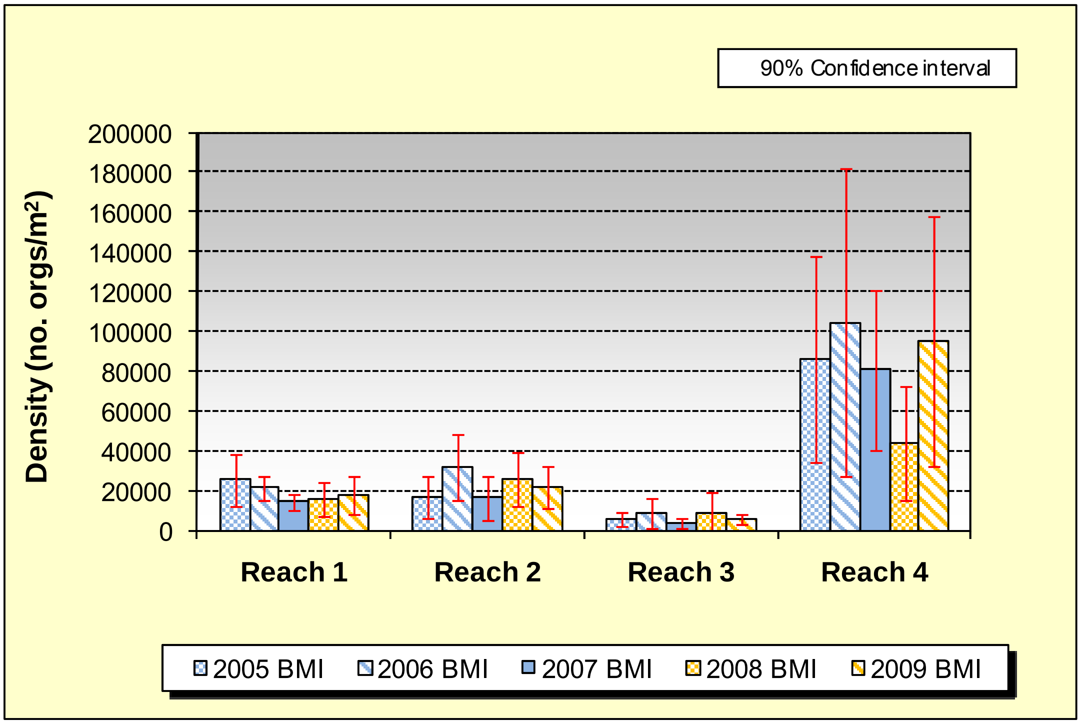


Figure 4.7-1: Average BMI Density in October, 2005 through 2009.

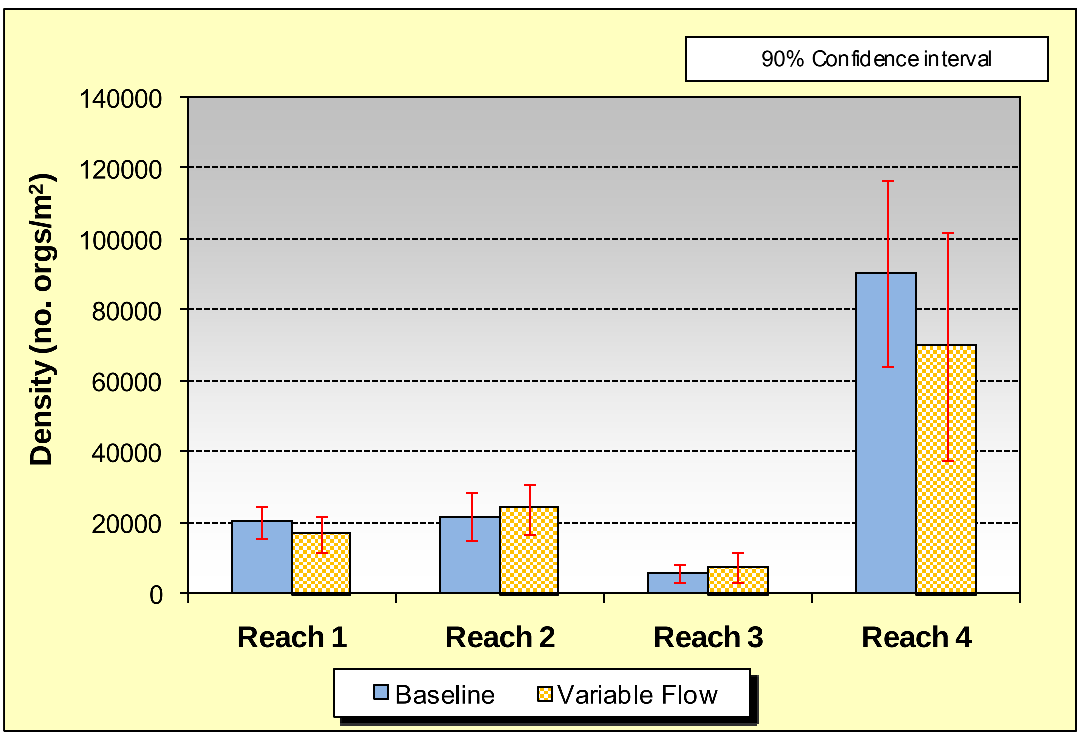


Figure 4.7-2: Average BMI Density, baseline period versus variable flow.

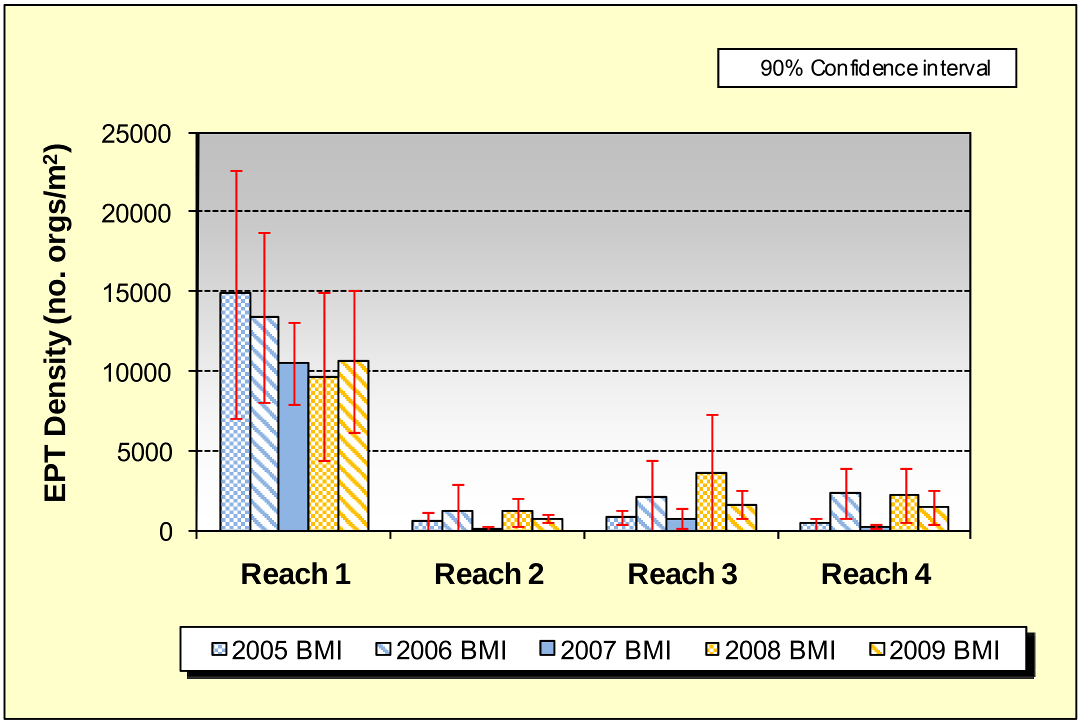


Figure 4.7-3: Average EPT Density in October, 2005 through 2009.

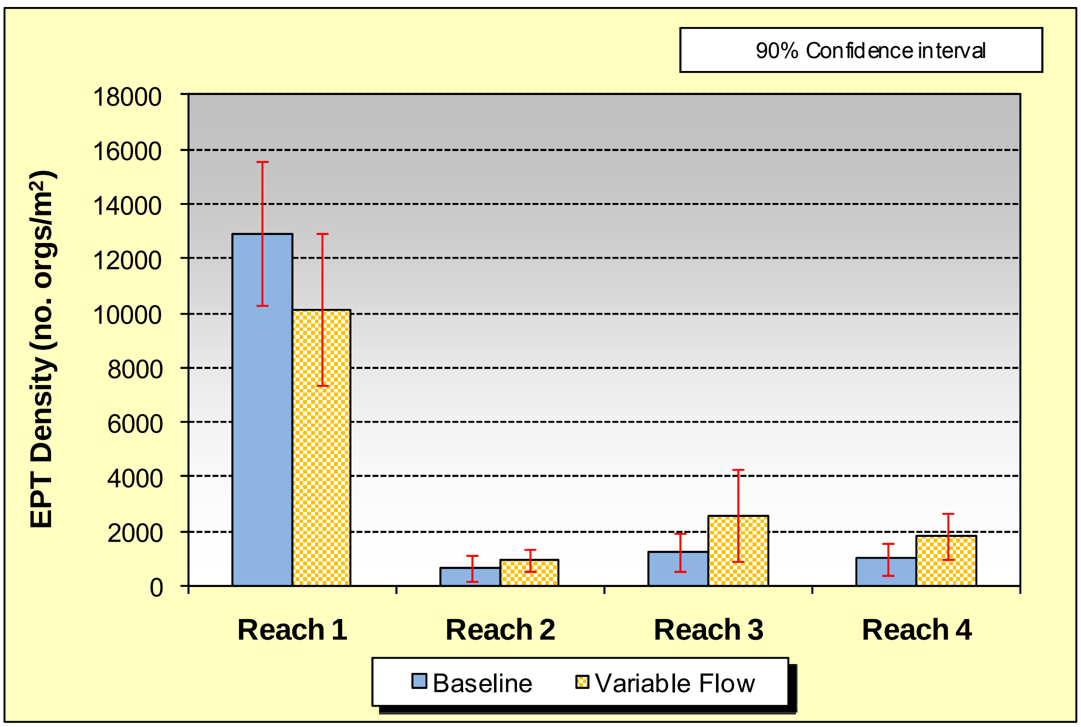


Figure 4.7-4: Average EPT Density, baseline period versus variable flow.

BMI taxa richness ranged from a low of 17 taxa in reach 4 to a high of 38 taxa in reach 3 (Figure 4.7-5). Reaches 1 and 2 each had 36 taxa. During the five-years of sampling, BMI taxa richness has varied between years within individual sites. Comparisons across all five sample years within a single study reach indicate taxa richness was significantly different between years in reaches 1, 2 and 4 but similar in reach 3 (p=0.0002, p=0.10 and p=0.000005 respectively, ANOVA). Reach 4 contained the most substantial change in BMI taxa; 17 taxa in 2009 compared to 35 taxa in 2008. These variations in taxa numbers occurred in previous sampling years under the baseline conditions suggesting other factors affect taxa richness beyond the variable flow conditions introduced in 2008 and 2009. In fact, BMI taxa richness comparisons between the three-year baseline sampling period and the variable flow regime found no significant differences in any of the study reaches.

EPT taxa richness ranged from a high of 16 taxa in reach 1 to a low of 3 taxa in reach 4 and 5 taxa in reach 2 (Figure 4.7-7). Reach 3 had 12 EPT taxa. EPT taxa richness was greater in reaches 1, 2 and 3 compared to 2008 but lower in reach 4. The 12 EPT taxa in reach 3 in 2009 was the highest number of EPT taxa measured in reach 3 over the five study years. Comparisons across all five sample years within a single study reach indicate EPT taxa richness was significantly different between years in reaches 1, 3 and 4 but similar in reach 2 (p=0.03, p=0.08 and p=0.0008 respectively, H-test).

