EFFECTS OF THE VARIABLE FLOW REGIME ON THE

ECOLOGY OF THE

BLACK CANYON OF THE BEAR RIVER, IDAHO

FINAL REPORT YEAR 7

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 associated with whitewater releases 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 present during the initial three-years of the variable flow regime.

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 was designed to evaluate and quantify the inter-annual changes in abundance, composition and distribution of aquatic biota and habitat within three individual sample sites through time as well as compare post-disturbance conditions to a reference reach.

In years 2005-2007, Phase I monitoring studies were conducted to annually 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 required PacifiCorp to provide periodic whitewater boating flows below Grace Dam. The objective in the 2008-2010 Phase II study was 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) was compared to results from the 2008-2010 Phase II study (variable flow conditions) to determine the inter-annual 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. The study was not designed for immediate before and after analysis of individual releases at respective sample sites.

Specifically the Black Canyon Monitoring Plan included 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 included a reference reach located upstream of Soda Reservoir and three experimental reaches within the Black Canyon. The reference reach was not subjected to the flow fluctuations associated with the whitewater releases but was partially regulated by Bear Lake.

Field sampling occurred once annually in October from 2005 through 2010 for a total of 6 sample years; 3-years under Phase I baseline conditions and 3-years under Phase II variable flow conditions. Field sampling was initiated in October 2005 proceeding for 6 years. This report summarizes the results of the 6-year sampling effort comparing baseline conditions to variable conditions.

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 forms 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.

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. 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.

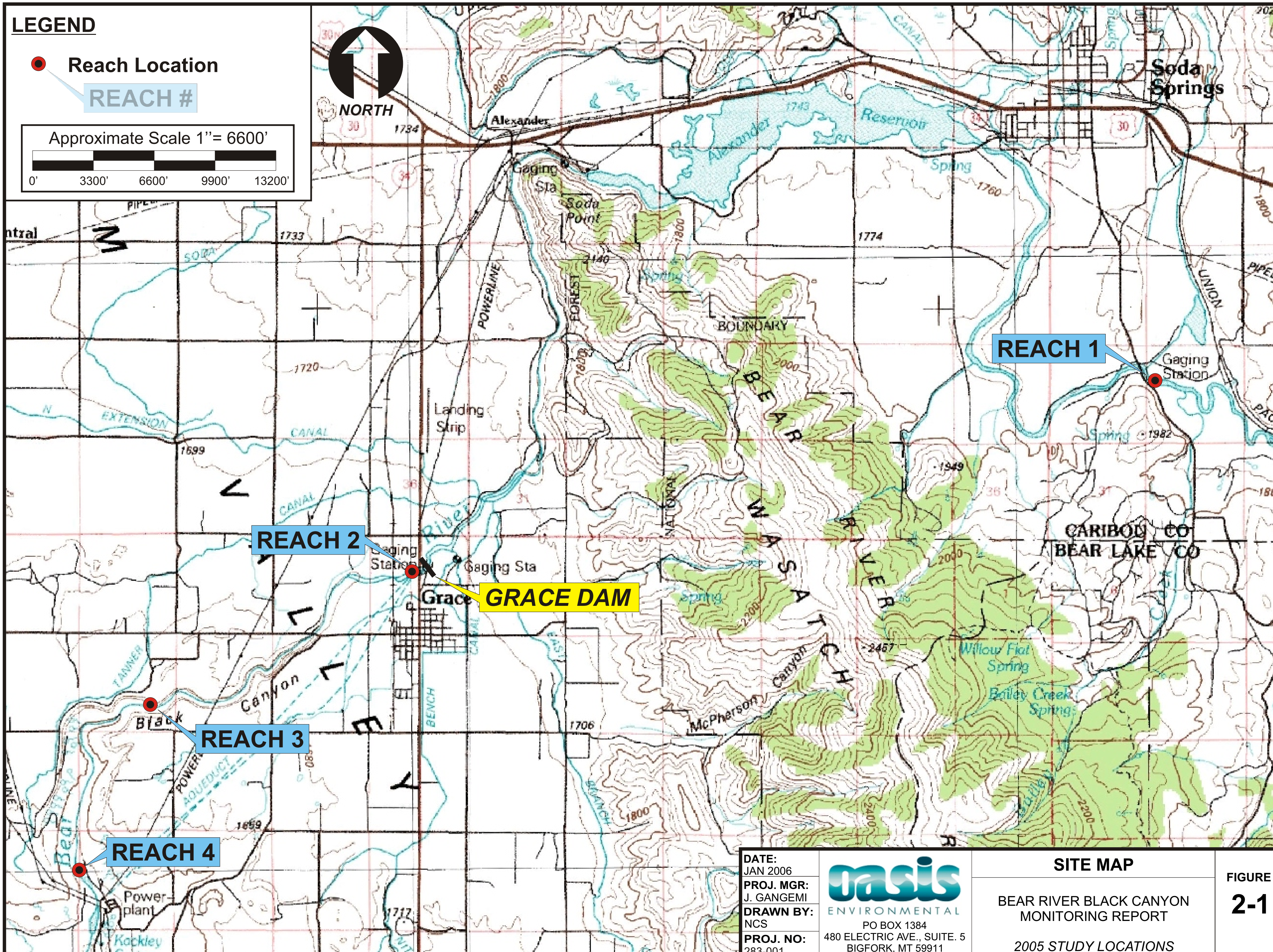
2.3 REACH 3: BLACK CANYON

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. 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 meander bend and continued through the meander, 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 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.



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SITE MAP

BEAR RIVER BLACK CANYON MONITORING REPORT

2005 STUDY LOCATIONS

FIGURE 2-1

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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 ID DEQ (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 through 2010 channel 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 throughout the six-year study 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 completely to the parent rock material with a razor blade (Steinman and Lamberti 1996). Periphyton and associated scraped material was rinsed from the razor blade with deionized water directly 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 2010 sampling event, all sampling was conducted from October 4, 2010 to October 6, 2010 under similar stream flow conditions. In October 2007, 2008, 2009, and 2010, 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. Species richness is the total number of species collected in two passes over a 100 meter reach.

Relative weight (Wr) was used to assess the condition of rainbow trout 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, 2009 and 2010 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.

For the remaining sample years, 2006 through 2010, 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 STATISTICAL ANALYSIS

Statistical analysis was carried out using a single factor ANOVA ($\alpha = 0.1$) to compare differences among the four study reaches within a sample year. Statistical comparisons between the six sample years within an individual study reach were undertaken with the single factor ANOVA ($\alpha = 0.1$) and the non-parametric Kruskal-Wallis H-Test. Baseline conditions for sample years 2005 through 2007 were compared to variable flow conditions sampled from 2008 through 2010 within individual study reaches using the single factor ANOVA ($\alpha = 0.1$) and the non-parametric Kruskal-Wallis H-Test.

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4. RESULTS

The monitoring results are organized into seven resource areas. 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 (2008-2010 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 6 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.

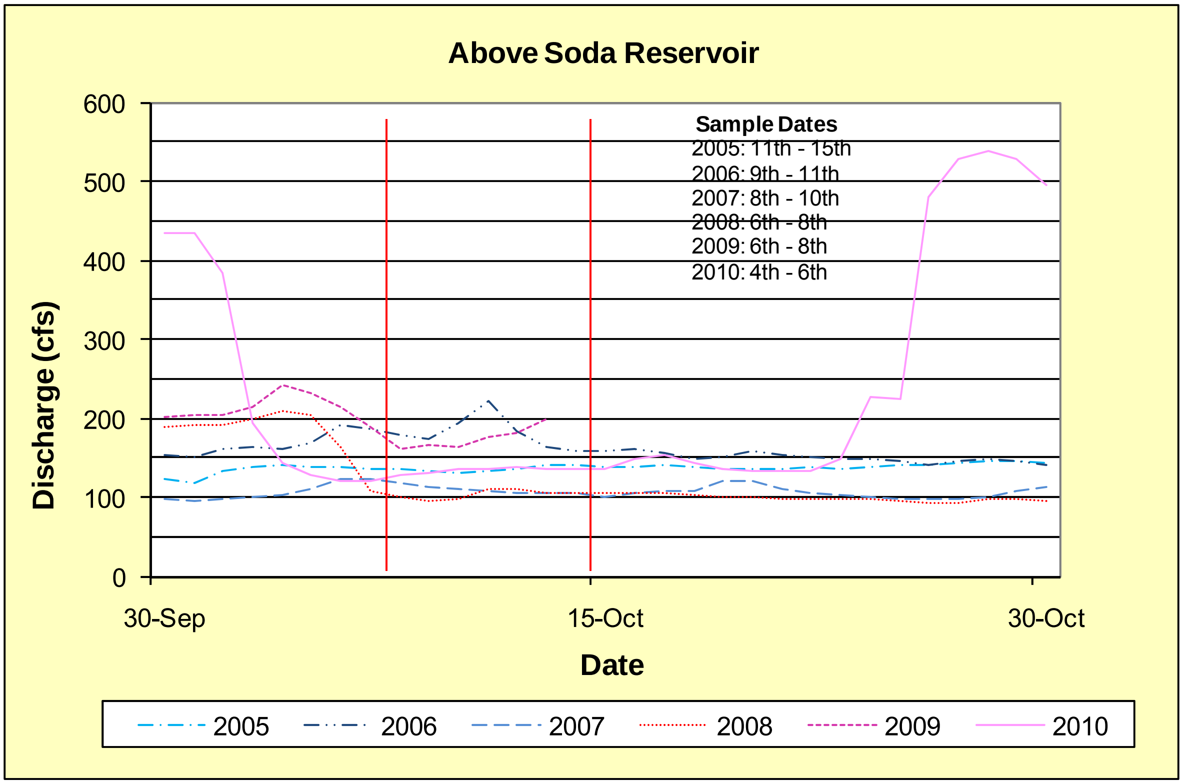
4.1 HYDROLOGY

Discharge varied 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). The 2010 sampling effort occurred from October 4 - 6 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. The instream flow conditions in 2010 below Grace Dam were the lowest observed during the six-years of field sampling whereas flows in reach 1 were close to the median based on the range of flows observed during the annual October sampling event.

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 19 through August 4 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 13 through July 27. In 2010, daily average discharge greater than 1000 cfs occurred from June 28 through August 28.

During the baseline sampling period in reach 1, the highest peak discharge was 1610 cfs on July 8, 2007. During the variable flow period, the highest average daily peak discharge for water years 2008, 2009 and 2010 was 1480 cfs (August 9, 2008), 1300 cfs (July 22, 2009) and 1780 cfs (July 13, 2010). The daily average flow in reach 1 during the summer irrigation season for 2008 through 2010 (July 1 to September 1) was 924 cfs, 794 cfs and 1341 cfs in 2008, 2009 and 2010 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 with an instantaneous maximum of 965 cfs equating to a daily average 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 through 2010) was 92 cfs in 2008 water year, 95 cfs in 2009 water year and 86 cfs in 2010 water year.



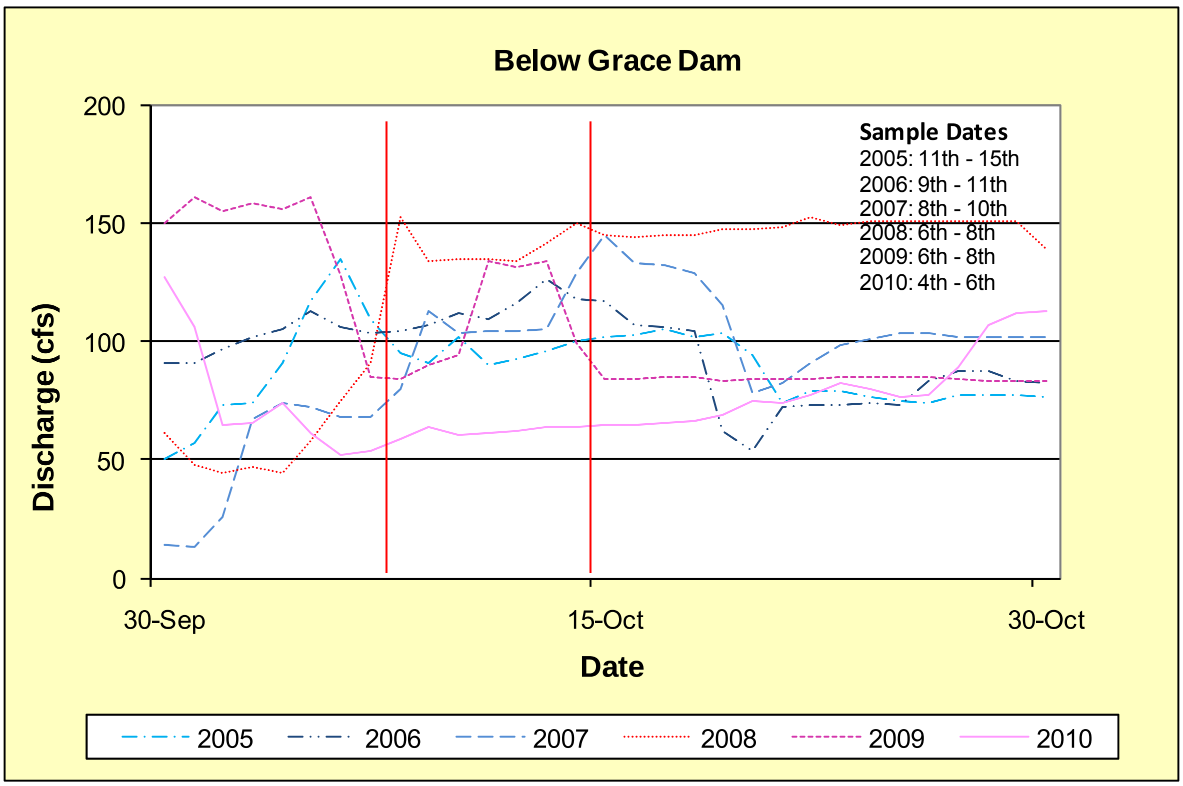
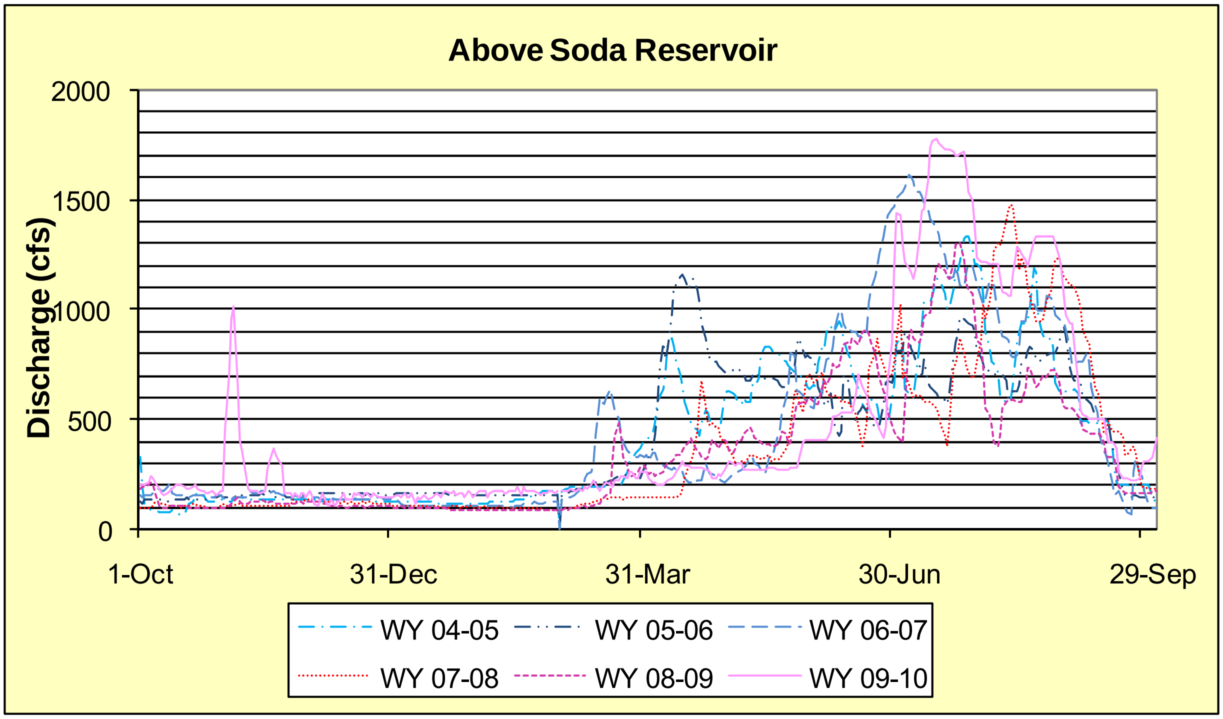