In reach 4, the EPT taxa community in 2009 contained 6 taxa, the same number as that observed in 2008. The Ephemeroptera taxa present consisted of *Baetis tricaudatus, Fallceon quilleri and Tricorythedes sp*.. Each of these taxa were observed during one or more of the previous baseline sampling years but not continuously. *Baetis tricaudatus was* present in all three baseline sampling years. *Tricorythedes sp*. was present in 2005 and 2007. *Fallceon quilleri,* was present in 2006 only. The Ephemeroptera taxa, *Ephemerella sp*., present only in 2006 was not present in 2008 or 2009 under the variable flow regime.

Trichoptera taxa in 2009 consisted of *Brachycentridae*, *Hydroptila sp* and *Nectopsyche sp.*. Each of these taxa was observed previously during one or more of the baseline sampling events. *Hydroptila sp.* was also observed in 2006. Hydroptilidae, the family level of identification, was observed in 2005. *Nectopsyche sp.* was present in 2005 and 2007. *Neotrichia sp*. was observed in 2006 and 2008. The Trichoptera taxa, *Chimarra sp.* and *Glossosomatidae*, observed in 2006 in reach 4 were not observed in any other sampling year. The Trichoptera taxa, *Amiocentrus aspilus*, previously found in reach 4 in 2005 was not observed in 2006, 2007, 2008 or 2009. Plecoptera taxa were not present in reach 4 in any of the sampling years.

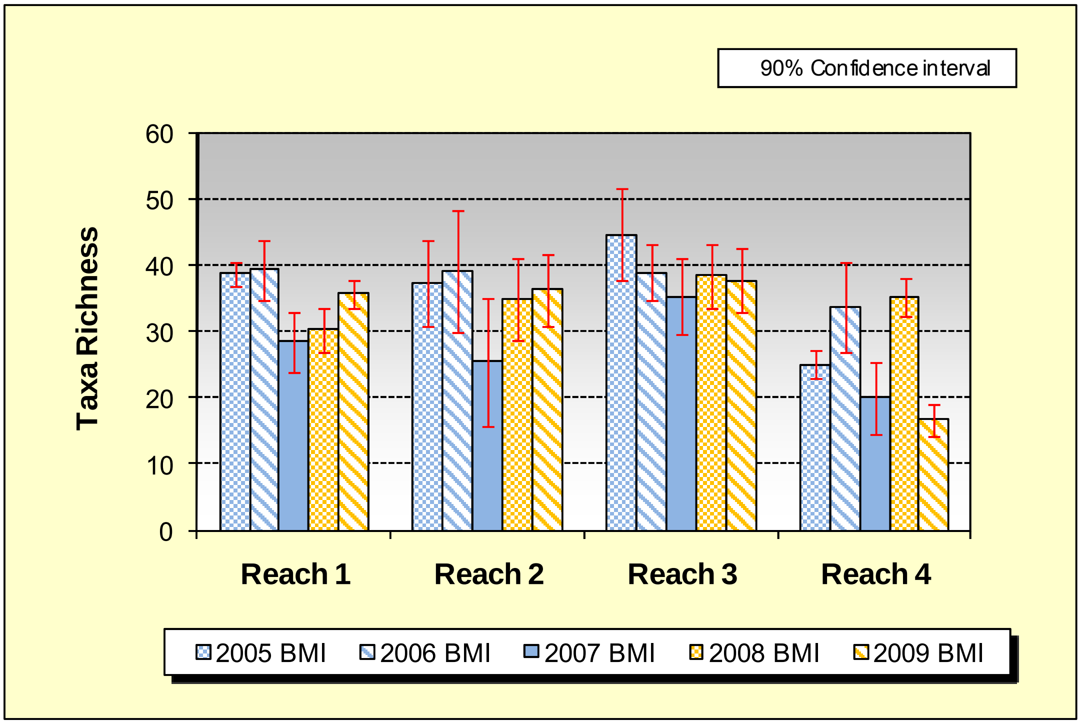


Figure 4.7-5: BMI taxa richness, 2005 through 2009.

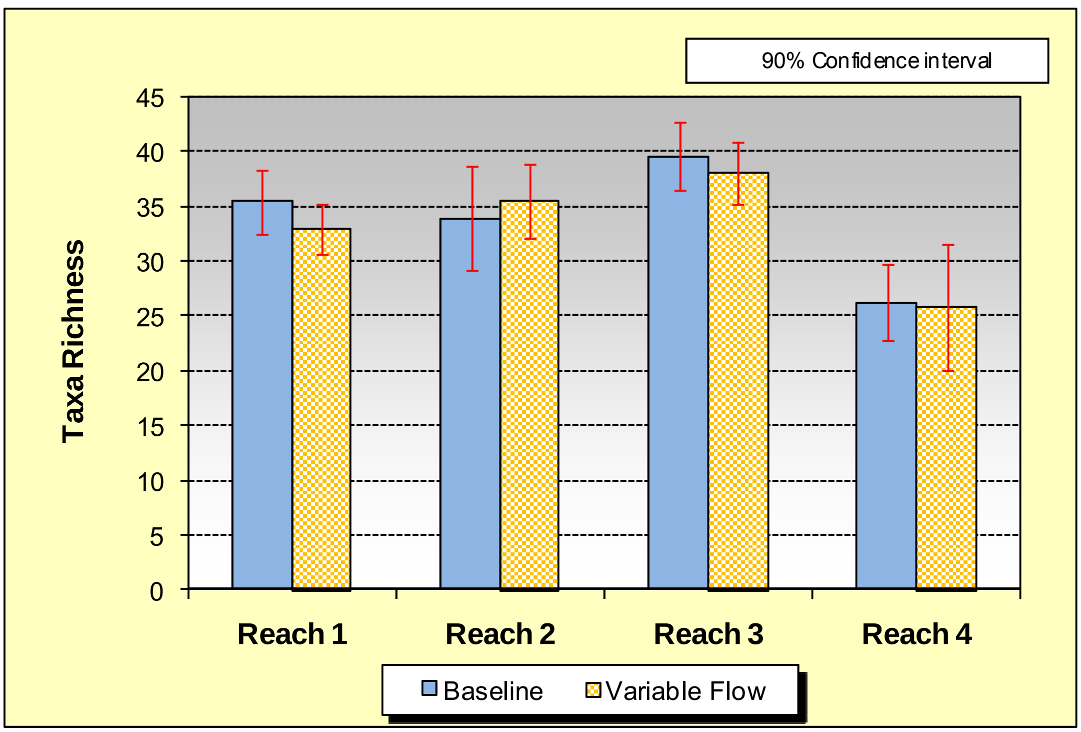


Figure 4.7-6: BMI taxa richness, baseline period versus variable flow.

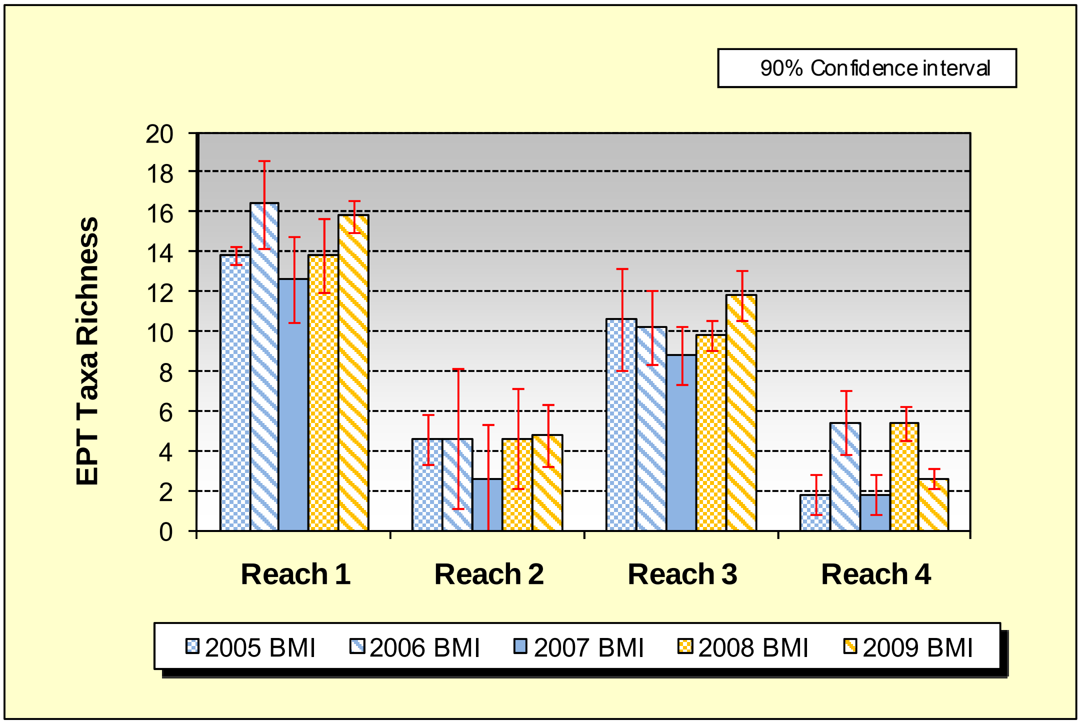


Figure 4.7-7: EPT taxa richness, 2005 through 2009

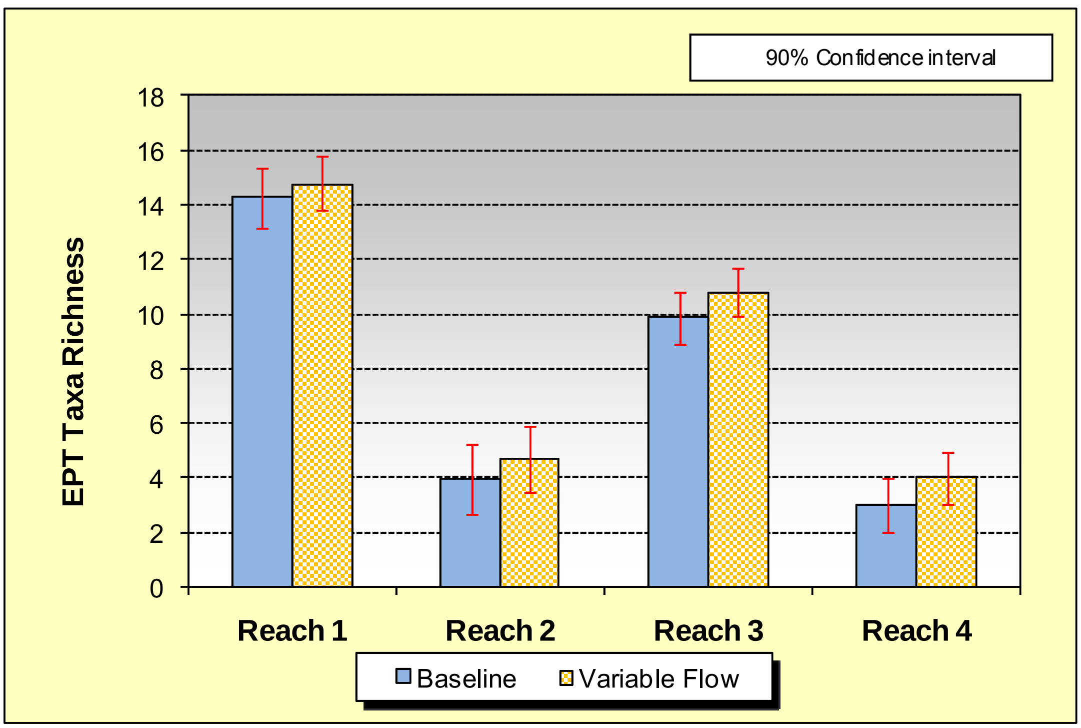


Figure 4.7-8: EPT taxa richness, baseline period versus variable flow.