Figure 4.1-1: Discharge in reaches 1 and 2, October sampling period, 2005 through 2010



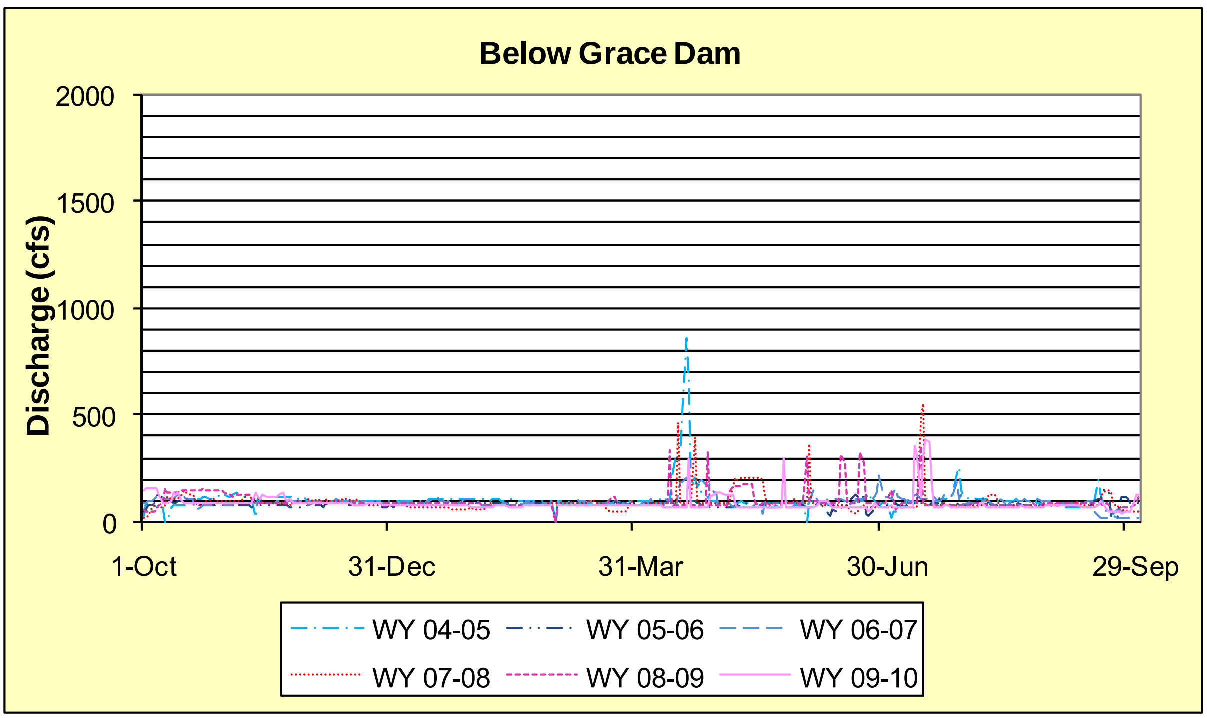


Figure 4.1-2: Annual daily average discharge for reaches 1 and 2 on the Bear River

Variable flow releases from Grace Dam were conducted in 2008, 2009 and 2010 affecting reaches 2, 3 and 4 (Figure 4.1-3). 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 2008. In 2009, eight variable flows occurred ranging from an instantaneous peak of 869 cfs to 1140 cfs between April and mid-July. In 2010, four variable flows occurred ranging from an instantaneous peak of 877 cfs to 1080 cfs between April and mid-July.

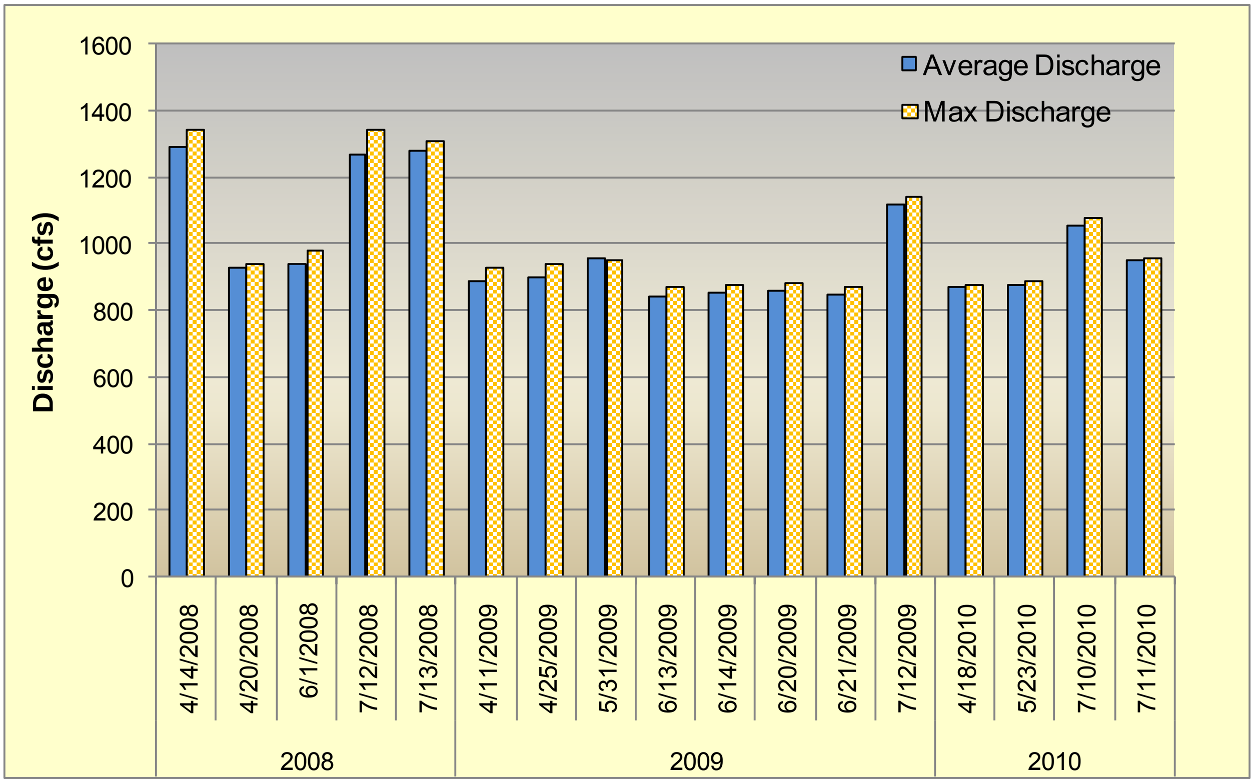


Figure 4.1-3: Variable flows released into the Black Canyon; 2008, 2009 and 2010

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 2004 (Figure 4.1-4). 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 in reach 1 were 1336 cfs, 1157 cfs and 1610 cfs in 2005, 2006 and 2007 respectively. In 2008, 2009 and 2010, the instantaneous peak discharge for reach 1 was 1800 cfs, 1300 cfs and 1780 cfs respectively. The instantaneous peak flows in reach 1 occurred in mid-July corresponding with water withdrawals from Bear Lake for downstream irrigation.

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

Year	Date	Description	Average Event Discharge (cfs)	Max Discharge (cfs)	Downramp Rate (ft/ hr)
2008	4/14/2008	Scheduled Varial Mapping Event	1290	1344	0.24
	4/20/2008	Scheduled Stranding Test	930	940	0.22
	6/1/2008	Scheduled Stranding Test	940	980	0.24
	7/12/2008	Inflow dependent event	1270	1344	0.29
	7/13/2008	Scheduled Stranding Test (Inflow Dependent Event Occurred so flow higher than 900)	1280	1310	0.27
2009	4/11/2009	Scheduled Stranding Test	889	931	0.23
	4/25/2009	Scheduled Stranding Test	898	939	0.43
	5/31/2009	Scheduled Stranding Test	954	954	0.4
	6/13/2009	Inflow dependent event	839	869	0.49
	6/14/2009	Inflow dependent event	854	877	0.53
	6/20/2009	Inflow dependent event	858	885	0.5
	6/21/2009	Inflow dependent event	845	869	0.52
	7/12/2009	Scheduled Stranding Test (Inflow Dependent Event Occurred so flow higher than 900)	1118	1140	0.46
2010	4/18/2010	Scheduled Stranding Test	870	877	0.72
	5/23/2010	Scheduled Stranding Test	874	891	0.65
	7/10/2010	Inflow dependent event	1054	1080	0.92
	7/11/2010	Scheduled Stranding Test (Inflow Dependent Event Occurred so flow higher than 900)	950	959	0.65

In reach 2 during the three-year baseline period, discharge was relatively stable reflecting the MIF requirement in the FERC license. On several occasions in the baseline period, spills from Grace Dam occurred to pass water downstream to meet irrigation demands, pass spring run-off or meet management objectives in the reach. In 2005, a spring instantaneous peak flow of 965 cfs equating to a daily average of 863 cfs occurred during spring run-off resulting in spill over the dam. Also in 2005, the instantaneous maximum summer flow below Grace Dam was 255 cfs on July 26, 2005. In 2006 and 2007 spring run-off did not result in spill from Grace Dam. 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 September 2006, pulse flows over Grace dam less than 500 cfs occurred to assist with channel restoration efforts associated with Cove Dam decommissioning. In 2007, the instantaneous maximum flow below Grace Dam was 218 cfs on June 27. For comparison purposes, the annual peak discharge in reach 2 for the period 1976 to 2004 was 1012 cfs.

Instantaneous annual peak discharges in reach 2 during the variable flow period in 2008, 2009 and 2010 were 1344, 1140 and 1080 cfs respectively. These instantaneous peaks were associated with whitewater inflow dependent events triggering releases from Grace Dam. In 2008 and 2009, the instantaneous peak flows in reach 2 also corresponded with pre-scheduled releases for the fish stranding study in the Black Canyon.

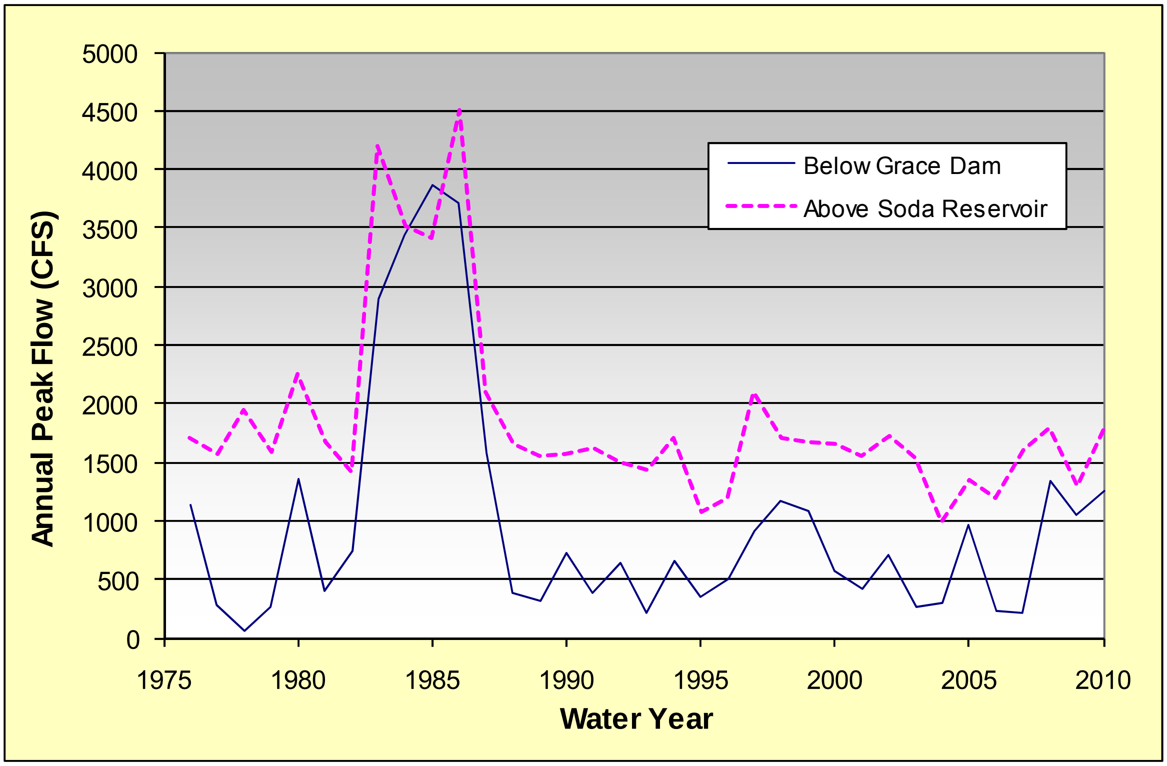


Figure 4.1-4: Annual peak discharge (1976-2010), Bear River, ID

4.2 CHANNEL SHAPE AND SUBSTRATE

Reach 2 transects were surveyed on October 4, 2010 between 0830 and 1430 hours. Discharge was lower than the previous sampling years. Reach 3 transects were surveyed on October 5, 2010 between 0900 and 1130 hours. The flow appeared lower compared to previous sampling years in reach 3. The average flows recorded for the Bear River during the respective sampling events over the six-year sampling period in reach 2 were 89 cfs in 2005, 104 cfs in 2006, 87 cfs in 2007, 75 cfs in 2008, 125 cfs in 2009 and 67 cfs in 2010.