Dominant taxa measures reveal the proportion of the dominant taxa relative to the larger BMI community. In 2009, the top three dominant taxa in reach 1 comprised 47.9% of the BMI density; dominant taxa 1—21.4%, dominant taxa 2—15.3% and dominant taxa 3—11.2% (Table 4.7-2). In reach 2, the top three dominant taxa comprised 49.6% of the BMI density; dominant taxa 1—25.0%, dominant taxa 2—13.0% and dominant taxa 3—11.7%. In reach 3, the top three dominant taxa comprised 45.1% of the BMI density; dominant taxa 1—24.1%, dominant taxa 2—11.6% and dominant taxa 3—9.4%. In reach 4, the top three dominant taxa comprised 92.8% of the BMI density; dominant taxa 1—88.7%, dominant taxa 2—2.3% and dominant taxa 3—1.8%.

Table 4.7-2: Top three dominant taxa percentages, 2005 through 2009

Study Reach	Dominant Taxa 1 (%)					Dominant Taxa 2 (%)					Dominant Taxa 3 (%)					Totals (%)				
	2005	2006	2007	2008	2009	2005	2006	2007	2008	2009	2005	2006	2007	2008	2009	2005	2006	2007	2008	2009
R1	20.2	17.3	19.3	18.0	21.4	12.5	12.6	15.1	12.2	15.3	8.9	10.6	12.3	10.6	11.2	41.6	40.5	46.7	40.8	47.9
R2	31.6	25.2	38.4	28.6	25.0	12.4	12.3	16.4	16.3	13.0	9.9	9.5	11.4	9.3	11.7	53.9	47.0	66.2	54.2	49.6
R3	21.7	13.4	23.0	32.2	24.1	9.8	10.4	14.0	16.5	11.6	8.4	9.7	9.4	8.2	9.4	40.0	33.5	46.4	56.9	45.1
R4	79.6	70.3	82.6	36.9	88.7	5.3	5.3	3.6	14.1	2.3	3.1	3.9	2.4	8.2	1.8	88.0	79.4	88.6	59.2	92.8

The percentage of dominant taxa in reaches 1 and 2 was similar across the five-year study period (Figure 4.7-9). In reaches 3 and 4, the percentage of dominant taxa was significantly different between years (p=0.04 and p=0.0009 respectively, H-test). The second dominant taxa exhibited a similar pattern. The second dominant taxa was significantly different over the five-year study period in reaches 3 and 4 (p=0.007and p=0.0008 respectively, H-test) but similar between years in reaches 1 and 2 (Figure 4.7-10). The third dominant taxa (Figure 4.7-11) was significantly different between years in reaches 1 and 4 (p=0.09 and p=0.003 respectively, H-test). These differences in dominant taxa percentages were similar to observations from the 2008 sampling.

The dominant taxa in reach 1 across all five study years consisted of Ephemeroptera, Trichoptera and Diptera taxa with a rotating list of individual taxon dominating the different transects in any given year. In 2005 three different dominant taxa were present in reach 1; *Simulium sp.* (TA), *Hydropsyche sp.* (TB) and *Ephemerella inermis/infrequens* (TC, TD and TE). The dominant taxa in 2006 was similar to that in 2005; *Simulium sp.* (TA and TD), *Hydropsyche sp.* (TB) and *Ephemerella infrequens* (TC and TE). In 2007, the dominant taxa included two new Trichoptera taxa in addition to *Hydropsyche sp.* and a chronomid; *Protoptila sp.* (TA), *Hydropsyche sp.* (TB), *Cricotopus trifascia gr.* (TC and TD) and *Culoptila sp.* (TE). In 2008, the dominant taxa in reach 1 included *Simulium sp.* (TA, TB and TE) and *Baetis tricaudatus* (TC and TD). In 2009, the dominant taxa included in reach 1 included *Simulium sp.* (TA), *Baetis sp.* (TB) and *Ephemerella inermis/infrequens* (TC, TD and TE). *Ephemerella inermis/infrequens* was the dominant taxon in 2005 and 2006 in transects TC, TD (2005 only) and TE.

The dominant taxa in reach 2 across all five study years consisted of a crustacean (*Ostracoda*), water mites (Acarina) and dipterans. In 2005, the dominant taxa in reach 2 was *Ostracoda* in transects TA, TB, TC and TE. Transect TD was dominated by the water mite *Hygrobates sp.* The dominant taxa in 2006 and 2007 in reach 2 was identical for four of the five transects, TB through TE; *Simulium sp.*(TB), *Ostracoda* (TC) and *Hygrobates sp*. (TD and TE). Transect TA contained *Microtendipes pedellus gr.* in 2006 and *Turbellaria* in 2007. In 2008, the dipteran *Dicrotendipes sp.* was present in transects TA, TB and TC. This taxon was observed in reach 2 in 2005 as the third dominant taxa in transect TA but has been present as a dominant taxa since that initial sample year. Transect TD and TE contained the water mite *Hygrobates sp.* in 2008. In 2009, the dominant taxon differed in each transect; *Turbellaria* (TA), *Ostracoda* (TB), *Dicrotendipes sp*. (TC), *Hygrobates sp*. (TD) and *Cricotopus trifascia gr*. (TE). The latter taxon is a dipteran.