In reach 2, channel cross section profiles remained unchanged over the six-year study period (Figure 4.2-1). Mean bankfull width in reach 2 ranged from a low of 62.51 meters in 2008 to a high of 63.34 meters in 2009 (Table 4.2-1). Bankfull widths for individual transects in respective sample years including mean annual bankfull widths are listed in Table 4.2-1. Individual transects exhibited relatively similar bankfull widths over time in reach 2. Differences in bankfull widths between sample years for respective transects were the result of poorly defined bankfull indicators in reach 2. Beaver activity in transect R2TA resulted in substantial changes in wetted perimeter width over the six-year study period but did not alter the channel shape relative to bankfull features.

The mean water depths associated with the bankfull elevation in reach 2 ranged from a low of 0.34 meters in 2005 to a high of 0.46 meters in both 2009 and 2010 (Table 4.2-2). Bankfull depths for individual transects in respective sample years including mean annual bankfull depth are listed in Table 4.2-2. As noted above for bankfull width variability, differences in bankfull depth between sample years for respective transects were the result of poorly defined bankfull indicators in reach 2.

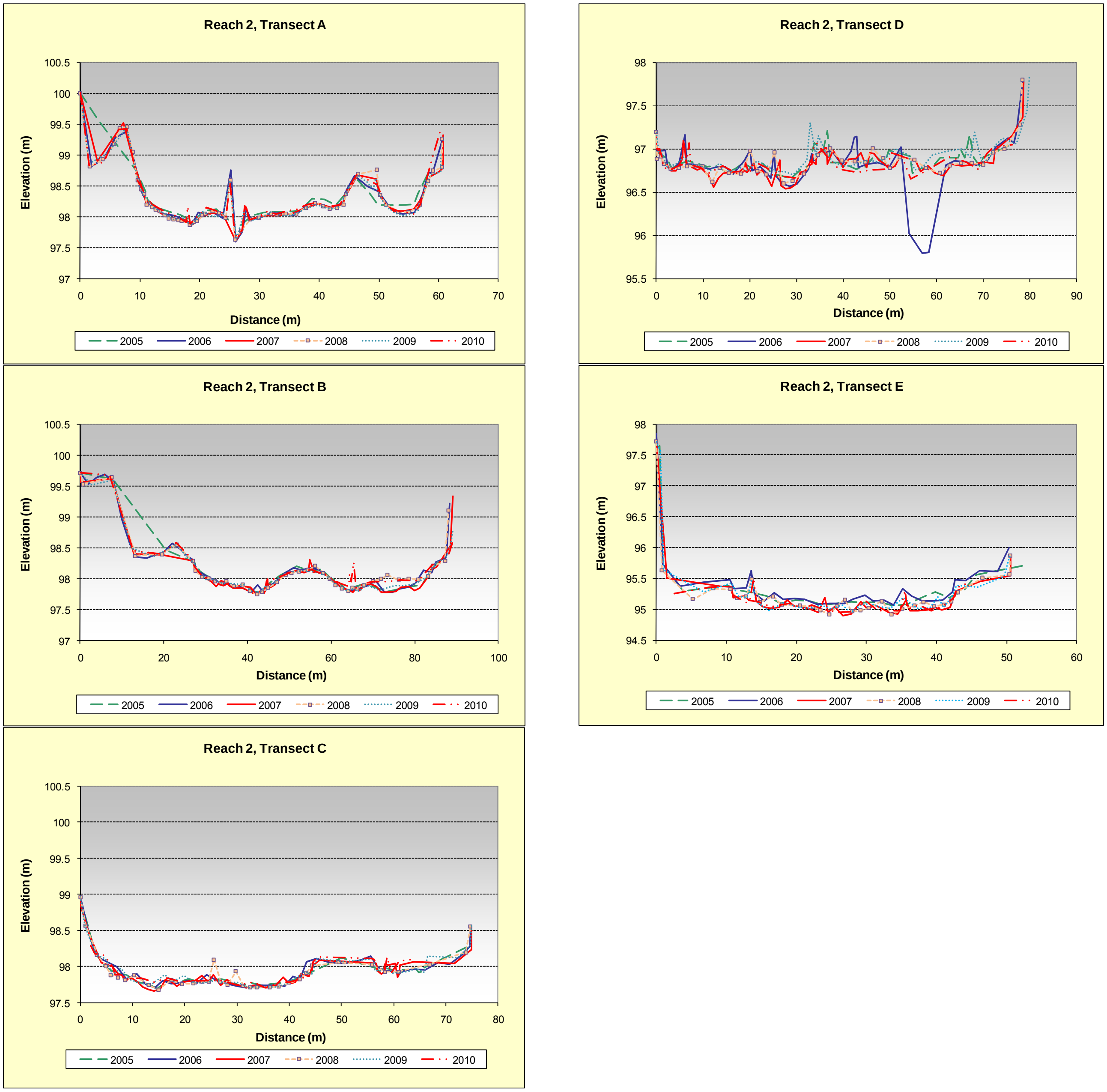


Figure 4.2-1: Reach 2 channel cross sections over the six-year study period

In reach 3, mean bankfull widths over the six-year study period ranged from 20.19 meters in 2008 to 23.99 meters in 2009. Bankfull widths for individual reach 3 transects in respective sample years including mean annual bankfull width are listed in Table 4.2-1. Mean bankfull widths differed from year to year under the variable flow conditions period compared to consistent widths of 21.78 meters under the three-years of baseline conditions. Bankfull pins established in 2004 under MIF conditions applicable under the previous FERC license period were difficult to relocate in subsequent sampling years particularly during the variable flow period due to deposition of fine sediments, organic material and annual growth of ephemerals and woody vegetation along the channel margins. The original pin locations were inundated by the variable flows in 2008, 2009 and 2010. Despite the variability in bankfull width measurements during the variable flow period, channel cross section profiles for the respective transects remained similar in shape across the six-years of survey (Figure 4.2-2).

Table 4.2-1: Bankfull width for reaches 2 and 3; October 2005 through 2010

Reach	Transect	Bankfull Width (m)							
		Baseline period				Variable Flow Period			
		2005	2006	2007	Mean	2008	2009	2010	Mean
2	TA	48.85	48.85	49.34	**49.01**	50.36	51.48	49.69	**50.51**
2	TB	67.22	67.22	69.19	**67.88**	64.26	65.28	65.12	**64.89**
2	TC	71.30	71.50	70.79	**71.20**	70.61	72.51	72.65	**71.92**
2	TD	76.57	76.57	76.13	**76.42**	77.75	78.81	78.48	**78.35**
2	TE	51.28	49.42	48.95	**49.88**	49.58	48.61	49.79	**49.33**
Reach 2 Mean		**63.04**	**62.71**	**62.88**	**62.88**	**62.51**	**63.34**	**63.15**	**63.00**
3	TA	28.80	28.80	28.80	**28.80**	27.88	31.83	24.20	**27.97**
3	TB	20.70	20.70	20.70	**20.70**	20.47	20.56	20.51	**20.51**
3	TC	17.10	17.10	17.10	**17.10**	17.09	19.40	17.26	**17.92**
3	TD	24.80	24.80	24.80	**24.80**	18.20	29.00	25.80	**24.33**
3	TE	17.50	17.50	17.50	**17.50**	17.33	19.17	16.55	**17.68**
Reach 3 Mean		**21.78**	**21.78**	**21.78**	**21.78**	**20.19**	**23.99**	**20.86**	**21.68**

Table 4.2-2: Bankfull depth for reaches 2 and 3; October 2005 through 2010

Reach	Transect	Bankfull Depth (m)							
		Baseline period				Variable Flow Period			
		2005	2006	2007	Mean	2008	2009	2010	Mean
2	TA	0.57	0.58	0.64	**0.59**	0.46	0.62	0.66	**0.58**
2	TB	0.48	0.45	0.48	**0.47**	0.42	0.53	0.47	**0.47**
2	TC	0.31	0.27	0.29	**0.29**	0.31	0.41	0.34	**0.35**
2	TD	0.16	0.25	0.30	**0.24**	0.25	0.31	0.36	**0.31**
2	TE	0.19	0.44	0.43	**0.35**	0.44	0.44	0.45	**0.44**
Reach 2 Mean		**0.34**	**0.40**	**0.43**	**0.39**	**0.38**	**0.46**	**0.46**	**0.43**
3	TA	0.73	1.21	1.33	**1.09**	0.74	0.84	0.84	**0.81**
3	TB	0.63	0.65	0.67	**0.65**	0.57	1.02	0.87	**0.82**
3	TC	0.62	0.65	0.63	**0.63**	0.62	0.85	0.52	**0.66**
3	TD	0.86	0.41	0.41	**0.56**	0.41	1.09	0.58	**0.69**
3	TE	1.03	1.00	1.00	**1.01**	0.76	1.24	0.98	**0.99**
Reach 3 Mean		**0.77**	**0.78**	**0.81**	**0.79**	**0.62**	**1.01**	**0.76**	**0.80**

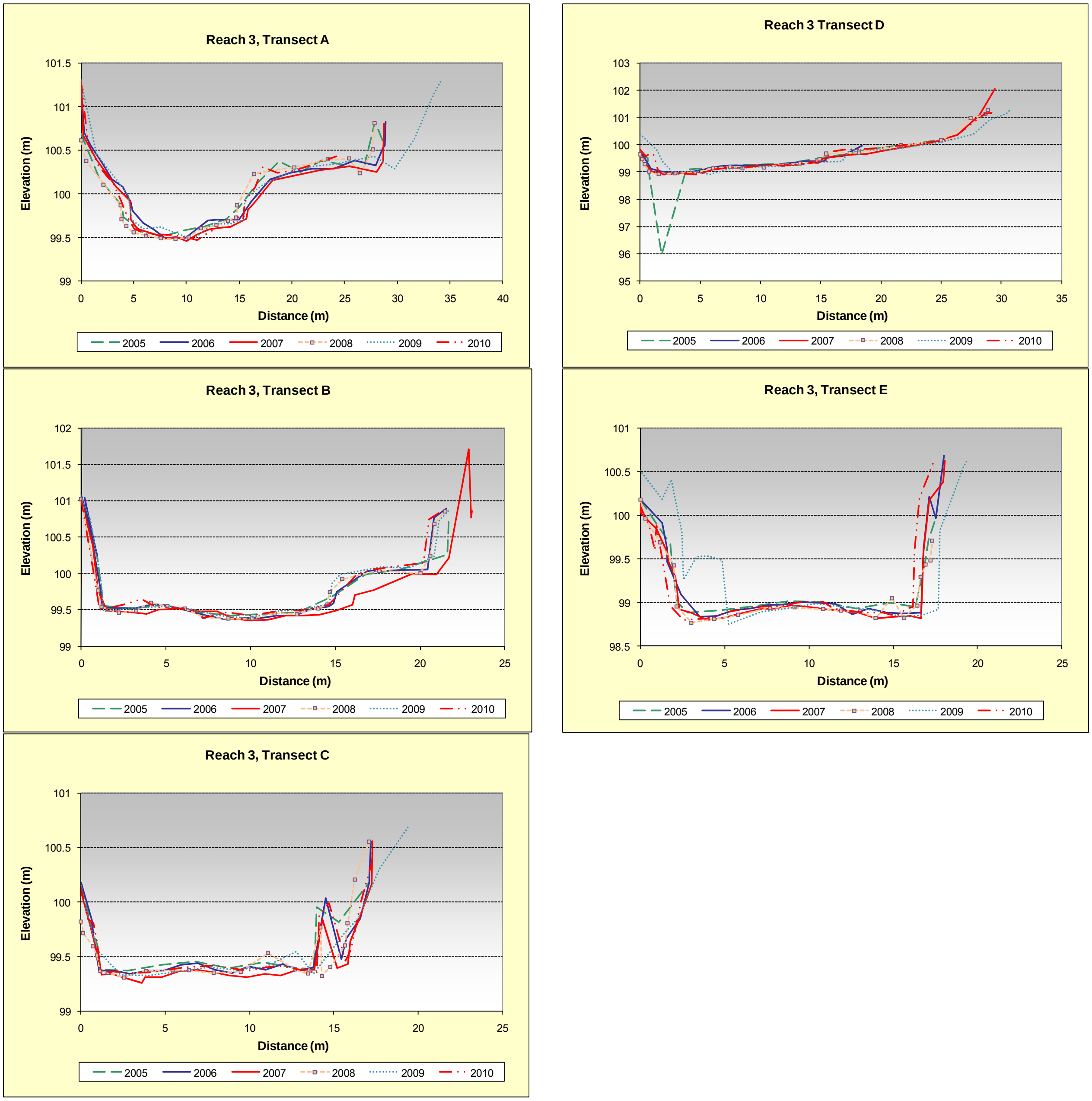


Figure 4.2-2: Reach 3 channel cross sections over the six-year study period

The mean bankfull water depths in reach 3 for the six-year study period ranged from 0.62 meters in 2008 to 1.01 meters in 2009. Bankfull depths for individual reach 3 transects in respective sample years including mean annual bankfull depth are listed in Table 4.2-2. Differences in bankfull water depths between the baseline and variable flow periods were unrelated to study period. Establishment of new bank pins from year to year likely accounts for the differences in bankfull water depth rather than any changes in channel profile.

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 over the six-year study period ranged from 149.55 in 2009 to 241.41 in 2005 (Table 4.2-3). BWD ratios for individual reach 2 and reach 3 transects in respective sample years are listed in Table 4.2-3. Rosgen's stream classification system ranks the BWD indices in reach 2 as "very high". The BWD ratio for reach 3 over the six-year study period ranged from 24.58 in 2009 to 33.64 in 2008. Rosgen ranks the BWD ratios in reach 3 as "moderate to high". ."

Table 4.2-3: Bankfull width/depth ratio for reaches 2 and 3; October 2005 through 2010

Reach	Transect	Bankfull Width/Depth Ratio							
		Baseline period				Variable Flow Period			
		2005	2006	2007	Mean	2008	2009	2010	Mean
2	TA	86.46	84.06	77.38	**82.63**	109.14	83.03	75.29	**89.15**
2	TB	140.97	150.74	145.12	**145.61**	154.80	123.17	138.55	**138.84**
2	TC	226.42	267.65	247.44	**247.17**	225.33	176.85	213.68	**205.29**
2	TD	483.48	312.19	252.06	**349.25**	309.02	254.23	218.00	**260.41**
2	TE	269.73	111.77	113.46	**164.98**	113.76	110.48	110.64	**111.63**
Reach 2 Mean		**241.41**	**185.28**	**167.09**	**197.93**	**182.41**	**149.55**	**151.23**	**161.06**
3	TA	39.34	23.81	21.66	**28.27**	37.57	37.89	28.88	**34.78**
3	TB	33.09	31.95	30.86	**31.96**	35.91	20.15	23.57	**26.55**
3	TC	27.37	26.45	27.21	**27.01**	27.57	22.82	33.19	**27.86**
3	TD	28.77	60.12	59.81	**49.57**	44.34	26.60	44.48	**38.48**
3	TE	17.03	17.44	17.47	**17.31**	22.78	15.46	16.89	**18.38**
Reach 3 Mean		**29.12**	**31.95**	**31.40**	**30.82**	**33.64**	**24.58**	**29.40**	**29.21**

Substrate composition in reach 2 during the 2010 sampling period continued to exhibit the dramatic reduction in fines observed during the 2008 and 2009 sampling periods compared to much higher percentage of fines observed under the baseline period (Figure 4.2-3). Under the variable flow conditions, Wolman pebble counts indicated that fines composed only 4% 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 comprised a substantially lower percentage under variable flow conditions compared to the baseline period; 6% compared to 14%. Gravel, cobble, boulder and bedrock were greater during the variable flow conditions compared to the baseline period; 20%, 20%, 17% and 33% respectively.