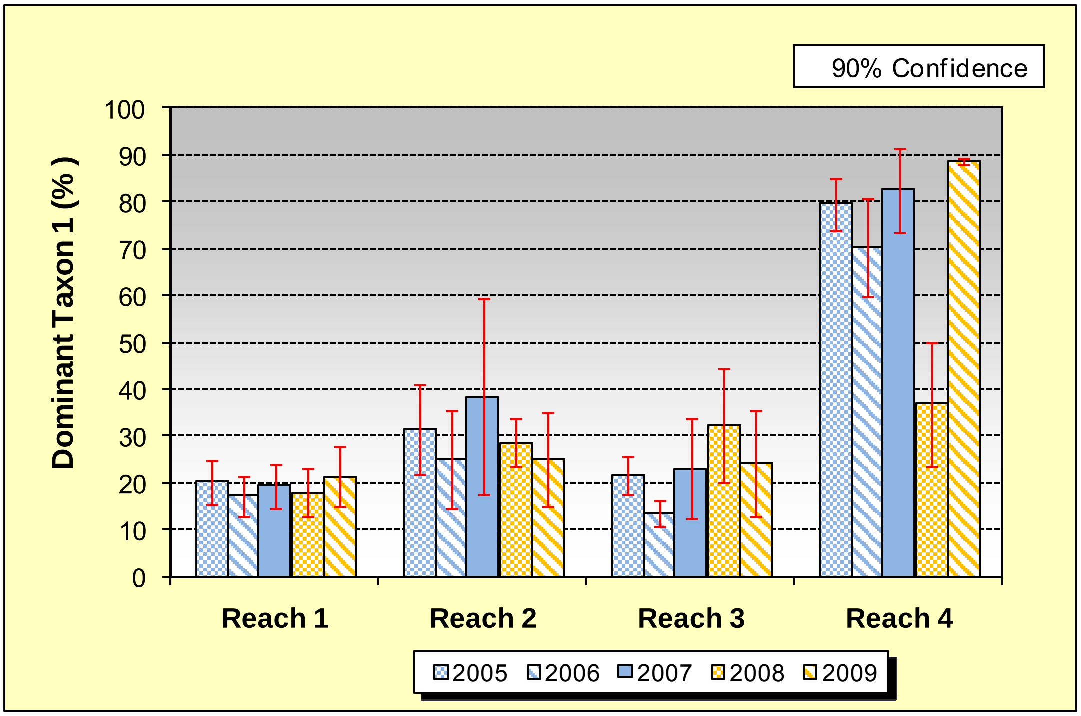


Figure 4.7-9: Dominant taxon percentage; 2005 through 2009

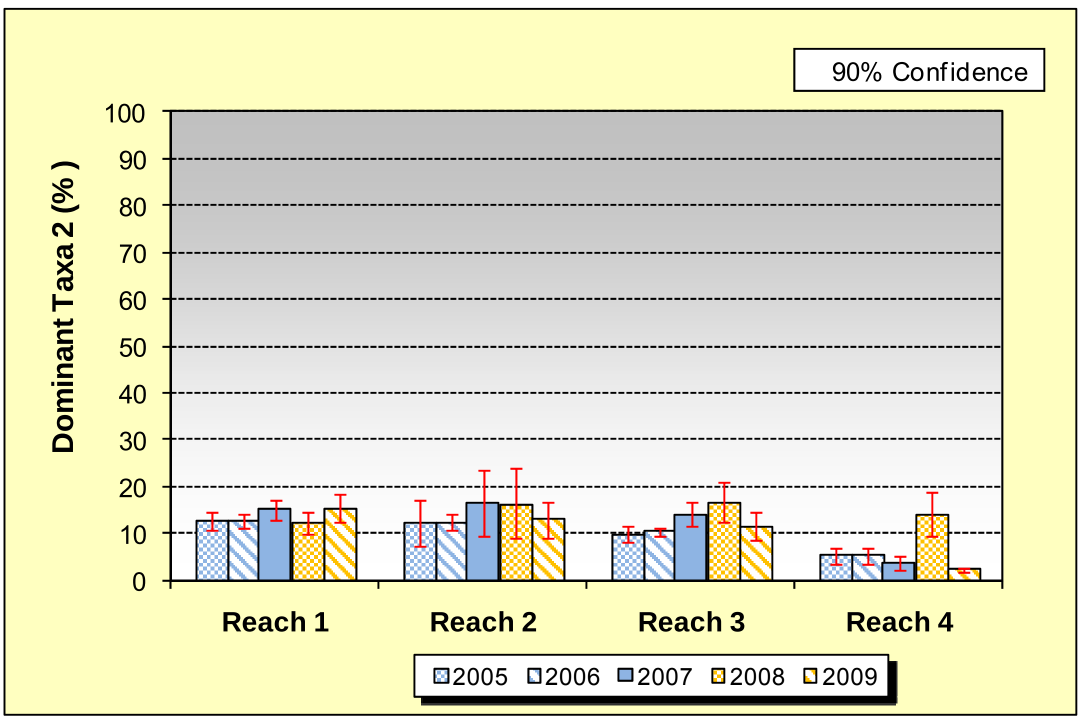


Figure 4.7-10: Second dominant taxon percentage; 2005 through 2009

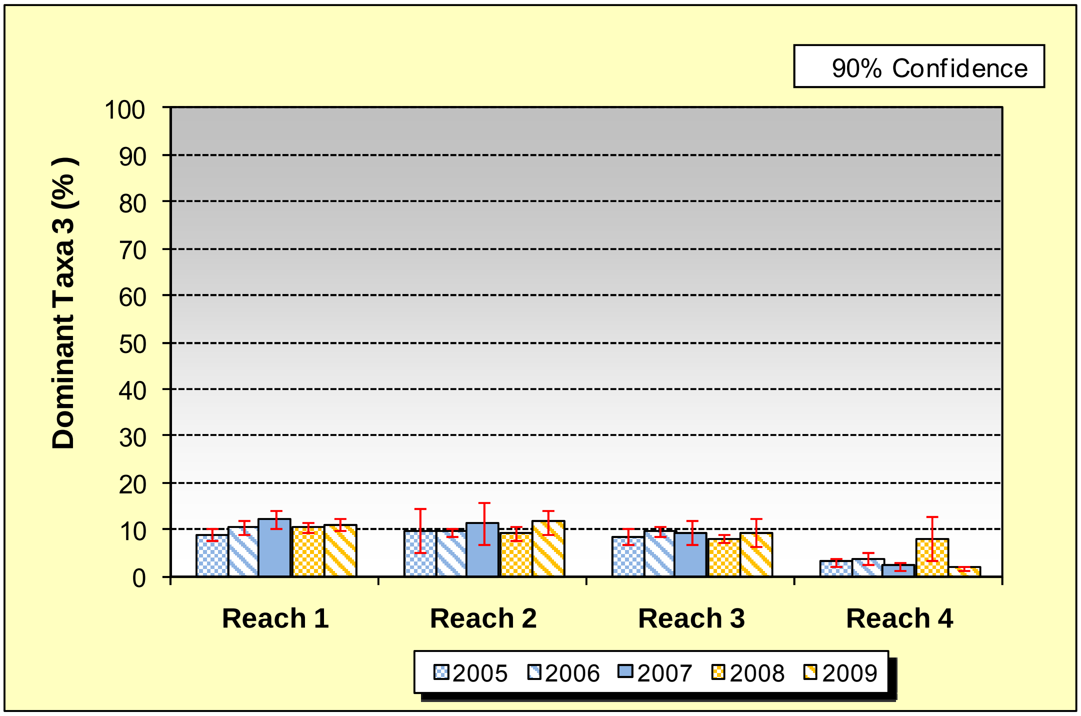


Figure 4.7-11: Third dominant taxon percentage; 2005 through 2009

The dominant taxa in reach 3 consisted largely of dipterans, water mites and an aquatic Lepidoptera (*Petrophila sp.*) over the five study years. In 2005, the water mite *Hygrobates sp*. was the dominant taxa at four of the five transects and *Orthocladius sp.*, a chironomid, was the dominant taxa at the fifth transect. In 2006, five different taxa dominated each transect; *Pseudochironomus sp.* (TA), *Hygrobates sp.* (TB), *Petrophila sp.* (TC), *Turbellaria* (TD) and *Prostoma sp.* (TE). In 2007, *Orthocladius sp.* was the dominant taxa in two transects (TA and TC), *Hygrobates sp.* (TB), *Petrophila sp.* (TD) and *Ostracoda* (TE). In 2008, the Ephemeroptera taxa, *Fallceon quilleri*, was the dominant taxa in transects TA and TC. This marked the only time an Ephemeroptera taxa was the dominant taxa in reach 3 for the five study years. The water mite, *Hygrobates sp.,* was the dominant taxa in transects TB and TC. In transect TE, *Microtendipes pedellus gr.,* a dipteran, was the dominant taxa. In 2009, *Hygrobates sp* was the dominant taxon in transects TA through TD while *Turbellaria* was the dominant taxon in TE.

In Reach 4, the BMI community has been overwhelmingly dominated by a single taxa in 2005, 2006 and 2007 (79.6%, 70.3% and 82.6% respectively. In 2008, the dominant taxa declined to only 36.9% of the BMI community, a significant decrease compared to 2005, 2006 and 2007 sampling years (p=0.00001, ANOVA). Despite the decline in the dominant taxa, reach 4 continued to be dominated in 2008 by the invasive Gastropoda, *Potamopyrgus antipodarum*. In 2005, transects TA through TE in reach 4 were dominated by *Potamopyrgus antipodarum*. In 2006, transects TA through TE in reach 4 were dominated by *Hydrobiidae*, the family level for the taxa *Potamopyrgus antipodarum.* This more conservative identification by taxonomists in 2006 was most likely *Potamopyrgus antipodarum.* In 2007, transects TA through TE in reach 4 were again dominated by *Potamopyrgus antipodarum*. In 2008, transects TA through TC and TE in reach 4 were dominated by *Potamopyrgus antipodarum*. Transect TD was dominated by the Dipteran, *Rheotanytarsus sp.*. In 2009, *Potamopyrgus antipodarum* was again the dominant taxon in all five transects in reach 4. Dominance rose from the 36.9% observed in 2008 to 88.7% in 2009, the highest dominance percentage observed in the five study years.

Table 4.7-3 and 4.7-4 list the density per square meter and relative abundance for all taxonomic orders present at each respective study reach. In reach 1, the BMI community composition in 2009 was dominated by Ephemeroptera (42%), the highest percentage for this order observed in the five study years. Trichoptera declined to 17% of the community composition in 2009, less than half the percentage observed in 2006, 2007 and 2008 although similar to 2005 percentages. In 2005, the BMI community composition consisted of Ephemeroptera (38%), Diptera (35%), Trichoptera (20%) and Annelida (4%). The remaining orders were less than 1% of the community composition. In 2006, the BMI community composition consisted of Diptera (35%), Trichoptera (32%) and Ephemeroptera (31%). In 2007, reach 1 community composition consisted of Trichoptera (55%), Ephemeroptera (19%), Chironomidae (19%) and Diptera (5%). In 2008, reach 1 community composition consisted of Ephemeroptera (31%), Trichoptera (31%), Chironomidae (19%) and Diptera (18%). In 2009, reach 1 community composition consisted of Ephemeroptera (42%), Trichoptera (17%), Chironomidae (21%) and Diptera (16%).

In reach 2, the BMI community composition remained similar for the most part over the five-year sampling period. In 2005, BMI community composition was dominated by Chironomidae (39%) followed by Crustacea (26%), Acarina (12%), and other organisms (12%). In 2006, BMI community composition was again dominated by Chironomidae (36%), Acarina (20%), other organisms (13%) and Crustacea (11%). In 2007, BMI community composition was dominated by Acarina (27%), Crustacea (26%), Chironomidae (22%) and other organisms (14%). In 2008, Chironomidae occupied a much larger percentage of the BMI community (54%) followed by Acarina (21%), other organisms (7%), Crustacea (5%) and Diptera (5%). %). In 2009, Chironomidae occupied (55%) of the BMI community, the largest percentage observed in the five sample years, followed by Acarina (15%), Crustacea (10%), other organisms (9%) and Diptera (3%). Ephemeroptera, Plecoptera and Trichoptera, the orders typically used as indicators for healthy water quality conditions, were nearly non-existent in the community composition in all study years. The order Trichoptera made up 4% of the BMI community composition in 2005 and 2006 respectively, 1% in 2007 and 3% in 2008 and 2009 respectively. The order Ephemeroptera was less than 1 percent of the BMI community all five years. The order Plecoptera was not present in reach 2 in any of the sample years.

BMI community composition in reach 3 contained a substantially larger percentage of Ephemeroptera in 2009 (12%) under the variable flow regime compared to the three-year baseline period (4%, 3% and 3% respectively in study years 2005. 2006 and 2007). In 2008, Ephemeroptera comprised 30% of the community composition. In 2005, BMI community composition consisted of Acarina (26%), Chironomidae (24%), Trichoptera (11%), Coleoptera (11%), Diptera (7%), Lepidoptera (5%) and Ephemeroptera (4%). In 2006, BMI community composition consisted of Chironomidae (28%), Trichoptera (21%), Acarina (17%), Coleoptera (13%), Lepidoptera (9%), Diptera (4%) and Ephemeroptera (3%). In 2007, BMI community composition consisted of Chironomidae (27%), Acarina (21%), Trichoptera (17%), Coleoptera (11%), Lepidoptera (9%), Crustacea (6%), Diptera (4%) and Ephemeroptera (3%). In 2008, Ephemeroptera comprised 30% of the community composition, a substantial increase compared to the three baseline sampling events. The remainder of the BMI community composition in reach 3 in 2008 consisted of Acarina (33%), Trichoptera (11%), Chironomidae (8%), Coleoptera (4%), Crustacea (4%), Diptera (3%) and Lepidoptera (1%). Lepidoptera declined in 2008 relative to the baseline period. In 2009, BMI community composition consisted of Acarina (31%), Trichoptera (15%), Chironomidae (13%), Ephemeroptera (12%), Diptera (6%), Coleoptera (6%), Lepidoptera (5%) and Crustacea (3%). The increase in Ephemeroptera composition relative to the three-year baseline period suggests changes in habitat and/or water quality under the variable flow conditions. Plecoptera were not present in reach 3 in 2007, 2008 and 2009 but comprised less than 1% in 2005 and 2006.

Reach 4 was dominated by the order Gastropoda in all five study years; 2005 (85%), 2006 (77%), 2007 (89%), 2008 (38%) and 2009 (92%). Declines in 2008 suggested a shift in the Gastropoda community potentially in response to variable flow conditions but the dominance of this order in 2009 indicates other factors may play a larger factor in this group's successful exploitation of reach 4. Reach 4 was the only site where gastropods dominated the BMI community composition. Gastropods made up less than 1% of the community composition in reaches 1, 2 and 3 in all five study years. Chironomidae was the second most dominant taxa in the five study years in reach 4; 2005 (8%), 2006 (11%), 2007 (5%), 2008 (36%) and 2009 (3%). In 2008, Ephemeroptera increased to 4% of the BMI community, a substantial increase compared to the baseflow period. However, in 2009, the percentage decreased to 1% for Ephemeroptera.

In reach 1, functional feeding group composition shifts between groups over the five-year study period (Table 4.7-5). The dominant functional group shifts nearly each sampling year. Filterers and gatherers tend to be the dominant functional feeding groups each year followed by shredders. Scrapers have exhibited the largest change in functional feeding group composition over the five-year study period; 2005 (8%), 2006 (7%), 2007 (34%), 2008 (11%) and 2009 (4%).

In reach 2, functional feeding group composition was dominated by gatherers in all five study years; 2005 (54%), 2006 (35%), 2007 (45%), 2008 (42%) and 2009 (36%). Predators were the second dominant group throughout the study period. Predators occupied 31%, 35%, 39%, 31% and 26% respectively in 2005, 2006, 2007, 2008 and 2009. In 2009, shredders increased to 24% of the functional feeding group composition compared to 7% in 2005, 10% in 2006 and 11% in 2007 and 2008. Filterer composition fluctuated between study years; 2005 (6%), 2006 (18%), 2007 (5%), 2008 (15%) and 2009 (14%). Scrapers were 1% or less of the community in all five sample years.

In reach 3, predators were the dominant functional group in 2008 (40%). Predators also dominated the functional feeding group community in 2005. Gatherers dominated the functional feeding group community in reach 3 in years 2006, 2007 and 2008 (35%, 38% and 41% respectively). Predators were the second dominant functional group in reach 3 in years 2006, 2007 and 2008 (27%, 26% and 35% respectively). Filterers comprised 19% of the community in 2009 compared to 6%, 15%, 14% and 12% in 2005, 2006, 2007 and 2008 respectively. Scrapers were the only group to exhibit a distinct difference between the baseflow period and the variable flow conditions; 2005 (15%), 2006 (20%), 2007 (20%), 2008 (4%) and 2009 (9%).

In reach 4 scrapers comprised the largest percentage of the functional feeding group composition in all five study years, 83%, 73%, 84%, 42% and 92% respectively. 2008 marked a sharp decline in scraper numbers in the BMI community. In contrast, gatherers, filterers and predators increased substantially in 2008. Gatherers comprised 8%, 13%, 6% in 2005, 2006 and 2007, an increase to 21% in 2008 and decrease to 2% in 2009. Filterers comprised 1% in 2005, 5% in 2006, 2% in 2007, 17% in 2008 then a decrease to 2% in 2009. Predators were the next most common group with 6% in years 2005 and 2006, 4% in 2007, an increase to 14% in 2008 and decrease to 2% in 2009.

Table 4.7-3: BMI relative abundance by taxonomic order, reaches 1 and 2

Taxonomic Order	Reach 1										Reach 2									
	2005		2006		2007		2008		2009		2005		2006		2007		2008		2009	
	No./m^2	%	No./m^2	%	No./m^2	%	No./m^2	%	No./m^2	%	No./m^2	%	No./m^2	%	No./m^2	%	No./m^2	%	No./m^2	%
Ephemeroptera	9508	38%	6,544	31%	2,680	19%	4,805	31%	7,304	42%	11	0%	116	0%	26	0%	281	1%	79	0%
Plecoptera	354	1%	81	0%	38	0%	50	0%	310	2%	0	0%	0	0%	0	0%	0	0%	0	0%
Trichoptera	4961	20%	6,798	32%	7,825	54%	4,803	31%	3,013	17%	584	4%	1,128	4%	98	1%	882	3%	643	3%
Odonata	3	0%	6	0%	0	0%	0	0%	0	0%	95	1%	83	0%	77	0%	243	1%	103	0%
Coleoptera	52	0%	73	0%	112	1%	65	0%	65	0%	58	0%	73	0%	40	0%	49	0%	20	0%
Chironomidae	6939	28%	4,438	21%	2,713	19%	2,976	19%	3,658	21%	6425	39%	11,444	36%	3,518	22%	13,795	54%	11,902	55%
Diptera	1770	7%	2,838	13%	761	5%	2,765	18%	2,876	16%	671	4%	2,171	7%	401	2%	1,293	5%	757	3%
Lepidoptera	266	1%	83	0%	179	1%	136	1%	151	1%	9	0%	24	0%	0	0%	4	0%	5	0%
Gastropoda	5	0%	0	0%	0	0%	0	0%	0	0%	1	0%	17	0%	0	0%	0	0%	0	0%
Bivalvia	145	1%	90	0%	15	0%	10	0%	7	0%	108	1%	1,096	3%	105	1%	9	0%	162	1%
Annelida	1042	4%	158	1%	4	0%	45	0%	27	0%	300	2%	1,683	5%	1,095	7%	589	2%	521	2%
Acarina	47	0%	72	0%	14	0%	9	0%	16	0%	2029	12%	6,502	20%	4,326	27%	5,356	21%	3,360	15%
Crustacea	31	0%	14	0%	17	0%	15	0%	28	0%	4221	26%	3,383	11%	4,167	26%	1,412	5%	2,225	10%
Other Organisms	0	0%	8	0%	7	0%	5	0%	0	0%	1889	12%	4,207	13%	2,302	14%	1,818	7%	2,028	9%
Total Organisms/m	25,123		21,202		14,366		15,685		17,455		16,400		31,927		16,156		25,730		21,803	

Table 4.7-4: BMI relative abundance by taxonomic order, reaches 3 and 4

Taxonomic Order	Reach 3										Reach 4									
	2005		2006		2007		2008		2009		2005		2006		2007		2008		2009	
	No./m^2	%	No./m^2	%	No./m^2	%	No./m^2	%	No./m^2	%	No./m^2	%	No./m^2	%	No./m^2	%	No./m^2	%	No./m^2	%
Ephemeroptera	216	4%	295	3%	123	3%	2,585	30%	731	12%	211	0%	1,188	1%	157	0%	1,751	4%	972	1%
Plecoptera	3	0%	2	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Trichoptera	607	11%	1,827	21%	604	17%	947	11%	892	15%	199	0%	1,116	1%	81	0%	422	1%	471	0%
Odonata	31	1%	2	0%	4	0%	27	0%	16	0%	19	0%	59	0%	0	0%	0	0%	0	0%
Coleoptera	588	11%	1,086	13%	384	11%	307	4%	367	6%	478	1%	1,040	1%	52	0%	234	1%	39	0%
Chironomidae	1,309	24%	2,453	28%	976	27%	674	8%	756	13%	6,829	8%	11,744	11%	4,042	5%	15,856	36%	2,410	3%
Diptera	374	7%	324	4%	161	4%	287	3%	376	6%	1,027	1%	3,484	3%	1,013	1%	3,242	7%	804	1%
Lepidoptera	267	5%	767	9%	325	9%	79	1%	276	5%	0	0%	0	0%	0	0%	0	0%	0	0%
Gastropoda	12	0%	0	0%	1	0%	0	0%	0	0%	72,841	85%	79,890	77%	71,841	89%	16,784	38%	88,457	92%
Bivalvia	0	0%	2	0%	18	0%	14	0%	2	0%	221	0%	341	0%	305	0%	32	0%	82	0%
Annelida	122	2%	41	0%	9	0%	36	0%	59	1%	491	1%	227	0%	63	0%	138	0%	17	0%
Acarina	1,427	26%	1,431	17%	748	21%	2,926	33%	1,824	31%	2,664	3%	1,554	1%	1,274	2%	4,213	10%	1,143	1%
Crustacea	136	3%	36	0%	230	6%	321	4%	182	3%	225	0%	497	0%	416	1%	630	1%	150	0%
Other Organisms	298	6%	351	4%	62	2%	552	6%	404	7%	994	1%	2,991	3%	1,220	2%	765	2%	1,091	1%
Total Organisms/m	5,391		8,618		3,644		8,754		5,884		86,201		104,131		80,465		44,068		95,637	

Table 4.7-5: Functional feeding group composition reaches 1, 2, 3 and 4.

Functional Feeding Group	Reach 1					Reach 2					Reach 3					Reach 4				
	2005	2006	2007	2008	2009	2005	2006	2007	2008	2009	2005	2006	2007	2008	2009	2005	2006	2007	2008	2009
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Filterers	31	43	32	37	29	6	18	5	15	14	6	15	14	12	19	1	5	2	17	2
Gatherers	34	36	20	40	34	54	35	45	42	36	30	35	38	41	24	8	13	6	21	2
Predators	8	3	3	2	8	31	35	39	31	26	44	27	26	35	40	6	6	4	14	2
Scrapers	8	7	34	11	4	1	1	0	0	0	15	20	20	4	9	83	73	84	42	92
Shredders	19	11	11	9	23	7	10	11	11	24	2	2	2	4	7	1	2	2	3	1
Piercer-Herbivores	0	0	0	1	1	1	0	0	0	0	1	0	1	4	1	0	1	0	1	0
Unclassified	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	2	2	0

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5. DISCUSSION

5.1 CHANNEL SHAPE AND SUBSTRATE

October discharge volumes in reaches 2 and 3 downstream from Grace Dam varied between the five sampling years. Because of these differences in discharge between sample years, survey metrics dependent on discharge vary between years. Consequently, between year comparisons are based on bankfull metrics only.

The mean bankfull width in reach 2 for the baseline period and the variable flow conditions were nearly the same, 62.88 and 62.92 meters respectively. The mean bankfull depth was also similar between the baseline period and variable flow conditions, 0.39 meters compared to 0.42. The majority of the river banks in reach 2 were severely impacted by cattle grazing, making typical bankfull indicators such as changes in vegetation and changes in slope very difficult to accurately locate in a single year let alone use the same bankfull elevation between years. The channel in reach 2 has not changed shape during the five-years of monitoring as evidenced in the consistency in the annual channel cross sections for reach 2. The small change in mean bankfull width is well within the margin of error for measuring bankfull width in the field particularly given the lack of bankfull indicators in this reach.

In reach 2, the substrate composition was similar for the three-year baseline sampling period with fines being the dominant substrate, approximately 40 percent of the overall substrate composition. After two-years of the variable flows in 2008 and 2009, the percentage of fines and sand were reduced to an average of 6 percent of the substrate composition. Sand also decreased between the baseline and the variable flow conditions; 14 percent to 8 percent. Gravel, cobble, boulder and bedrock all nearly doubled in percent composition under the variable flow conditions compared to the baseline period. The variable flows likely mobilized the abundant fines previously observed in the 2005, 2006 and 2007 Wolman pebble counts accounting for the high turbidity values observed in reaches 2, 3 and 4 during the variable flow events (Mark Stenberg, personal communication).

The mean bankfull width in reach 3 for the baseline period and the variable flow conditions were nearly the same, 21.78 and 22.09 meters respectively. The mean bankfull depth for the three-year baseline period was 0.79 meters compared to a mean of 0.81 meters under the variable flow conditions. During the baseline period, channel cross section markers (rebar pins) were difficult to locate on the inside of the meander bend (river left bank) due to the dense vegetation encroaching on the floodplain. After the first year of variable flows in 2008, field staff observed increased depositional zones of sand and fine gravel along the inside of the meander bend. In other words, the meander bend was performing a floodplain function filtering out smaller material from suspension in the water column. In 2009, deposition of fine material and sand was again observed in the floodplain. Furthermore, the channel appeared to have more habitat diversity with scour pools behind boulders on both banks and increased heterogeneity to the channel cross-section.

Under the variable flow conditions, the substrate composition in reach 3 shifted to a higher percentage of gravels (62.5 versus 54.3 percent) and an absence of fines (0.0 versus 7.7 percent). In 2008, field staff noted what appeared to be an increase in gravels and cobbles in reach 3 compared to previous years. However, Wolman pebble count data indicated little change overall in the substrate composition in 2008 compared to the baseline period. The absence of fines within the reach may have lead field staff to observe an ocular increase in gravels and cobbles.

5.2 PERIPHYTON

Periphyton, sometimes referred to as benthic algae, is the algal growth found on substrates in aquatic environments. In addition to algae, this benthic layer on rock substrates typically hosts a wide assemblage of micro and macroscopic organisms as well as detritus and fine sediments. Accordingly, AFDW values represent the weight of the algal material contained in the periphyton community as well as bacteria, benthic macroinvertebrates and detritus trapped in the longer algal filaments. Chlorophyll analysis, on the other hand, measures the ability of pigments to absorb light and, as such, serves as a measure of algal community productivity.

Periphyton AFDW and chlorophyll concentrations typically change rapidly in streams due to disturbance events such as discharge fluctuations (Steinman and McIntire 1990) or rapid growth responses to changing environmental conditions such as turbidity (Sheath et al. 1986). Consequently, identifying environmental factors responsible for differences in the periphyton community between sample years based on a single annual sampling event of periphyton AFDW and chlorophyll can be problematic. The fall sampling event associated with the Black Canyon Monitoring Study provides a snapshot of the periphyton community in the respective reaches in the same time frame. Because of the single sampling event researchers were not able to identify the factors contributing to differences in the periphyton community between reaches or explain causes in inter-annual variation when it occurs. Understanding the environmental factors influencing the periphyton community in a given reach is best achieved through systematic sampling where periphyton is sampled on a weekly or biweekly basis. This latter study approach enables researchers to track periphyton growth rates while simultaneously monitoring biotic and abiotic factors (Biggs 1990; Biggs 1996; Biggs and Kilroy 2000). Nonetheless, the present study design allows managers to document the periphyton community annually and identify statistically significant differences where they exist.

Years 4, 5 and 6 of the the Black Canyon Monitoring effort mark the experimental phase of the study design when variable flows will be released into the Black Canyon below Grace Dam serving as the treatment to study reaches 2, 3 and 4. Discharge, in particular, has been determined to be an important environmental factor influencing site specific algal growth (Biggs and Kilroy 2000). In reaches 2, 3 and 4, discharge remained virtually the same for all three reaches during the annual October sampling events with the exception that reach 4 had 30 to 60 cfs more discharge than reaches 2 and 3. In 2008, five variable flow events ranging in magnitude from 940 to 1344 cfs were released into the Black Canyon of the Bear River between April and July. In 2009, a total of eight variable flow events were released into the Black Canyon ranging from 869 to 1140 cfs. The annual October periphyton sampling documents potential changes in the periphyton community resulting, in part, from these variable flow releases from Grace Dam.

Periphyton AFDW exhibited a positive response to the variable flows in reaches 2, 3 and 4 but was significantly higher in reaches 2 and 4 only. In contrast, periphyton AFDW was lower in reach 1 under variable flows than during the baseline period but not significant.

Periphyton chlorophyll a was higher in reaches 2 and 4 under the variable flow conditions but not significant, whereas, in reach 3, chlorophyll a was significantly lower under variable flows compared to the baseline period. In reach 1, chlorophyll a failed to exhibit differences between the baseline and variable flow periods. The lack of a consistent response in the periphyton chlorophyll a and AFDW in the treatment reaches suggests that other environmental factors in addition to discharge influence periphyton AFDW at the individual study reaches.