In reach 3, Wolman pebble counts in 2010 indicated an absence of fines similar to that observed in the previous two-years under variable flow conditions (Figure 4.2-4). In contrast, fines comprised 8% of the substrate in reach 3 during the baseline period. Sand comprised 15% under baseline conditions compared to 10% during the variable flow period. For the larger substrate classes, gravel, cobble, boulder and bedrock, percent composition was similar between the baseline and variable flow periods in reach 3.

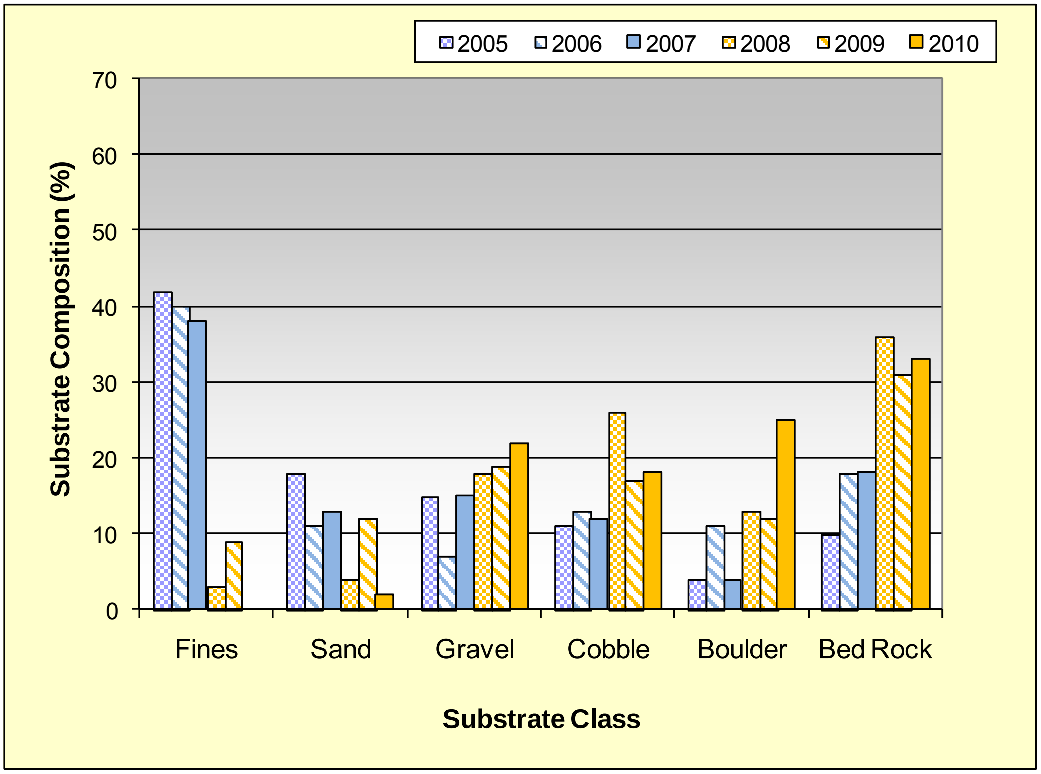


Figure 4.2-3: Substrate composition over six-year study period in reach 2

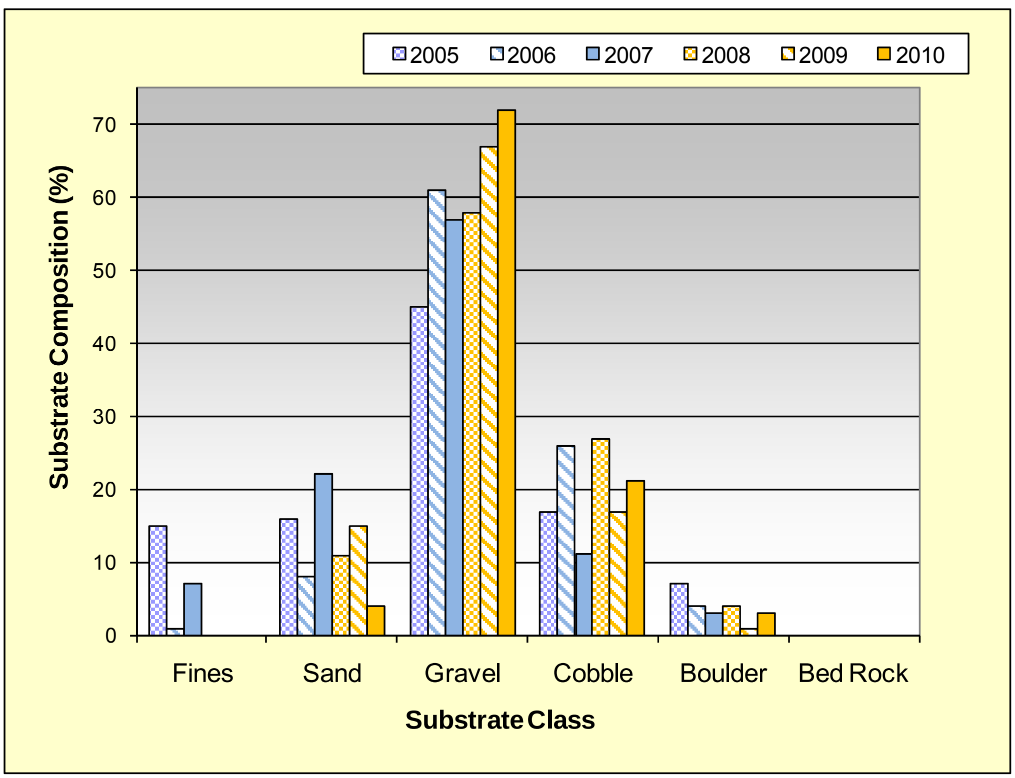


Figure 4.2-4: Substrate composition over six-year study period in reach 3

4.3 PERIPHYTON— ASH-FREE DRY WEIGHT AND CHLOROPHYLL

Periphyton AFDW comparisons indicate significant differences between sample years within individual study reaches (Figure 4.3-1). Sample variance required the use of non-parametric statistics in some reaches. In 2010, the average AFDW was 41.4 g/m^2 124.8 g/m^2, 122.1 g/m^2 and 137.6 g/m^2 for reaches 1, 2, 3, and 4 respectively. Periphyton AFDW was significantly lower in reach 1 (p=0.09, H-test) than reaches 2, 3 and 4 in 2010.

AFDW data was compared for the six-year study period within each individual reach. In reach 1, AFDW was significantly different between sampling years (p=0.002, H-test) but observed differences were not correlated with the baseline and variable flow phases. Sample years 2005, 2008 and 2010 were more similar than sample years 2006, 2007 and 2009. The highest AFDW value in reach 1, 208.9 g/m^2 occurred in 2007 compared to 21.1 g/m^2 in 2005, 117.3 g/m^2 in 2006, 24.3 g/m^2 in 2008, 92.0 g/m^2 in 2009 and 41.4 g/m^2 in 2010. In Reach 2, significant differences in periphyton AFDW were observed (p=0.06, ANOVA) with years 2005 and 2006 exhibiting comparable values that were substantially lower than samples from 2007 through 2010. In Reach 3, periphyton AFDW showed no differences (parametric and non-parametric tests) over the six-year sampling period. In reach 4, periphyton AFDW was significantly different between sample years (p=0.005, ANOVA). AFDW in 2009 and 2010 was substantially greater than the previous four sample years.

AFDW data collected during the baseline period was compared to data for the variable flow phase within respective study reaches (Figure 4.3-2). In reach 1, periphyton AFDW means for the three-year baseline period were more than double values for the three-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 three-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=0.007, H-test and p=0.005, ANOVA respectively). Reaches 1 and 3 did not exhibit significant differences between the three-year baseline sampling period and three-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.

In 2010, periphyton chlorophyll a was highest in reach 4 (Figure 4.3-3). The chlorophyll a average for reach 4 in 2010 was 498.6 mg/m^{2,} compared to 38.2 mg/m^2, 122.0 mg/m^2 and 193.3 mg/m^2 for reaches 1, 2 and 3 respectively. Over the six-year study period, reach 4 had the highest chlorophyll a values annually.

Periphyton chlorophyll a comparisons within individual reaches indicate significant differences between sample years in reaches 1 and 4 only (p=0.007 and p=0.06 respectively, ANOVA). In reach 1, sample years 2006 and 2009 were similar whereas sample years 2005, 2007, 2008 and 2010 had similar values. In reach 4, the 2010 chlorophyll a values were nearly double values recorded in the five previous sampling years.

Comparisons between the baseline sampling period and the variable flow regime were significant in reaches 3 and 4 (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 140.3 mg/m^2 (p=0.07, H-test). In reach 4, the opposite pattern occurred, baseline chlorophyll a concentration (236.4 mg/m^2) was significantly lower than the variable flow period (339.6 mg/m^2) (p=0.09, ANOVA). No significant differences between the baseline sampling period and the variable flow regime were observed in reaches 1 and 2.