The autotrophic index (AI), the ratio AFDW/Chlorophyll a, provides information on the relative viability of the periphyton community. If large amounts of non-photosynthesizing organic material are present, the numerator becomes inflated, and the ratio exceeds the normal range of 50-200 (APHA 1999). In all five October sampling events, the four study reaches exceed the normal AI range. The inflated numerators indicate that the periphyton matrix contains a large amount of non-algal organic material. This organic material likely includes bacteria, BMI and detritus trapped in the algal filaments. Under the variable flow conditions, the AI values were higher in reaches 2, 3 and 4 relative to the baseline period but significant in 3 and 4 only indicating there was even more non-photosynthesizing organic matter than previous years. The elevated AI values in reaches 3 and 4 may be the result of increased biological productivity associated with mobilization of fine sediments and silt containing elevated nutrient levels. AI values in reaches 1 and 2 were similar between the baseline period and the first year of variable flows.

5.3 FILAMENTOUS ALGAE

Filamentous algae coverage was significantly higher in reaches 2 and 3 under the variable flow regime conditions compared to the baseline conditions. Reach 4 remained similar between the baseline and variable flow conditions. In contrast, filamentous algae coverage decreased in reach 1 during the variable flow regime period compared to the baseline period but was not significant. Initially, it was anticipated the variable flows would reduce filamentous algae coverage through increased flows scouring the substrate. Reach 3 was assumed to be the most vulnerable to scour due to the smaller substrate size lending to increased movement at lower flow thresholds relative to some transects in reach 2 with bedrock and boulders (TC, TD and TE) and all the transects in reach 4 consisting primarily of bedrock ledges. The fact that algal coverage did not respond in the fashion expected might be due to several factors; 1) the buildup of fines in reaches 2 and 3 limited filamentous algae growth; 2) Variable flows mobilized fines and sand in reaches 2 and 3 exposing larger, more stable, substrate materials for filamentous algae; 3) Mobilization of nutrients during the variable flow release may in fact stimulate algal growth; and 4) Variable flow volumes lacked the power to scour filamentous algae from bedrock surfaces. The study plan is not capable of differentiating the factors influencing filamentous algal growth in the study reaches because sampling is limited to a single annual event in the fall season. In order to detect factors causing the filamentous algal growth from the variable flow regime, monitoring should be conducted immediately before and after the variable flow events. From an overall perspective, the variable flows can neither be labeled positive or negative on filamentous algae growth.

5.4 FISHERIES

Sampling results from October 2009 may have been affected by problems with the Halltech backpack electrofishing unit used to collect fish. The unit showed a few signs of problems during sampling including blown fuses and an occasional electrical burning smell. The unit was subsequently sent into the manufacturer for diagnosis / repair. The manufacturer informed us that the main transformer was bad and the voltage switch needed to be replaced. Based on this diagnosis and the problems observed in the field, we believe that the unit's effectiveness may have been compromised during the October 2009 sampling event. Accordingly, the metrics calculated for 2009 (total catch, catch rate, species composition, and biomass) may be inaccurate and the results should be interpreted with this in mind.

In 2009, reaches 3 and 4 contained the highest fish species richness of the four study reaches with 4 species collected, while reaches 1 and 2 each had 3 species collected. No single species was collected in all 4 reaches in 2009.

Multi-year comparisons within each study reach indicate that species richness increased in 3 of the 4 reaches between 2005 and 2006. Between sample years 2006 and 2007 species richness increased in only 2 reaches (from 4 species to 5) and decreased in the other 2 reaches (from 5 species to 4). In 2008, species richness increased in reach 1 from 4 to 5 species while richness remained constant in the other 3 reaches. In 2009, species richness decreased in 3 of the 4 reaches (reaches 1, 2, and 3) and remained constant in reach 4. In nearly all cases, when an additional species was detected in a sample, they were only collected in small numbers (1 or 2 fish per 100 meters), and therefore had low relative abundances. The opposite was also true; when a species went undetected in a sample, they had only been collected in small numbers during past sampling years. Thus, while it is possible that these apparent changes in species richness were a result of a species not being present in a reach during the sampling period, it is also possible that some species were present in small numbers but were not detected during sampling. The exception to this occurred in reach 3 where redside shiner had been collected in relatively large numbers in previous years (101, 73, 52, and 35) but none were collected in 2009.

In 2009, reach 4 had the highest total catch of fish per 100 meters (33) compared to the other three reaches (Figure 5.4-1). The majority of these were mottled sculpin (58%), redside shiner (21%), and rainbow trout (15%). Total catch in reach 2 was the next highest at 16 fish per 100 meters and was dominated by longnose dace (50%) and redside shiner (38%). Reach 3 had a total catch of 13 fish per 100 meters, and reach 1 had the lowest total catch at 5 fish per 100 meters.

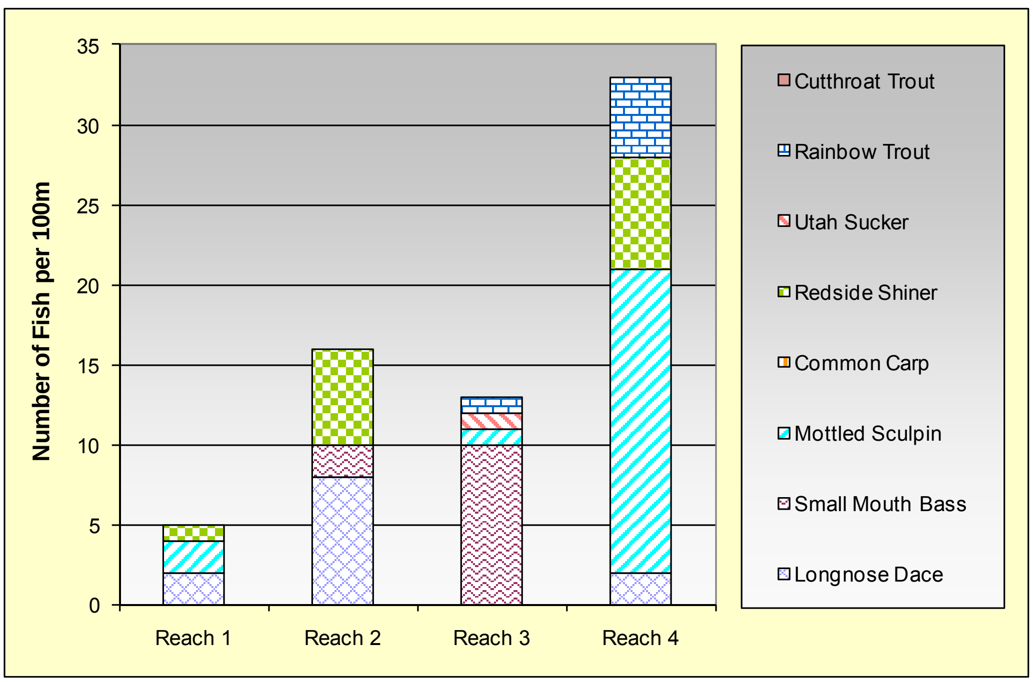

Figure 5.4-1: Total catch per 100 meters for reaches 1, 2, 3, and 4, October 2009

In 2009, the highest overall catch rate was 1.92 fish / minute in reach 4, followed by 0.83 fish/minute in reach 3, 0.72 fish/minute in reach 2, and the lowest catch rate was 0.25 fish/minute in reach 1 (Figure 4.5-3). Longnose dace and mottled sculpin had the highest catch rates in reach 1, longnose dace had the highest catch rate in reach 2, smallmouth bass in reach 3, and mottled sculpin in reach 4. Accordingly, the relative species composition was highest for longnose dace and mottled sculpin in reach 1, longnose dace in reach 2, smallmouth bass in reach 3, and mottled sculpin represented the largest percentage of the sample in reach 4 (Figure 4.5-1).

Multi-year comparisons within each reach indicate that total catch varied considerably between years in all 4 study reaches. Consequently, comparisons also indicate that catch rate follows the same trend between years as total catch, and thus shows the same degree of variation. However, it should be noted that 2009 represented the lowest total catch and accordingly, the lowest catch rates for all four study reaches to date. It should be noted that these low catch rates may be due to the aforementioned problem with the electrofishing unit.

Total biomass varies considerably between the reaches and is typically associated with collection of a few large adults within a reach. In 2009, the highest total biomass was in reach 3 (2.59 kg), and was followed by reach 4 (0.95 kg) (Figure 5.4-2). Reach 1 and reach 2 had far less total biomass at 0.04 kg and 0.09 kg, respectively. In reach 1, mottled sculpin accounted for a large majority of the biomass (78%). In reach 2, longnose dace were the most abundant (50% of total catch) however smallmouth bass accounted the largest proportion of the biomass at 55%. In reach 3, smallmouth bass were by far the most abundant (77% of the catch), however Utah sucker comprised a very large majority of the biomass at 72% despite the fact that only 1 was collected. In reach 4, rainbow trout accounted for 80% of the biomass, but they only accounted for 15% of the catch in terms of abundance.

Multi-year comparisons within each reach show that there is a large amount of variation in total biomass between years in reaches 1, 3, and 4 while reach 2 shows considerably less variation than the other reaches. A large amount of the variation between years in total biomass is the result of collecting just a few large bodied adult carp, suckers, or rainbows in some year(s) while none were collected in other years. Data from reach 2 further supports this idea since no large bodied adults were collected in any of the sample years and accordingly, there was less variation between years.

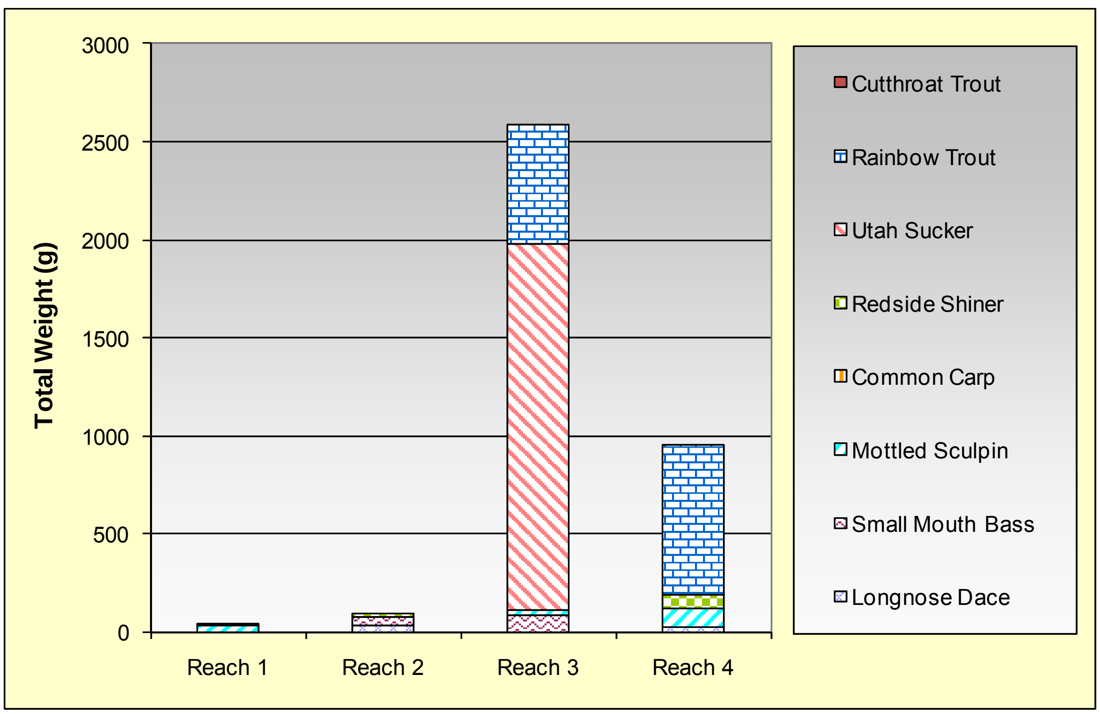

Figure 5.4-2: Fish biomass per 100 meters, reaches 1, 2, 3 and 4, October 2009

5.5 TEMPERATURE

Surface water releases from Grace Reservoir during the variable flow regime period have the potential to increase stream water temperatures in reaches 2, 3 and 4 during the summer season. During the three-year baseline period when no releases occurred beyond the MIF, daily average stream temperatures sporadically exceeded the 20 ºC salmonid threshold in both reaches 2 and 3, but not in reach 4 between June 21 and September 21. In reach 2, MIF exceeded the 20 ºC salmonid threshold in all three baseline study years; 37, 37 and 40 days respectively. In reach 3, water temperatures were monitored from July 5 2006 to October 10, 2006. Daily minimum water temperatures exceeded the 20 ºC salmonid threshold on 32 days starting on July 5. Increased discharges from Grace Dam associated with the variable flow releases are not likely to cause large increases in stream temperatures in reaches 2 and 3 since those temperatures are already greatly influenced by meteorological conditions similar to those influencing surface water temperatures in the Grace impoundment. In reach 1, daily minimum water temperatures also exceeded the 20 ºC salmonid threshold over each summer season in the baseline period; 2005 (21 days), 2006 (17 days) and 2007 (34 days).

In reach 4, daily average stream temperatures and daily maximums remained consistently below 20 ºC for much of the summer season except for three dates annually; July 25, 2005, July 19, 2006 and July 23, 2007. The July 19, 2006 rise in daily maximum temperatures above 20 ºC corresponded to an increase in discharge from Grace Dam of 122 cfs. In 2005, discharge spikes below Grace Dam on July 26 (255 cfs) and September 16, 2005 (194 cfs) did not appear to alter daily maximum stream temperatures. Outside the summer season (June 21 to September 21), daily average water temperatures in reaches 1, 2 and 3 were below the 20 ºC threshold. Deployment of an additional hobo temp in the epilimnion of the Grace impoundment would yield additional data on surface water temperature discharged into the Black Canyon.

Temperature data for the three-year baseline monitoring period at the four study reaches revealed distinct seasonal patterns. Comparisons between reaches 1, 2, 3 and 4 also revealed distinct differences in water temperature. These differences were particularly notable during the summer months. Reach 3 exhibited the highest maximum temperatures (27.1 ºC) of all four reaches over the three-year baseline period. Reach 4 exhibited the coolest water temperatures with daily averages consistently below 20 ºC throughout the summer months and a single day each year when a maximum water temperature exceeded 20 ºC. Daily averages in reaches 1, 2 and 3 exceeded 20 ºC for a substantial number of days each summer season. In all three-years, daily minimums in reaches 1 and 2 exceeded the 20 ºC threshold for a continuous 20 days or more with the maximum 40 days in 2007 in reach 2.

Similar water temperature analysis should be undertaken for the variable flow regime conditions particularly in reaches 2, 3 and 4 to determine the influence of surface water releases on downstream stream temperatures. Stream temperatures in reaches 2 and 3 already exceed the salmonid threshold prior to release of the variable flows. It is unlikely that variable flow releases will further increase stream temperatures in reaches 2 and 3. In reach 4, changes in stream temperature were not analyzed under the variable flow conditions. This temperature data should be analyzed to determine the potential of variable flow releases to increase stream temperatures in reach 4 and the duration of the temperature change. This information will provide important information regarding potential impacts to coldwater aquatic organisms, salmonids and benthic macroinvertebrates, which require high oxygen concentrations typically found in cooler thermal regimes.

5.6 HYDROLOGY

Discharge data measured at the USGS gage located upstream of Soda Reservoir and the USGS gage located in the bypass channel below Grace dam were included for comparison of hydrologic differences between the reference site and study reaches 2, 3, and 4 located below the dam. In addition, the latter gaging station records the discharge associated with the variable flow releases in years 2008, 2009 and 2010 relative to flows during the baseline period.

Reach 1 differs from reaches 2, 3 and 4 hydrologically. Water storage in Bear Lake partially regulates flows in reach 1 by decreasing the magnitude of peak flow events during spring snowmelt and shifting the snowmelt hydrograph into July, August and early September to fulfill downstream water rights. In 2007, releases from Bear Lake started in June due to the increased air temperatures and below normal run-off relative to the 2005 and 2006 water years. Regulated releases from Bear Lake peaked at 1610 cfs in 2007 compared to 933 cfs in 2006 and 1336 cfs in 2005. In 2008, the daily average flows remained above 1000 cfs for most of August with a peak of 1480 cfs on August 9. In 2009, demands for irrigation water came earlier with the daily average flows above 1000 cfs for most of July with a peak of 1300 cfs on July 22. These hydrologic differences between sample years varied slightly in the timing and duration of peak flows but were relatively similar in magnitude.

Reaches 2, 3 and 4, located in the Black Canyon of the Bear, are fully regulated by upstream irrigation and power generation diversions. Instream flows below Grace Dam remain relatively stable year round. Groundwater upwellings and springs just upstream of reach 4 contribute an additional 30-60 cfs on top of the existing base flow. During the three-year baseline monitoring period, no variable flow releases occurred in the reaches below Grace Dam. However, several spill events above the prescribed MIF did occur during the three-year baseline period. In April 2005, a single day spill flow of 863 cfs occurred from spring run-off overtopping Grace Dam. In mid-September of 2006, pulse flows were released from Grace Dam to assist channel restoration efforts in the former Cove impoundment. Daily average flows reported for those releases were 152 cfs on September 18, 2006. Instantaneous peak flow data for these pulse flows were not available but were assumed not to exceed 500 cfs from Grace Dam. Variable flows started in the spring of 2008. In that year, five variable flows were released between April and mid-July ranging from 940 to 1344 cfs. In 2009, eight variable flow events occurred between April and mid-July ranging from 869 to 1140 cfs. The peaks associated with the variable flows were an order of magnitude greater than the MIF conditions from 2005 through 2007 but similar in magnitude to flows observed in reach 1 in July and August and periodic spills over Grace Dam when spring run-off or operational needs exceed the capacity of the Grace flow line.

5.7 BENTHIC MACROINVERTEBRATES

BMI density for the four respective study reaches was similar between the initial three-year baseline period and the two-year variable flow period. BMI taxa richness also remained unchanged for each of the four respective study reaches between the baseline and variable flow period. EPT density, on the other hand, was significantly greater in the treatment reaches during the variable flow period compared to the baseline period whereas reach 1, the reference reach, showed no change over the same period of time.

Although still a small percentage of the overall BMI community composition, the increased EPT densities in reach 2 signify a change in habitat conditions under the variable flow releases. In reach 3, EPT comprised 41 percent of the BMI community composition in 2008 declining to 27 percent in 2009 compared to 15 percent, 24 percent and 20 percent in 2005, 2006 and 2007 respectively. In 2008, the Ephemeroptera, *Fallceon quilleri*, was the dominant taxa in two of the five transects in reach 3. This marked the first time the dominant taxa in any of the treatment reaches was an Ephemeroptera taxa. In 2009, the water mite, *Hygrobates sp.*, was the dominant taxa at four of the five transects in reach 3. In contrast, the dominant taxa in reach 1 in 2009 were *Baetis sp.* (transect TB) and *Ephemerella* inermis/*infrequens* (transect TC, TD and TE).

In reach 1, EPT comprised the largest percentage of the BMI community composition in all five study years. In contrast, the combined EPT percentages in reaches 2 and 4 failed to equal that of *Chironmidae* in reach 2 or *Gastropoda* in reach 4. The small percentage of EPT in the community composition during both the baseline and variable flow conditions suggests poor habitat conditions are the overriding limiting factor. EPT taxa are typically found in water bodies with cold, well oxygenated water and favor good quality habitat with sufficient interstitial spaces in the substrate. As such, these orders are used as an index for assessing water quality and habitat conditions. The previous lack of EPT taxa in reaches 2, 3 and 4 during the baseline period indicated poor water quality and/or habitat conditions. Water quality, although not part of the study design, was roughly similar between the baseline and variable flow sampling events. The substrate in reaches 2 and 3, on the other hand, did have less silt and sand under the variable flow conditions which would increase the interstitial spaces in gravels and cobble and flow of oxygenated water. The increase in EPT density in reaches 2 and 3 was likely the result of changes in the substrate composition. Despite this increase in EPT density these reaches continue to exhibit poor habitat quality. For example, reach 2 continued to be dominated by dipterans (chironomids in particular) and Acarina (water mites) in 2008 and 2009 despite the increase in EPT density. Dipterans are typically indicative of poor water quality and habitat condition.

As noted in 2006, the presence of NZMS, *Potamopyrgus antipodarum*, in reach 4 raises concerns. NZMS is an invasive species. *Potamopyrgus antipodarum* was the dominant taxa in reach 4 for all five October sampling events; 2005 (81%) 2006 (74%), 2007, (83%), 2008 (37%) and 2009 (89%). The dramatic decline in NZMS in 2008 under the variable flow releases appeared promising initially. In 2008, the changes in the BMI community composition in reach 4 in the first year of the variable flow releases resulted in increased taxa diversity, an increase in EPT density and a reduction in the dominant invasive taxa. The shifts in the BMI community composition reflected positive changes for reach 4 under the variable flow regime.

At the conclusion of the 2008 field effort, researchers believed the variable flows, in part, might serve as a mechanism for limiting the dominance of NZMS in reach 4. However, the dramatic increase in NZMS density in 2009 suggests additional factors likely influenced NZMS density in 2008 beyond the variable flow releases. Variable flow volumes were approximately 200 cfs greater in 2008 than 2009 suggesting a potential, although unlikely, flow threshold between 1100 and 1300 cfs.

Mobilization of fine sediments, in concert with the variable flows, could be a factor affecting NZMS density. The 2008 variable flows marked the first year of releases which may have resulted in higher turbidity levels potentially affecting periphyton and filamentous algae through scour or distributing a blanket of fines thereby impeding algal growth during that season. NZMS are classified as scrapers. Accordingly, filamentous algae serves as a key food source for NZMS. Variable flow releases in 2009 may not have mobilized as much fine sediment as 2008. Turbidity measures during the 2008 and 2009 variable flows should be examined to discern differences between years. Clearly, variable flows alone are not sufficient to account for the dramatic decline in NZMS observed in 2008.

Reach 1 was dominated by gatherers (34%), filterers (29%), shredders (23%) and scrapers (4%) in 2009. The 2009 functional group composition in reach 1 was typical of previous years. Given the October sampling date coupled with leaf fall from the adjacent riparian community these functional groups were expected for this time period (Vannote et al. 1980). In 2007, scrapers increased to 34 percent of the community composition. Scrapers are typically a small percentage of the community composition in fall sampling events due to the decline of algal food resources. The filter feeders likely take advantage of the high nutrient concentrations resulting from agricultural land-use practices adjacent to and upstream from reach 1.

In Reach 2, the BMI community was dominated by gatherers and predators in all five sample years. The gatherer feeding group in reach 2 consists largely of chironomids. The percentage of shredders more than doubled in 2009 compared to previous years (increase from 11% to 24% in 2009). The low percentage of shredders in reach 2 in previous years was thought to be the general lack of riparian vegetation due to grazing practices coupled with the upstream reservoir trapping leaf litter input. Recent changes in riparian management , e.g., livestock grazing practices, on the river left may have increased allochthonous inputs stimulating an increase in shredder density. The percentage of filterers increased slightly under the variable flow conditions compared to the three years of baseline. Poor habitat quality likely also plays a significant role in the lack of diversity in the functional feeding groups in reach 2.