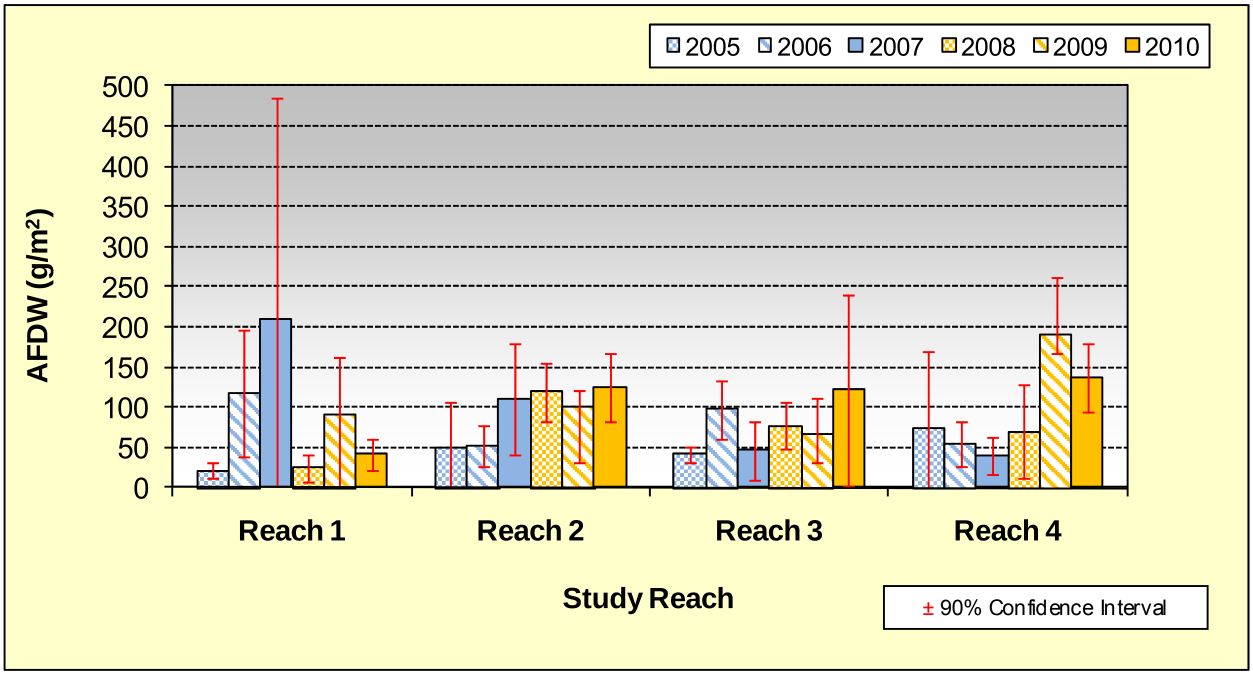


Figure 4.3-1: Periphyton mean AFDW, October 2005 through 2010

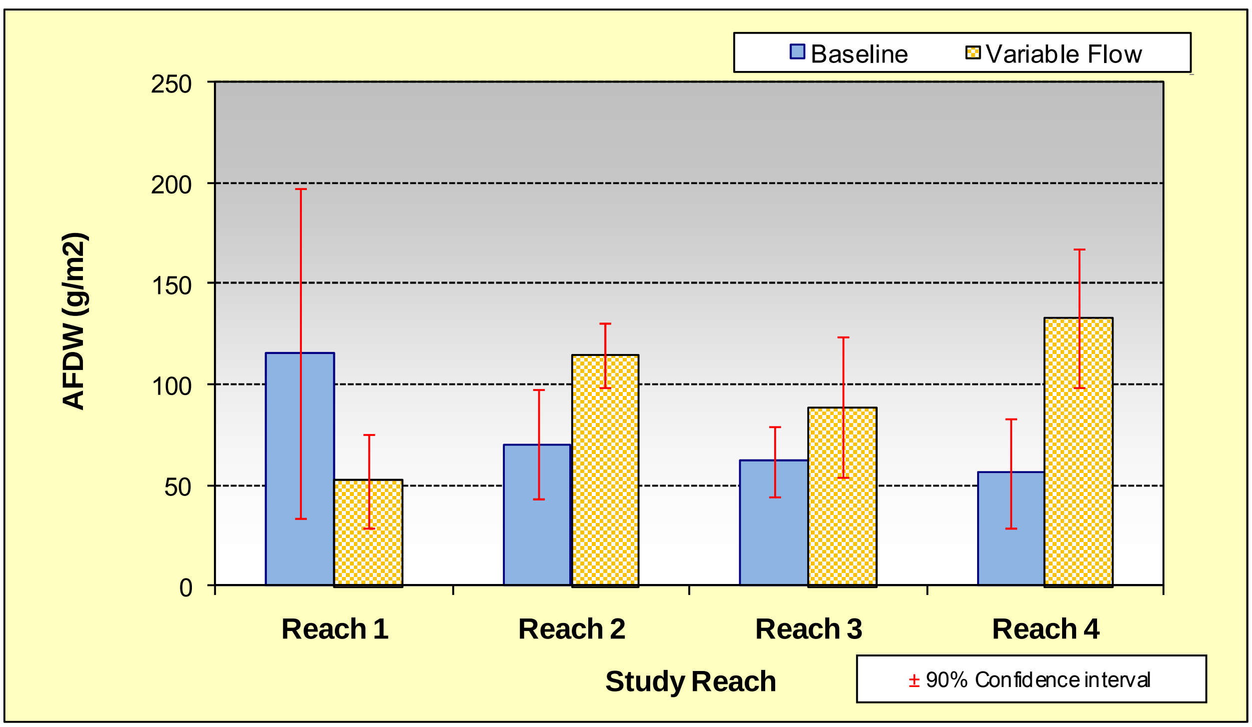


Figure 4.3-2: Periphyton mean AFDW, baseline period versus variable flow phase

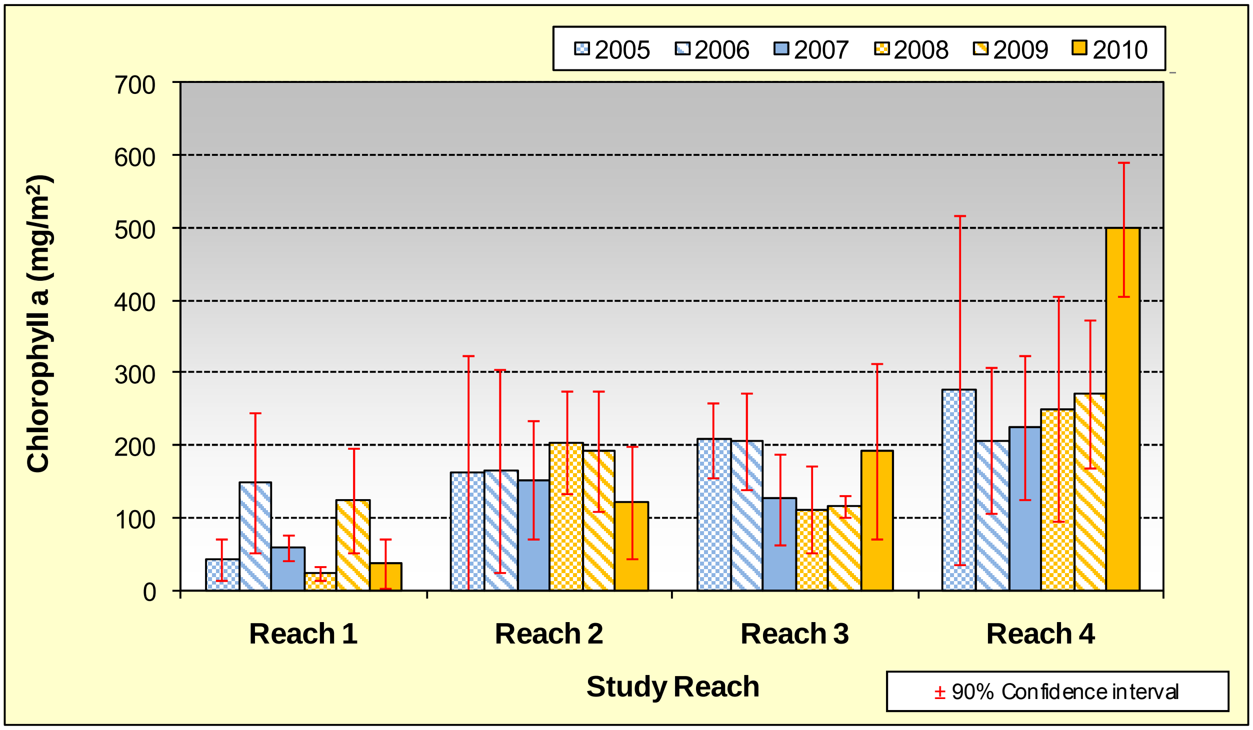


Figure 4.3-3: Periphyton mean chlorophyll a concentration, October 2005 through 2010

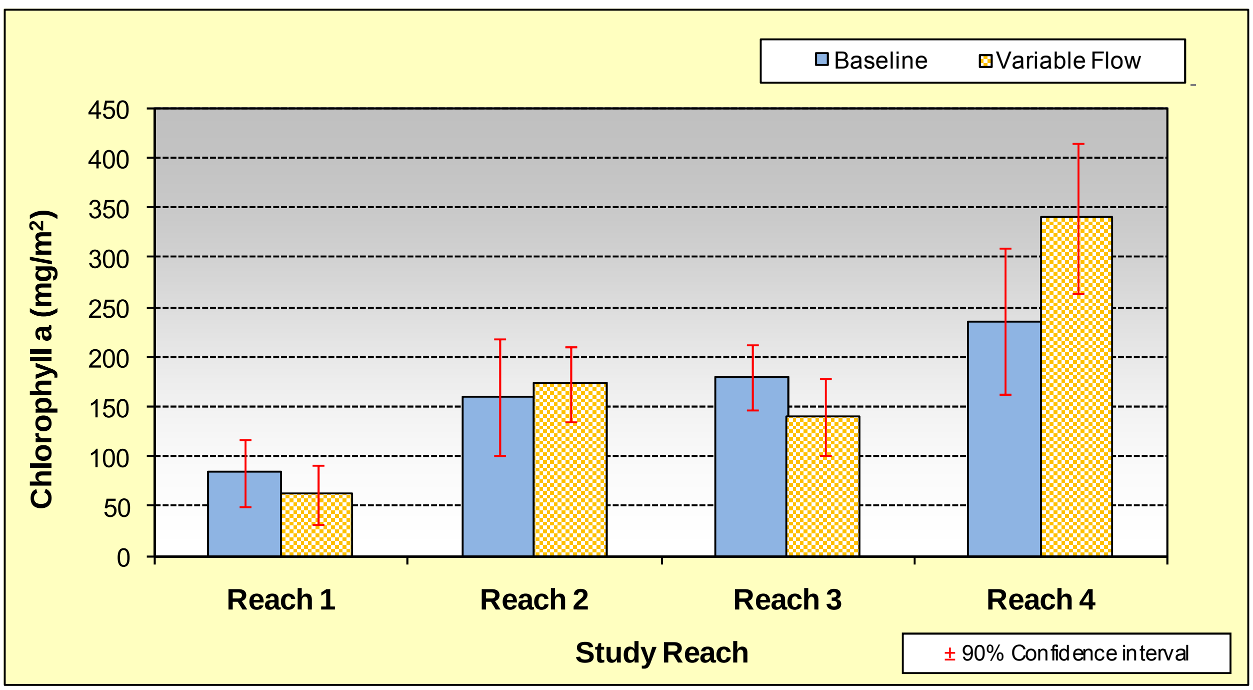


Figure 4.3-4: Periphyton mean chlorophyll a, baseline period versus variable flow phase

In 2010, the Autotrophic Index (AI) varied between the four study reaches (Figure 4.3-5). Reach 1 AI, 2079.8, was substantially greater than the other three reaches; 1311.7, 515.6 and 293.7 in reaches 2, 3 and 4 respectively. Reach 1 exhibited the highest AI values for each individual study year relative to the other reaches except for 2008 when AI values in reach 3 were slightly greater.

Periphyton AI comparisons across the six-year period within a single study reach indicate significant differences in all four reaches (reach 1 p=0.02, reach 2 p=0.009, reach 3 p=0.05, and reach 4 p=0.04, H-test).

Periphyton AI was significantly greater in reaches 2, 3 and 4 during the variable flow regime conditions compared to the baseline period only (p=0.003, ANOVA, p=0.02, H-test and p=0.03, ANOVA, respectively) (Figure 4.3-6). In contrast, reach 1 periphyton AI was greater during the baseline period but not significant. Furthermore, reach 1 AI values were substantially greater than values in reaches 2, 3 or 4 during both the baseline and variable flow periods.

4.4 FILAMENTOUS ALGAE

In 2010, filamentous algae cover (Figure 4.4-1) was highest in reach 4 (88%) followed by reach 2 (79%), reach 3 (45%) and, lastly, reach 1 (14%). In reach 1, filamentous algae coverage decreased substantially relative to previous sample years.

Filamentous algae cover was compared for the six-year study period within each individual study reach. Significant differences in filamentous algae coverage were observed in all four study reaches (reach 1 p=0.03 ANOVA, reach 2 p=0.0002 ANOVA, reach 3 p=0.003 H-test and reach 4 p=0.06, H-test).

Filamentous algae comparisons between the baseline sampling period and the variable flow phase within individual study reaches also indicated significant differences in all four reaches (Figure 4.4-2). In reaches 1 and 4, mean filamentous algae cover was significantly higher during the three-year baseline period than the variable flow conditions; 77% versus 43% m^2 in reach 1 and 92% versus 82% in reach 4 (p=0.007 ANOVA and p=0.04 respectively , H-test). In reaches 2 and 3, the opposite pattern occurred with mean percent filamentous algae cover significantly higher during the variable flow conditions than the three-year baseline period; 78% versus 40% m^2 in reach 2 and 38% versus 8% in reach 3 (p=0.0006 and p=0.003 respectively, ANOVA).