Reach 3 in the Black Canyon was dominated by predators and gatherers under the variable flow conditions whereas the percentage of scrapers declined substantially compared to the baseline period. The decline in the scraper community corresponds to the decrease in chlorophyll a in reach 3 under the variable flow conditions. Chlorophyll a serves as a measure of higher food quality for grazing taxa. Lower chlorophyll a values signify a decrease in the availability of high quality food. Gatherers were the dominant group in reach 3 in 2008 corresponding to the increase in the autotrophic index in reach 3. Inflated AI values suggest more bacterial content in the periphyton providing a higher quality food resource for gatherers. Shredders continued to comprise only a small percentage of the community in all five sample years.

Reach 4 was dominated by scrapers in all five sampling years likely capitalizing on the abundant filamentous algae. However, in 2008, scrapers comprised less than half the community percentage observed in the other sampling years. Reach 4 continues to be favorable for scrapers with its open canopy coupled with the stable bedrock substrate, stable flow regime and nutrient inputs from groundwater upwellings making the site conducive to algal growth. Other researchers have found increases in scraper densities corresponding to reaches with open canopies (Hawkins et al. 1982; Noel et al. 1986; Fuller et al. 1986; Behmer and Hawkins 1986). The NZMS is classified as a scraper. The lack of disturbance under baseline conditions might have further enabled the NZMS scraper specialist to outcompete generalist species. Resh et al (1988) attributed increased BMI species richness to the increased habitat complexity that results in streams with intermediate levels of disturbance. Prior to the variable flows introduced in 2008, reach 4 received little disturbance annually and, as expected, the species diversity was low, dominated by the invasive NZMS capitalizing on the abundant filamentous algae. Disturbance was introduced in 2008 under the variable flow releases. The NZMS density in reach 4 declined precipitously. Other functional groups increased substantially such as filter feeders (17%), gatherers (21%) and predators (14%). In 2009, a similar disturbance event was introduced to reach 4 with a slightly lower flow threshold. NZMS density rebounded with numbers similar to those observed in the baseline period.

Reach 4 supported a substantially higher BMI density than the other three study reaches in all five study years. Autochthonous food sources such as filamentous algae are considered to be of higher nutritional value than allochthonous inputs (Anderson and Cummins 1979; Minshall

1978). The quality of the food resources in Reach 4 combined with the stable channel structure and low level of disturbance likely results in the success of the invasive species in reach 4. The high density of NZMS demonstrates the invasive is at a competitive advantage over other BMI taxa for food resources in reach 4. The NZMS is a questionable food source for salmonids even in high densities. From a fishery management perspective, the conditions in 2008 that lead to the significant increase in EPT abundance in reach 4 should be further investigated to increase the available food resources for salmonids.

6. CONCLUSIONS

The new license for the Bear River Hydroelectric Project (FERC No. 20) includes a condition requiring PacifiCorp to implement and study a variable flow regime at the Grace Hydropower Facility in the 6.2 mile reach known as the Black Canyon between Grace Dam and the Grace powerhouse. PacifiCorp, in collaboration with the ECC, developed the Bear River Black Canyon Monitoring Study to examine the effect of the variable flow regime on the river channel shape, substrate and aquatic biota. Specifically, the Black Canyon Monitoring Plan includes investigation of: 1) Macroinvertebrates—population trends, diversity and community indices; 2) Organic Matter Ash-Free Dry Weight (AFDW); 3) Periphyton—chlorophyll concentration and biomass; 4) Fisheries—population trends, community composition, fish condition; 5) Filamentous Algae—density; and 6) Channel Morphology—shape and substrate composition.

The monitoring effort comprises four study reaches. Reach 1, partially regulated by Bear Lake, serves as the reference reach. Reaches 2, 3 and 4, subject to the variable flow regime below Grace Dam, serve as the experimental reaches. The monitoring study spans six-years of data collection. The first three-years serve as a baseline period collecting data in all reaches prior to implementation of the variable flow regime. The second three-year term, years four through six, serve as the experimental phase when reaches 2, 3 and 4 will be subjected to flows ranging from 800 to 1500 cfs, approximately 700 to 1400 cfs greater than the minimum instream flow of 65 cfs below Grace Dam. Field sampling occurs once annually in October. Field sampling was initiated in October 2005 and will conclude October 2010.

This report compares the study results from the baseline monitoring effort, years 2005 through 2007 with two-years of variable flows in 2008 and 2009. The year 3 report, the 2005, 2006 and 2007 data, served as a baseline characterization of the four study reaches. The baseline data analysis determined that reaches 1, 2, 3 and 4 were distinctly different from each other. Because of these distinct differences in community composition and habitat, the comparative analysis between sample years and treatments examines changes within respective study reaches rather than comparisons between reaches.

Channel morphological characteristics remained largely unchanged in reaches 2 and 3 under the two-years of variable flow conditions in 2008 and 2009 compared to baseline monitoring in 2005, 2006 and 2007. Variable flows ranging from 940 to 1344 cfs were released on five occasions between April and July 2008 into the Black Canyon of the Bear River inundating study reaches 2, 3 and 4. In 2009, a total of eight flows were released ranging between 869 and 1140 cfs between April and July. The releases mobilized silt and sand deposited in the channel resulting in high turbidity levels in 2008 (Mark Stenberg, personal communication). The mobilization of these materials resulted in a substantial decrease in silt and sand size particles in the substrate composition in reaches 2 and 3 in 2008 and 2009. In reach 3, field staff observed increased deposition of silt and sand in the floodplain and less in the active channel. After the first year of variable flow releases in 2008, field staff sampling reach 3 noted the visible increase in the percentage of gravels and cobbles available for spawning as well as interstitial spaces for benthic macroinvertebrates. These habitat features were less evident in previous sampling years under baseline conditions.

The periphyton community response to the variable flow releases varied between study reaches. In reach 2, chlorophyll a and AFDW were higher under the variable flows compared to baseline conditions. In contrast, chlorophyll a was significantly lower in reach 3 under variable flow conditions but AFDW was similar to the baseline period. In reach 4, AFDW was significantly greater but chlorophyll a exhibited no changes between the baseline period and the variable flow releases. In reach 1, chlorophyll a and AFDW were similar between the baseline period and the variable flow conditions. The AI was significantly higher in reaches 3 and 4 under variable flow conditions compared to the baseline period.

The inconsistent responses in periphyton metrics to the variable flow treatment for respective reaches suggests environmental factors other than discharge play a role influencing periphyton biomass. Periphyton biomass exhibits considerable spatial and temporal heterogeneity even within a given study reach (Steinman and McIntire 1990). Furthermore, the annual fall sampling incorporated into the study design may not have the temporal resolution to detect short term changes in the periphyton community in response to the variable flow releases. Alternatively, the reach specific responses in the periphyton community could be a manifestation of the interaction between substrate and discharge unique to each reach. Reach 3 contains the smallest average substrate particle sizes for the four reaches with the exception of transects TA, TB and TC in reach 2. Consequently, reach 3 would be more vulnerable to scour at lower discharges compared to reaches 2 and 4. This scour could cause disturbance in the periphyton community. Chlorophyll a did decline in reach 3 but the AFDW values remained similar between the baseline and variable flow periods.

Filamentous algae coverage was significantly higher in reaches 2 and 3 during the variable flow sampling period. Reaches 1 and 4 did not exhibit any differences in filamentous algal growth between the baseline and variable flow periods. The cause for the increase in reaches 2 and 3 remains uncertain. The variable flow releases were expected to scour some of the filamentous algae causing a decrease in growth between the baseline and variable flow sampling periods. On the other hand, scour associated with the higher discharge during the variable flow period may have mobilized nutrients thereby stimulating algal growth in reaches 2 and 3. Additional sampling in year 6 will track filamentous growth over time to determine if the differences continue.

In 2009, a total of six fish species were collected throughout the combined four reaches compared with 8 species in 2008 and 7 species in all other sampling years. No common carp were collected in 2009 however they were typically only sporadically collected in small numbers in previous years in reaches 1, 2, and 3. No cutthroat trout were collected in 2009, but only 1 (reach 1, 2008) had been collected in previous years. Accordingly, the patchy distribution, overall low density, and subsequent low detection probability of these two species likely accounted for the lack of collection in 2009.

Reach 4 had the highest total catch (33 fish) and catch rate (1.92 fish/minute) in 2009 while reach 1 had the lowest total catch (5 fish) and catch rates (0.25 fish/minute). Reach 4 has typically had the highest or second highest total catch and catch rates throughout the study, both before and after the whitewater flows, so the 2009 data is consistent with past years. However reach 1 had relatively high total catch and catch rates in the first three years of the study but has had very low total catch and catch rates the last two years. This large decline in total catch and catch rates is consistent with the timing of the whitewater flow releases (2008 and 2009), but reach 1 is the control reach and is therefore not subject to these flows.

Reach 4 was the only reach where rainbow trout were collected in all five sample years. Rainbow trout were not present in the other study reaches with the exception of a single rainbow trout collected in reach 3 in 2006 and 2009, and one in reach 1 in 2008. In reach 4, rainbow trout total catch and CPUE was considerably higher in 2005 than in 2006, 2007, 2008, or 2009 (Table 4.5-9). It should be noted that these differences are likely a result of the rainbow trout stocking schedule. In 2005, Idaho Fish and Game released 250 freeze-branded rainbow trout below the foot bridge near the Grace power plant on October 14. This release was approximately 1 hour prior to and 75 meters downstream of the fish sampling for reach 4. As a result, some of the fish collected that day may have just been released from the nearby hatchery truck. In 2006, the most recent stocking prior to sampling occurred on September 12, in 2007 and 2008 the most recent stocking occurred on August 29th and in 2009 the most recent stocking occurred on September 21st. Accordingly in 2006, 2007, 2008 and 2009 the rainbow trout had more time to disperse throughout the river or be caught and removed by anglers. Either scenario could have contributed to the decreased total catch and decreased CPUE. Low rainbow trout abundance and catch rates observed in 2006, 2007, 2008 and 2009 compared to 2005 suggests a strong relationship between catch rates in this study and the rainbow trout stocking schedule. Similarly, the relative weights of freeze-branded rainbow trout collected during the study are likely heavily influenced by the condition of the fish at the time of release and thus may not be a true indication of conditions in the river.

BMI density showed no significant differences between the baseline and the variable flow periods in reaches 1, 2, 3 and 4. EPT density, on the other hand, exhibited significant increases in reaches 2, 3 and 4 under the variable flow conditions. Under the baseline conditions there EPT densities were low particularly in reaches 2 and 4. EPT taxa are more available in general as a salmonid food source than NZMS. The increase in EPT taxa in reaches 2 and 3 was likely the result of changes in the substrate composition. In reach 4, the increase in EPT taxa may be due to, in part, to less competition with NZMS for habitat or simply reduced interactions with NZMS. Little information is available on the interactions between NZMS and native BMI taxa. The potential ecological effects of this invasive species on other trophic levels in reach 4 remains uncertain.

In 2008, following the initial year of variable flow conditions, BMI density in reach 4 decreased significantly, primarily due to a decline in NZMS density. The decrease in NZMS coinciding with onset of the variable flow conditions suggested a possible tool for managing the invasive species. However, in 2009, NZMS density increased back to levels observed during the baseline period despite continued variable flow releases. The 2008 variable flows were approximately 200 cfs greater than the 2009 releases. Further investigation and experimentation with flow volumes and associated water quality conditions may be warranted before flow management is ruled out as a management tool for controlling NZMS density in reach 4.

As of the October 2009 sampling, NZMS were not present in reaches 1, 2 or 3. Educational signs have been installed at the footbridge in reach 4 warning anglers and boaters of the potential to inadvertently transport these aquatic hitchhikers to upstream reaches and adjacent water bodies. Installation of wash stations may be the next step to help protect non-infected waters.

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7. LITERATURE CITED

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