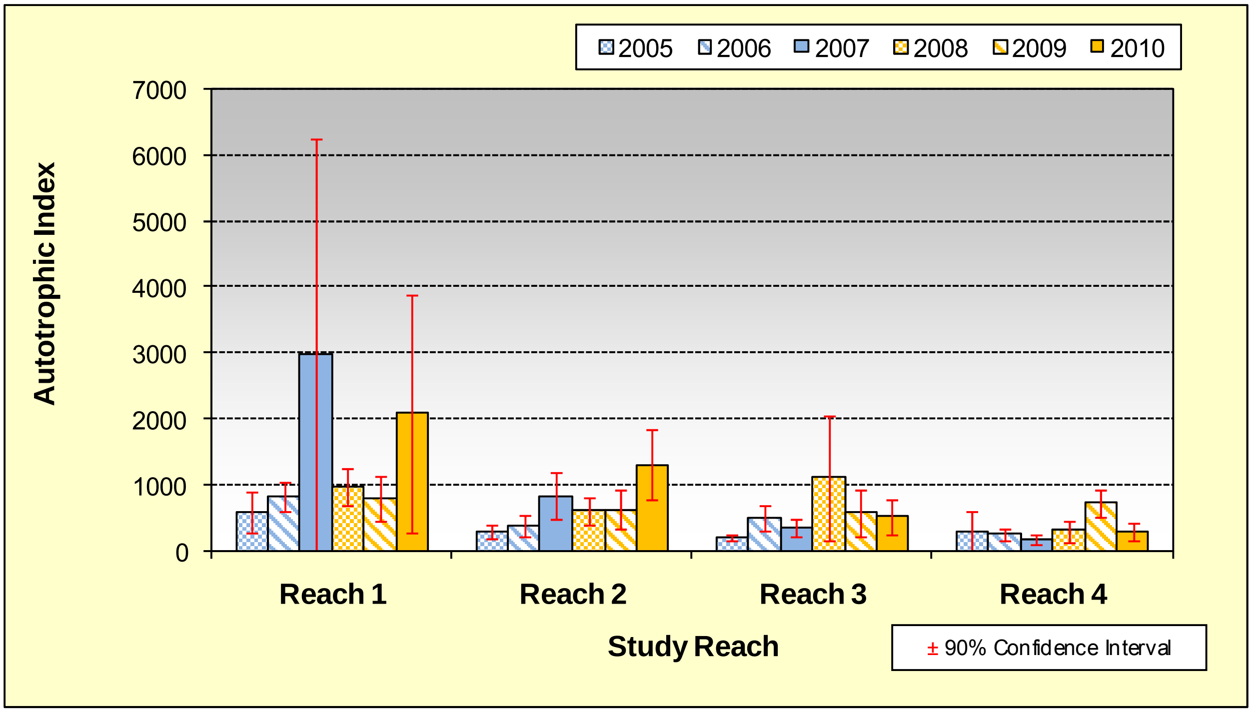


Figure 4.3-5: Periphyton mean autotrophic index, October 2005 through 2010

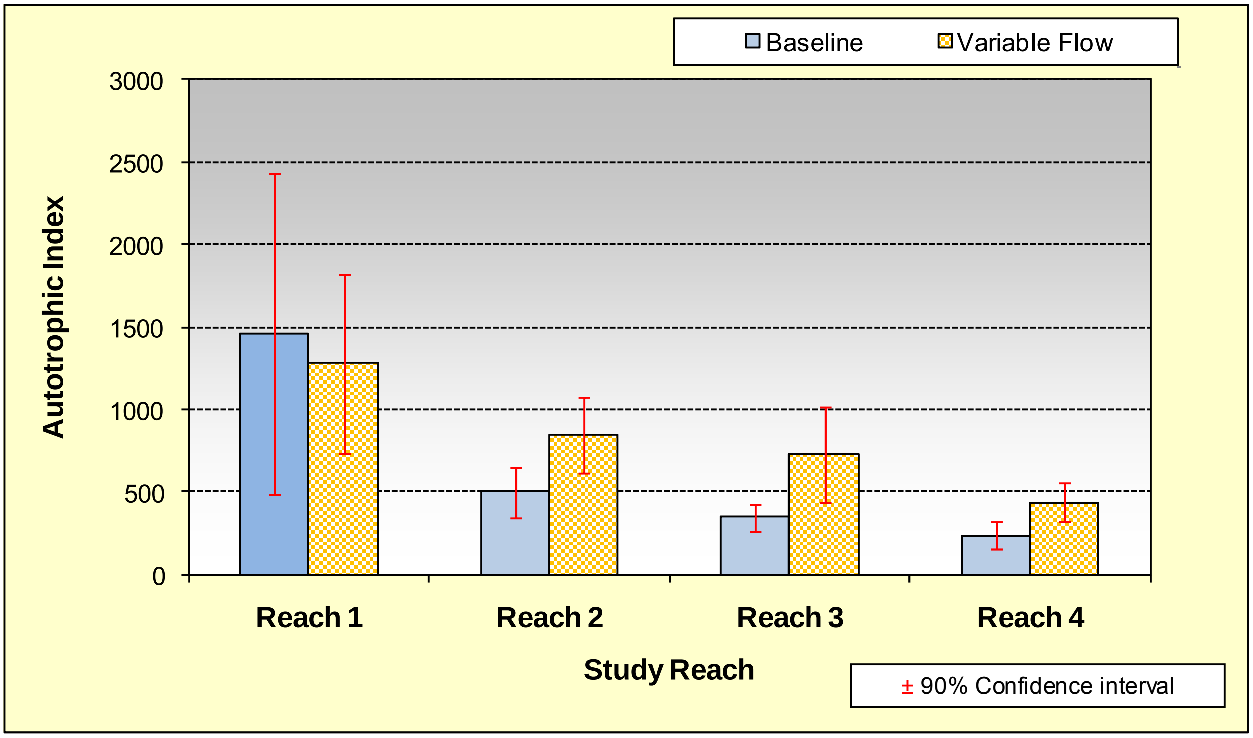


Figure 4.3-6: Periphyton mean AI, baseline period versus variable flow phase

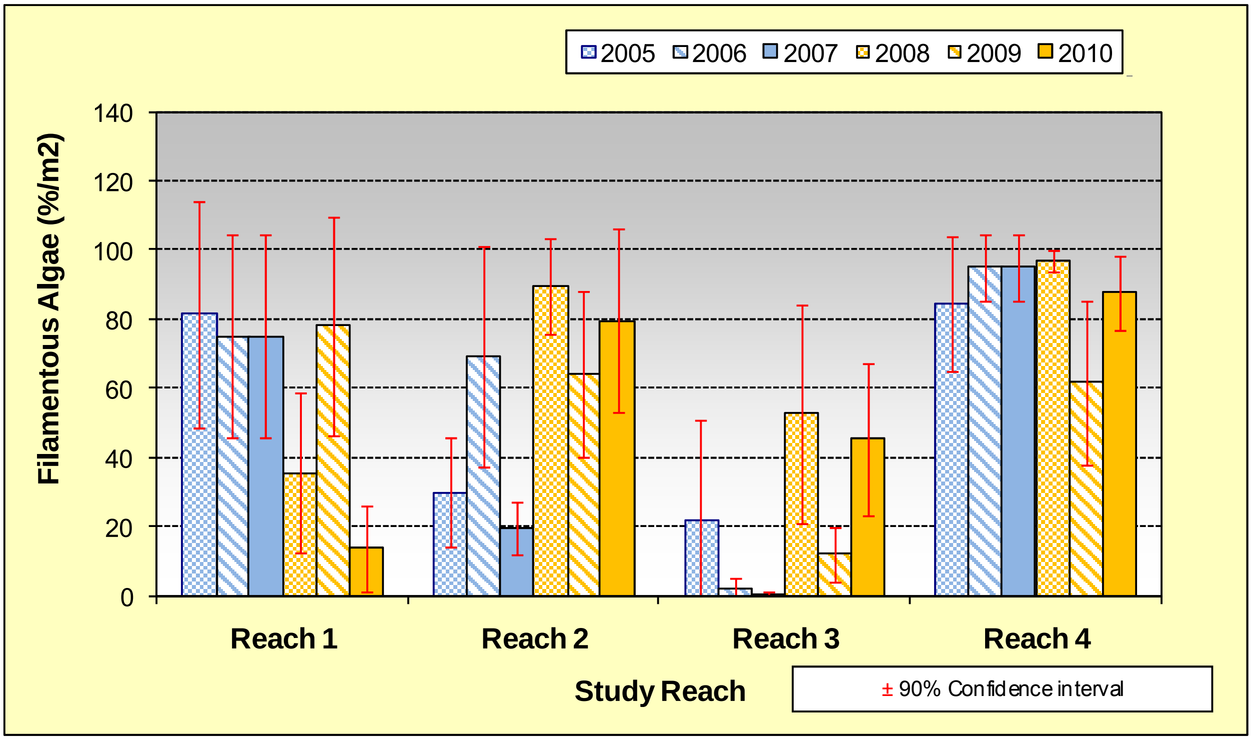


Figure 4.4-1: Filamentous algae cover, October 2005 through 2010

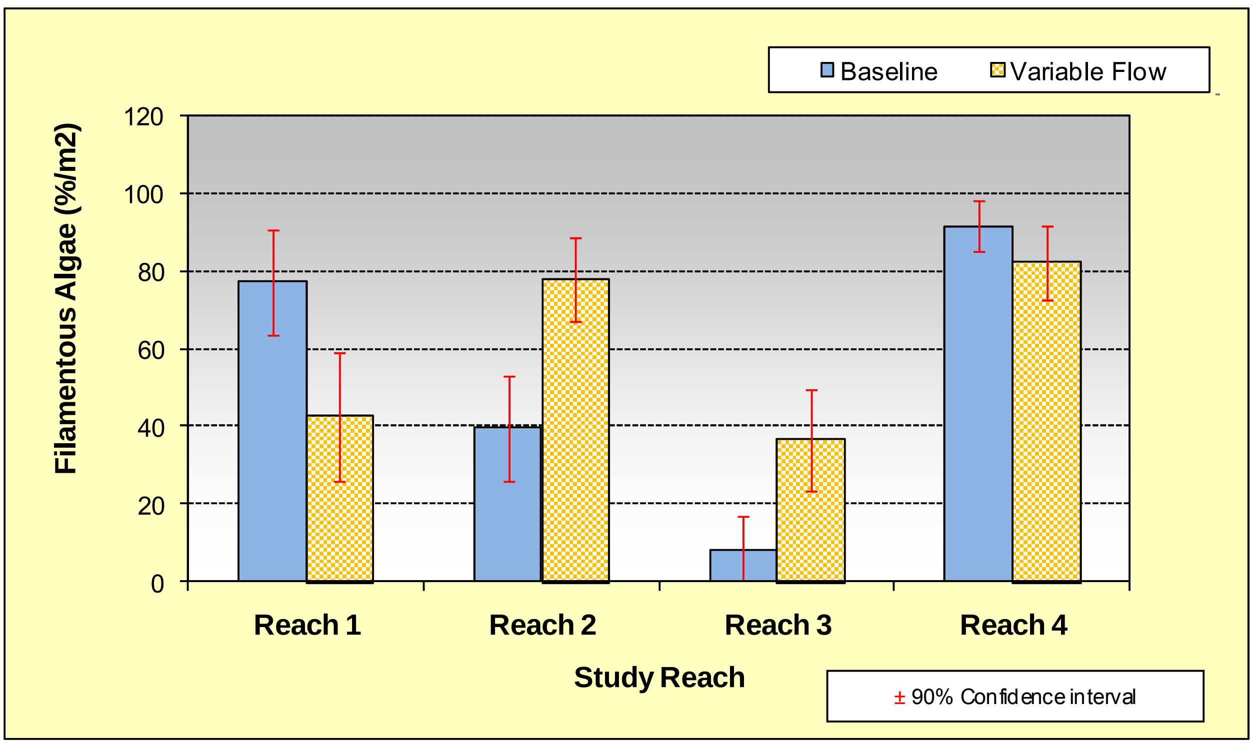


Figure 4.4-2: Filamentous algae cover, baseline period versus variable flow phase

4.5 FISHERIES

Fisheries data was analyzed to determine species richness, relative 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 the 2010 sampling effort but not all species were present in each study reach. Over the course of the six-year study, a total of eight fish species have been collected, but again, not at all four study reaches. The analysis was divided into results for each respective study reach starting first with results for the 2010 sample year prior to analysis within respective reaches across the six-year study period and between phases.

4.5.1 Reach 1—Above Soda Reservoir

In 2010, five species were collected in reach 1 for a total catch of 68 fish and biomass of 322 g (Table 4.5-1, Figure 4.5-1 and Figure 4.5-2). Longnose dace were the most abundant (57 fish; 84% of the catch) followed by common carp (4, 6%), Utah sucker (3, 4%), smallmouth bass (2, 3%) and Mottled sculpin (2, 3%) (Figure 4.5-3). Longnose dace comprised the majority of the biomass at 61% (196 g), followed by Utah sucker (14%, 44 g), mottled sculpin (12%, 40 g), common carp (9%, 30 g), and smallmouth bass (4%, 12 g) (Figure 4.5-4). Catch per unit effort (CPUE) was highest for longnose dace at 3.00 fish/minute, followed by common carp (0.21 fish/minute), Utah sucker (0.16 fish/minute), smallmouth bass (0.11 fish/minute) and mottled sculpin (0.11 fish/minute) (Figure 4.5-5).

Table 4.5-1: Fish density and biomass per 100 meters in reach 1, October 2010

Species	N	Weight (g)	CPUE (fish / minute)
Longnose Dace (*Rhinichthys cataractae*)	57 (84%)	196 (61%)	3.00
Small Mouth Bass (*Micropterus dolomieu*)	2 (3%)	12 (4%)	0.11
Mottled Sculpin (*Cottus bairdi*)	2 (3%)	40 (12%)	0.11
Common Carp (*Cyprinus carpio*)	4 (6%)	30 (9%)	0.21
Redside Shiner (*Richardsonius balteatus*)	0	0	0
Utah Sucker (*Catostomus ardens*)	3 (4%)	44 (14%)	0.16
Rainbow Trout (*Oncorhynchus mykiss*)	0	0	0
Cutthroat Trout (*Oncorhynchus clarki*)	0	0	0
Total	68	322	3.59

4.5.2 Reach 2— Below Grace Dam

In 2010, three species were collected in reach 2 for a total catch of 78 fish and biomass of 334 g (Table 4.5-2). Longnose dace were the most abundant as they accounted for 69 of the 78 fish collected (81% of the catch) followed by smallmouth bass (8; 10%), and common carp (1; 1%). Longnose dace also comprised a majority of the biomass at 81% (270 g) followed by smallmouth bass (18%, 60 g), and common carp (1%; 4 g). CPUE was greatest for longnose dace at 3.16 fish/minute followed by smallmouth bass (0.37 fish/minute), and common carp (0.05 fish/minute).

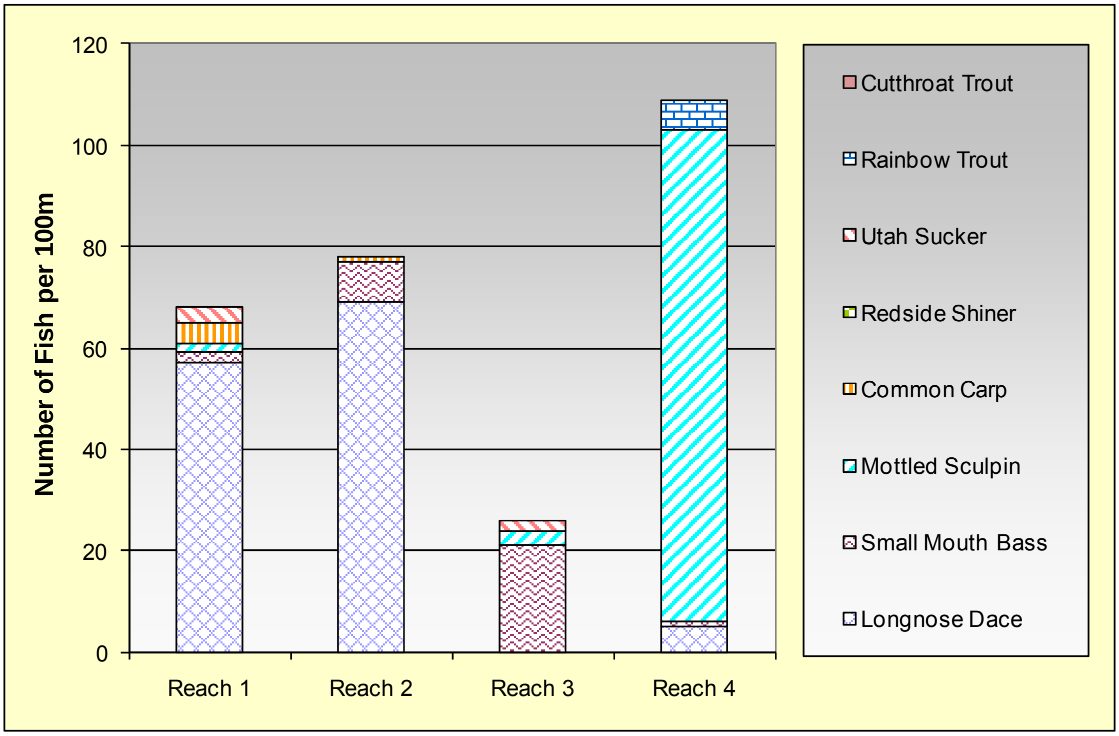


Figure 4.5-1: Total catch per 100 meters for reaches 1, 2, 3, and 4, October 2010

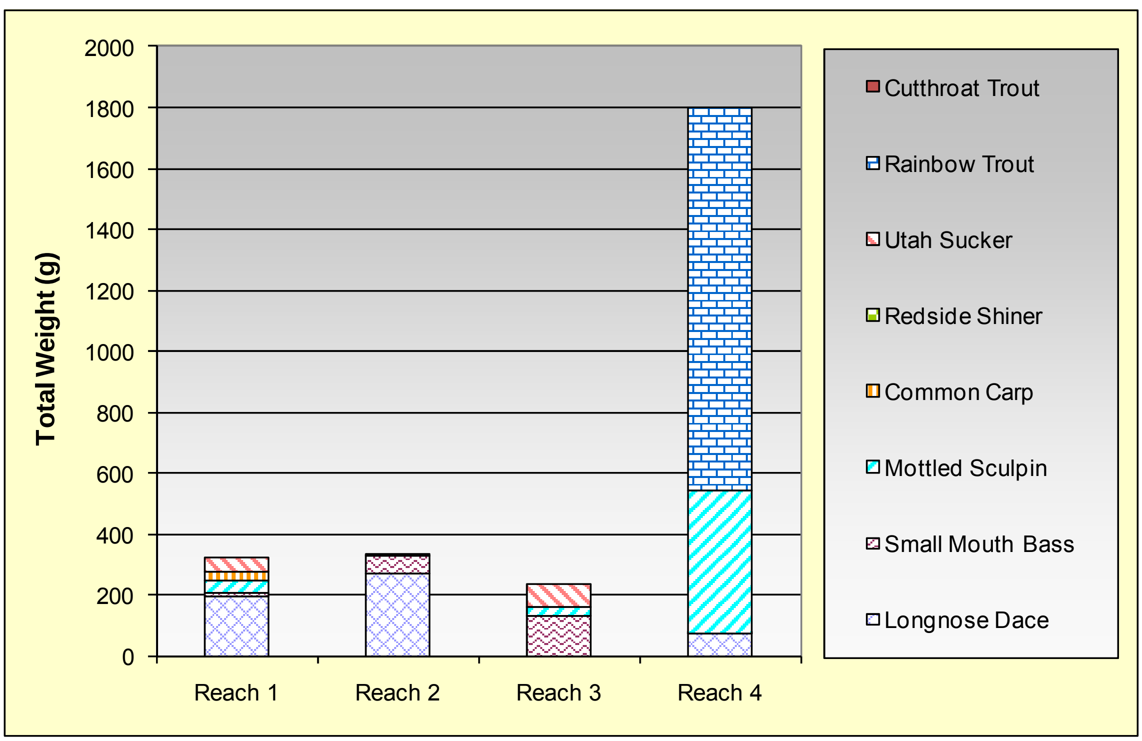


Figure 4.5-2: Fish biomass per 100 meters, reaches 1, 2, 3 and 4, October 2010

Table 4.5-2: Fish density and biomass per 100 meters in reach 2, October 2010

Species	N	Weight (g)	CPUE (fish / minute)
Longnose Dace (*Rhinichthys cataractae*)	69 (88%)	270 (81%)	3.16
Small Mouth Bass (*Micropterus dolomieu*)	8 (10%)	60 (18%)	0.37
Mottled Sculpin (*Cottus bairdi*)	0	0	0
Common Carp (*Cyprinus carpio*)	1 (1%)	4 (1%)	0.05
Redside Shiner (*Richardsonius balteatus*)	0	0	0
Utah Sucker (*Catostomus ardens*)	0	0	0
Rainbow Trout (*Oncorhynchus mykiss*)	0	0	0
Cutthroat Trout (*Oncorhynchus clarki*)	0	0	0
Total	78	334	3.58

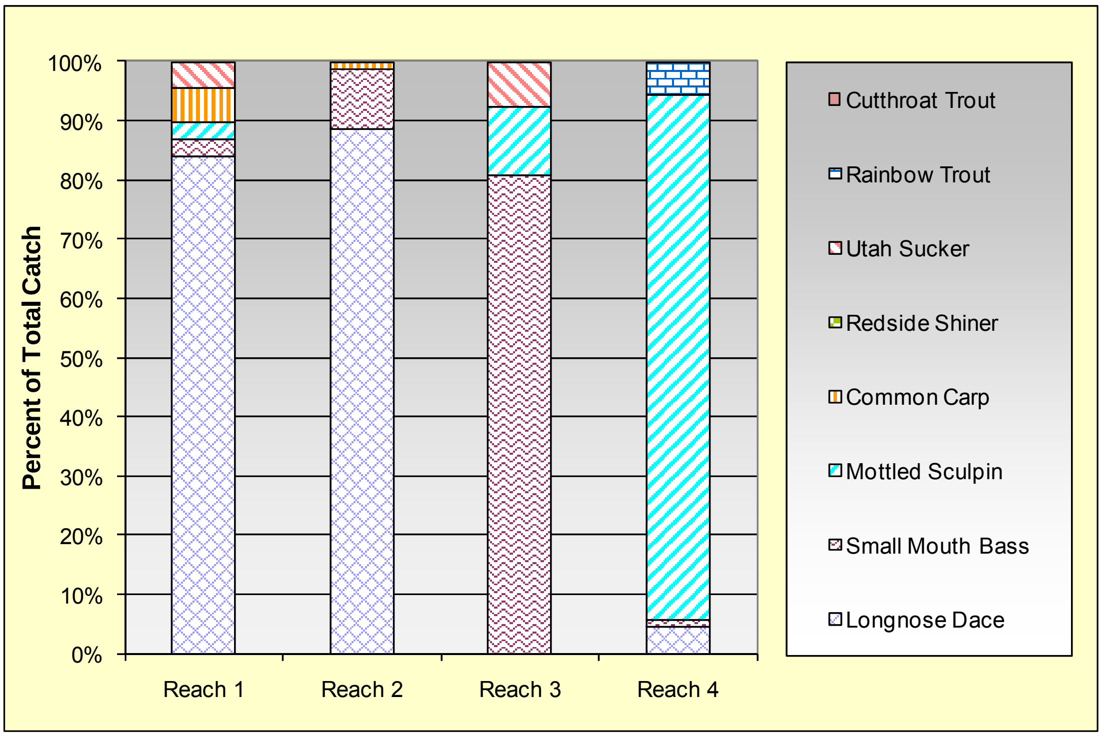


Figure 4.5-3: Fish species composition, October 2010

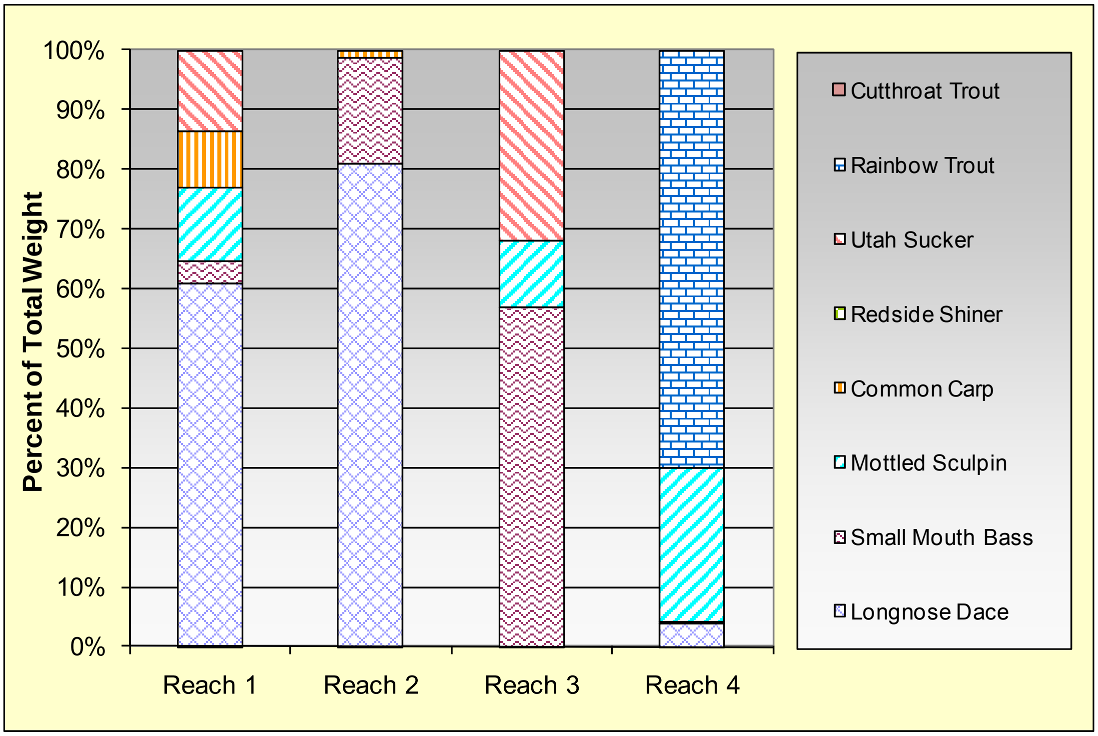


Figure 4.5-4: Fish species biomass, October 2010

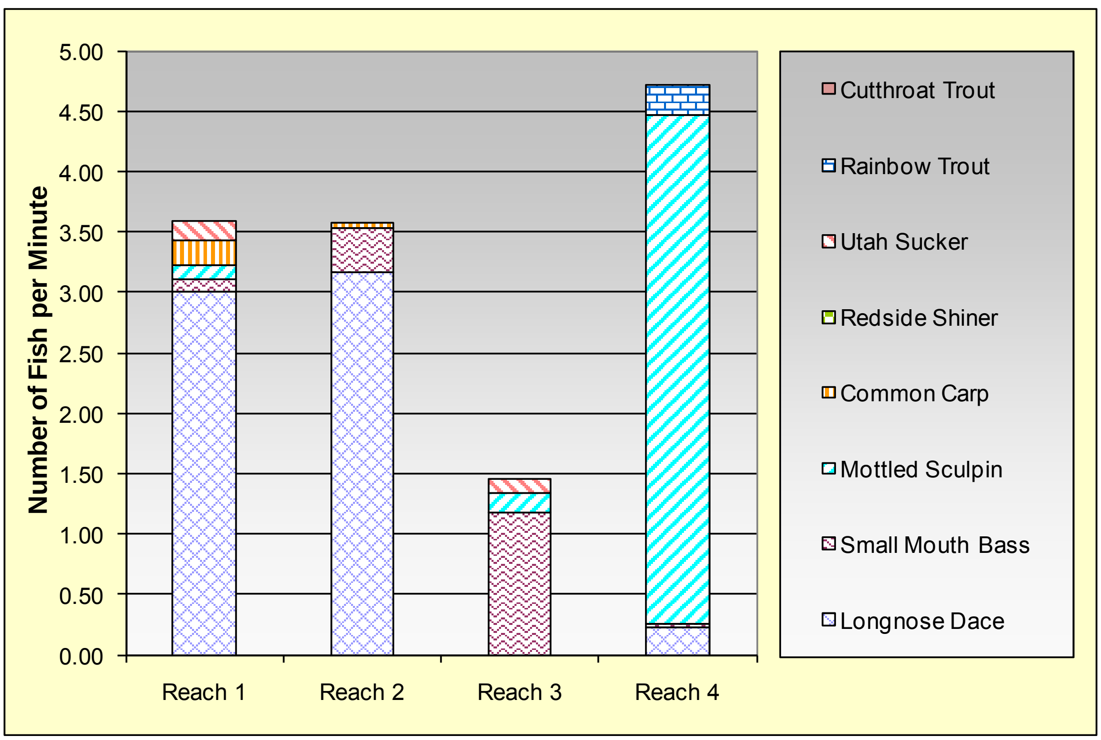


Figure 4.5-5: Catch per unit effort for reaches 1, 2, 3 and 4, October 2010

4.5.3 Reach 3— Black Canyon

Three species were collected in reach 3 for a total catch of 26 fish and a biomass of 232 g (Table 4.5-3). Smallmouth bass dominated in abundance (21 fish; 81% of catch) followed by mottled sculpin (3; 12%), and Utah sucker (2; 8%). Smallmouth bass also accounted for a majority of the biomass at 57% (1872 g), followed by Utah sucker (32%; 74 g), and mottled sculpin (11%; 26 g). CPUE was greatest for smallmouth bass at 1.17 fish/minute, followed by mottled sculpin (0.17 fish/minute), and Utah sucker (0.11 fish/minute).

Table 4.5-3: Fish density and biomass per 100 meters in reach 3, October 2010

Species	N	Weight (g)	CPUE (fish / minute)
Longnose Dace (*Rhinichthys cataractae*)	0	0	0
Small Mouth Bass (*Micropterus dolomieu*)	21 (81%)	132 (57%)	1.17
Mottled Sculpin (*Cottus bairdi*)	3 (12%)	26 (11%)	0.17
Common Carp (*Cyprinus carpio*)	0	0	0
Redside Shiner (*Richardsonius balteatus*)	0	0	0
Utah Sucker (*Catostomus ardens*)	2 (8%)	74 (32%)	0.11
Rainbow Trout (*Oncorhynchus mykiss*)	0	0	0
Cutthroat Trout (*Oncorhynchus clarki*)	0	0	0
Total	26	232	1.45

4.5.4 Reach 4—Above Grace Power Plant

Four species were collected in reach 4 for a total catch of 109 fish with a biomass of 1800 g (Table 4.5-4). Mottled sculpin were the most abundant (97 fish; 89% of the catch) followed by rainbow trout (9; 6%), longnose dace (5; 5%), and smallmouth bass (1; 1%). Rainbow trout accounted for a large majority of the biomass at 70% (1260 g). The remaining 30% of the biomass was comprised largely of mottled sculpin (26%; 466 g), with small proportions of longnose dace (4%; 70g) and smallmouth bass (<1%; 4 g).

Catch per unit effort was greatest for mottled sculpin (4.20 fish/minute) followed by rainbow trout (0.26 fish/minute), longnose dace (0.22 fish/minute), and smallmouth bass (0.04 fish/minute).

Table 4.5-4: Fish density and biomass per 100 meters in reach 4, October 2010

Species	N	Weight (g)	CPUE (fish / minute)
Longnose Dace (*Rhinichthys cataractae*)	5 (5%)	70 (4%)	0.22
Small Mouth Bass (*Micropterus dolomieu*)	1 (1%)	4 (<1%)	0.04
Mottled Sculpin (*Cottus bairdi*)	97 (89%)	466 (26%)	4.20
Common Carp (*Cyprinus carpio*)	0	0	0
Redside Shiner (*Richardsonius balteatus*)	0	0	0
Utah Sucker (*Catostomus ardens*)	0	0	0
Rainbow Trout (*Oncorhynchus mykiss*)	9 (6%)	1260 (70%)	0.26
Cutthroat Trout (*Oncorhynchus clarki*)	0	0	0
Total	109	1800	4.72

A total of six rainbow trout were collected in reach 4. None of the six fish were marked with a freeze-brand. In 2009 and 2010, fish were not freeze-branded at the Grace Hatchery prior to release in the river. The six fish ranged in weight from 70 g to 480 g with a mean weight of 210 g (Table 4.5-5). The six rainbow trout collected in reach 4 ranged in length from 199 mm to 355 mm and had a mean length of 263 mm (Figure 4.5-6).

The relative weight of one of the six rainbow trout collected in reach 4 fell above the standard weight-length curve (Wr = 100) while four of the five rainbows had relative weights that fell below the curve (Figure 4.5-7). The mean relative weight (Wr) for all six rainbows was 95 and ranged from 82 to 119.

Table 4.5-5: Rainbow Trout lengths and weights in reach 4, October 2010

Number	Freeze brand	Length (mm)	Weight (g)	Relative Weight
1	None	236	138	97
2	None	291	234	87
3	None	199	70	82
4	None	229	154	119
5	None	355	480	98
6	None	269	184	87
	Average	263	210	95

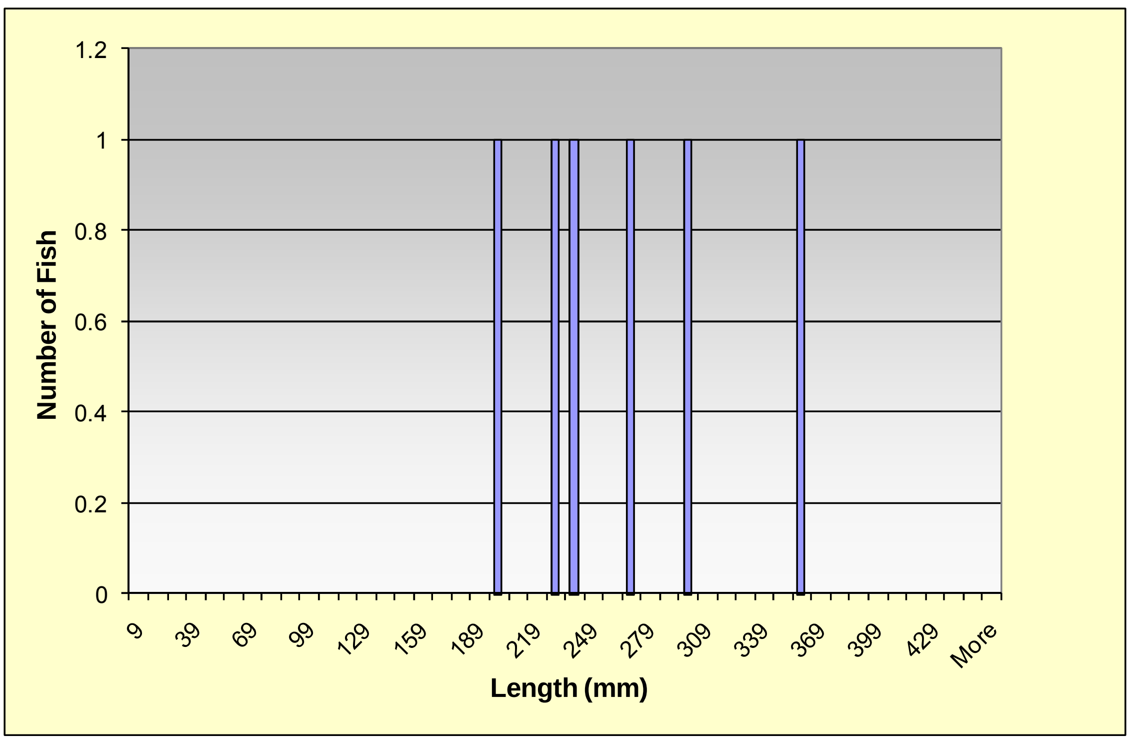


Figure 4.5-6: Length frequency distribution for RBT in reach 4, October 2010

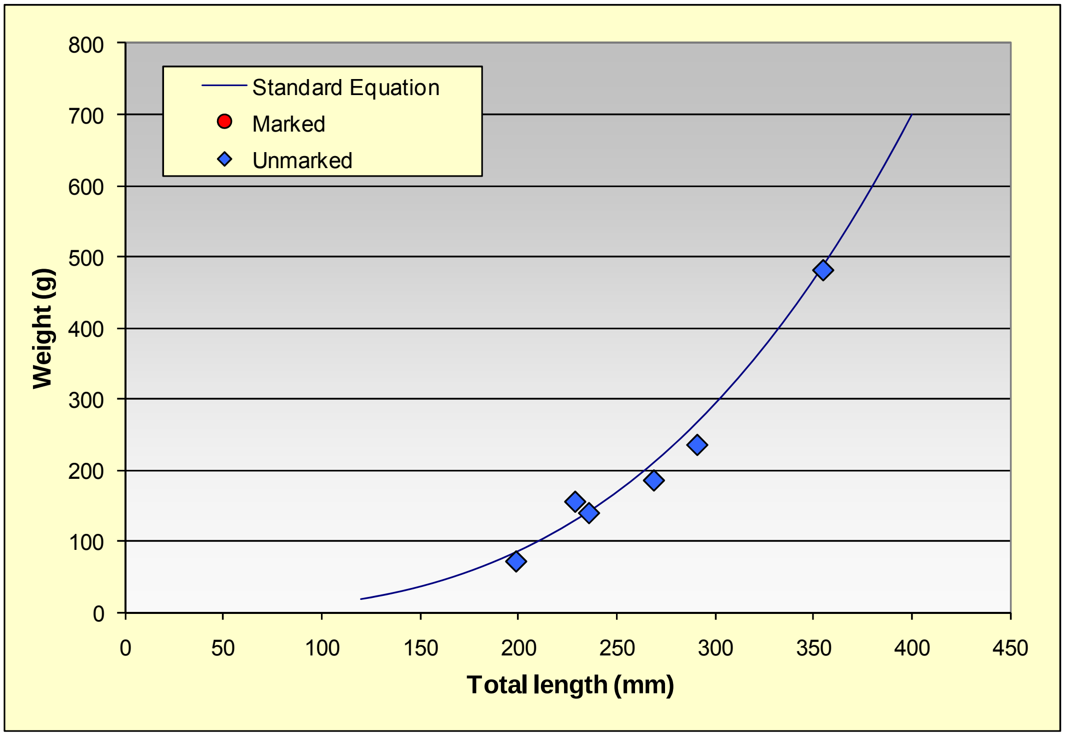


Figure 4.5-7. Length-weight relationship for rainbow trout in reach 4, October 2010

4.5.5 Within Reach Comparisons—2005 through 2010

In reach 1, species richness was greatest in 2006, 2008, and 2010 (Figure 4.5-8). Five species were collected in reach 1 in those years 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 six years, while common carp and smallmouth bass were collected in four of the six-years. A few juvenile Utah suckers were collected in 2006 and 2010, 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 1, longnose dace accounted for the largest proportion of the relative species composition in all six-years (65%, 36%, 59%, 56%, 40%, and 85% of catch). Mottled sculpin were the next most abundant in five of the six 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 smallmouth bass accounted for 23% and 13%, respectively, and in 2009 when redside shiner comprised 20% of the catch.

In reach 1, the total biomass was 7306 g in 2005, but was considerably less at only 270 g in 2006, 390 g in 2007, 902 g in 2008, 36 g in 2009, and 320 g in 2010 (Figure 4.5-9). The large difference in total biomass was largely the result of collecting two large adult common carp in 2005 while only a few small juvenile carp were collected in 2006, 2007, and 2010, and no carp were collected in 2008 or 2009. Accordingly, common carp accounted for 91% of the biomass in 2005 at 6654 g while in 2006, 2007, and 2010 they accounted for only 18%, 7%, and 6%, respectively. Despite only two trout being collected in 2008, Cutthroat trout accounted for a majority of the biomass at 63% (568 g) followed by rainbow trout at 28% (250 g). In 2006 and

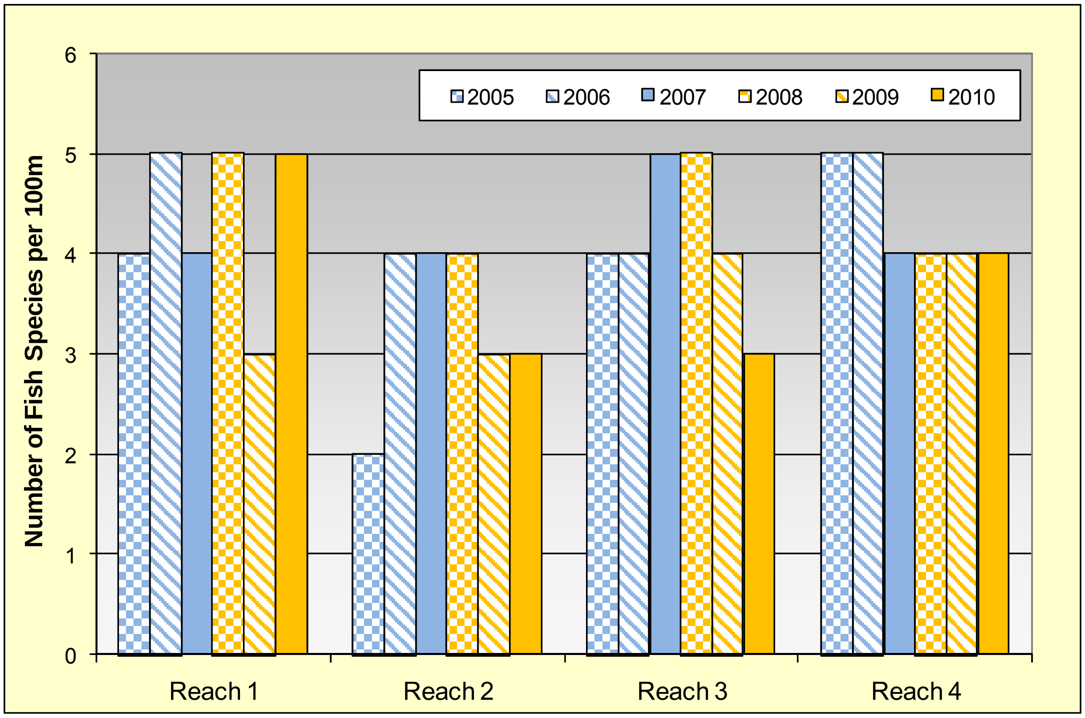


Figure 4.5-8: Species richness, reaches 1, 2, 3, and 4, 2005 through 2010

2009, mottled sculpin accounted for the largest proportion of the biomass at 35% and 78%, respectively, while longnose dace comprised 29% and 17% in those years. In 2007 and 2010, longnose dace accounted for the highest proportion of the biomass at 48% (186 kg) and 61% (196 g), respectively.

In reach 1, total catch and CPUE varied considerably between the six study years (Figure 4.5-10). Total catch was highest in 2005 at 84 fish, followed by 59 fish in 2007, 39 fish in 2006, 19 fish in 2008, just five fish in 2009, and 68 fish in 2010. Likewise, catch per unit effort (CPUE) was also highest in 2005 at 5.03 fish/minute, 3.33 fish/minute in 2007, 2.31 fish/minute in 2006, 0.86 fish/minute in 2008, 3.59 fish/minute in 2010, and lowest in 2009 at just 0.25 fish/minute.

In reach 2, species richness was greater in 2006, 2007, and 2008 than in 2005, 2009, and 2010 (Table 4.5-7). Four species were collected in 2006, 2007, and 2008, three species were collected in 2009 and 2010, and only two species were collected in 2005. Longnose dace and smallmouth bass were present all years, redside shiner were collected in four of six-years (2006, 2007, 2008, and 2009), Utah sucker were collected in 2006 and 2007, and common carp were collected in 2008 and 2010.

In reach 2, longnose dace were the most abundant in five of the six-years (97%, 88%, 82%, 50%, 88% of catch), while it was redside shiner which were the most abundant in 2008 at 45%. Redside shiner accounted for relatively small proportions of the catch in 2006 (6%) and 2007 (13%) and were not collected in 2005 or 2010, however, in 2009 they comprised 38% of the catch. Common carp accounted for 22% of the catch in 2008 and 1% in 2010, but were not collected in reach 2 in any other years. Smallmouth bass were collected all 6 years and comprised 3% to 13% of the catch. Utah sucker accounted for only a small proportion of the catch (3%) in 2006 and 2007, and were not collected in this reach in any other years.

Table 4.5-6: Fish density and biomass for reach 1, October 2005 through 2010

	Species	2005 N	2005 Weight (g)	2005 CPUE	2006 N	2006 Weight (g)	2006 CPUE	2007 N	2007 Weight (g)	2007 CPUE
Baseline 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	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 N	2008 Weight (g)	2008 CPUE	2009 N	2009 Weight (g)	2009 CPUE	2010 N	2010 Weight (g)	2010 CPUE
Variable Flows	Longnose Dace	9 (56%)	40 (5%)	0.49	2 (40%)	6 (17%)	0.10	57 (84%)	196 (61%)	3.00
	Small Mouth Bass	2 (13%)	6 (1%)	0.11	0	0	0	2 (3%)	12 (4%)	0.11
	Mottled Sculpin	3 (19%)	38 (4%)	0.16	2 (40%)	28 (78%)	0.10	2 (3%)	40 (12%)	0.11
	Common Carp	0	0	0	0	0	0	4 (6%)	30 (9%)	0.21
	Redside Shiner	0	0	0	1 (20%)	2 (6%)	0.05	0	0	0
	Utah Sucker	0	0	0	0	0	0	3 (4%)	44 (14%)	0.16
	Rainbow Trout	1 (6%)	250 (28%)	0.05	0	0	0	0	0	0
	Cutthroat Trout	1 (6%)	568 (63%)	0.05	0	0	0	0	0	0
	Total	16	902	0.86	5	36	0.25	68	322	3.59

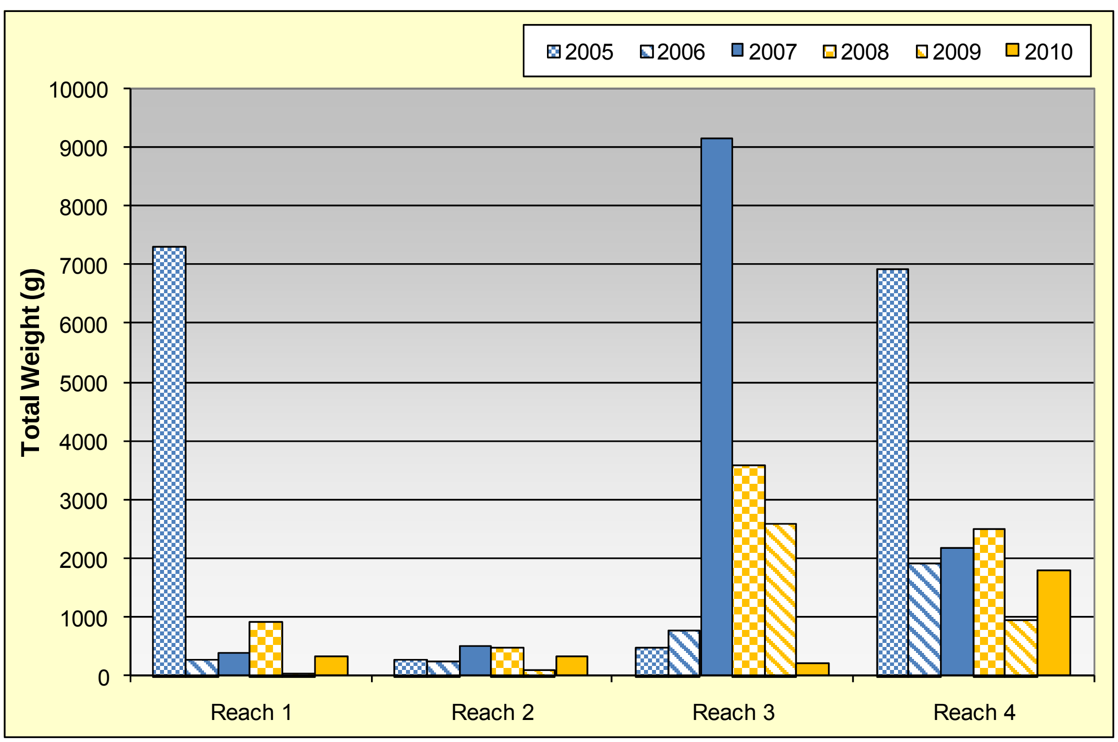


Figure 4.5-9: Fish biomass per 100 meters, reaches 1, 2, 3, and 4, 2005 through 2010

Table 4.5-7: Fish density and biomass for reach 2, October 2005 through 2010

	Species	2005			2006			2007		
		N	Weight (g)	CPUE	N	Weight (g)	CPUE	N	Weight (g)	CPUE
Baseline 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	0	0	0
	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
Variable Flows	Longnose Dace	19 (26%)	150 (33%)	0.95	8 (50%)	28 (32%)	0.36	69 (88%)	270 (81%)	3.16
	Small Mouth Bass	6 (8%)	64 (14%)	0.30	2 (13%)	48 (55%)	0.09	8 (10%)	60 (18%)	0.37
	Mottled Sculpin	0	0	0	0	0	0	0	0	0
	Common Carp	16 (22%)	138 (30%)	0.80	0	0	0	1 (1%)	4 (1%)	0.05
	Redside Shiner	33 (45%)	108 (23%)	1.65	6 (38%)	12 (14%)	0.27	0	0	0
	Utah Sucker	0	0	0	0	0	0	0	0	0
	Rainbow Trout	0	0	0	0	0	0	0	0	0
	Cutthroat Trout	0	0	0	0	0	0	0	0	0
	Total	74	460	3.70	16	88	0.72	78	334	3.58

Total biomass in reach 2 was lowest in 2009 at 88 g, but was similar in 2005, 2006 and 2010 at 265 g, 246 g, and 334 g respectively, and, in 2007 and 2008, biomass was slightly greater at 516 g and 460 g. The increase in biomass in 2007 was due mainly to the capture of one Utah sucker (140 g, 27% of biomass). 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 five of the six-years (97% in 2005; 84 % in 2006, 66% in 2007, 33% in 2008, and 81% in 2010) while in 2009, smallmouth bass was the majority at 55% and longnose dace comprised 32%. In all other years, the remaining biomass was typically comprised of small proportions of smallmouth bass, common carp, and redside shiner. In reach 3, species richness was greater in 2007 and 2008 than in 2005, 2006, 2009 and 2010 (Table 4.5-8). Five species were collected in 2007 and 2008, four species were collected in 2005, 2006, and 2009, and only three species in 2010. Utah sucker were the only species collected all six-years, smallmouth bass were collected five of six-years, redside shiner were collected four of six-years, and Longnose dace were collected three of six-years. One large adult common carp was collected in 2007 and two juvenile carp were collected in 2008. A few mottled sculpin were collected in 2008, 2009, and 2010, and one rainbow trout was collected in this reach in both 2006 and 2009.

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, decreased to 16 in 2009, and then increased to 78 fish in 2010. 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, subsequently decreased to 0.72 in 2009, and then increased again to 3.58 fish/minute in 2010.

In reach 3, species richness was greater in 2007 and 2008 than in 2005, 2006, 2009 and 2010 (Table 4.5-8). Five species were collected in 2007 and 2008, four species were collected in

2005, 2006, and 2009, and only three species in 2010. Utah sucker were the only species collected all six-years, smallmouth bass were collected five of the six-years, redside shiner were collected four of the six-years, and longnose dace were collected three of the six-years. One large adult common carp was collected in 2007 and two juvenile carp were collected in 2008. A few mottled sculpin were collected in 2008, 2009, and 2010, and one rainbow trout was collected in this reach in both 2006 and 2009.

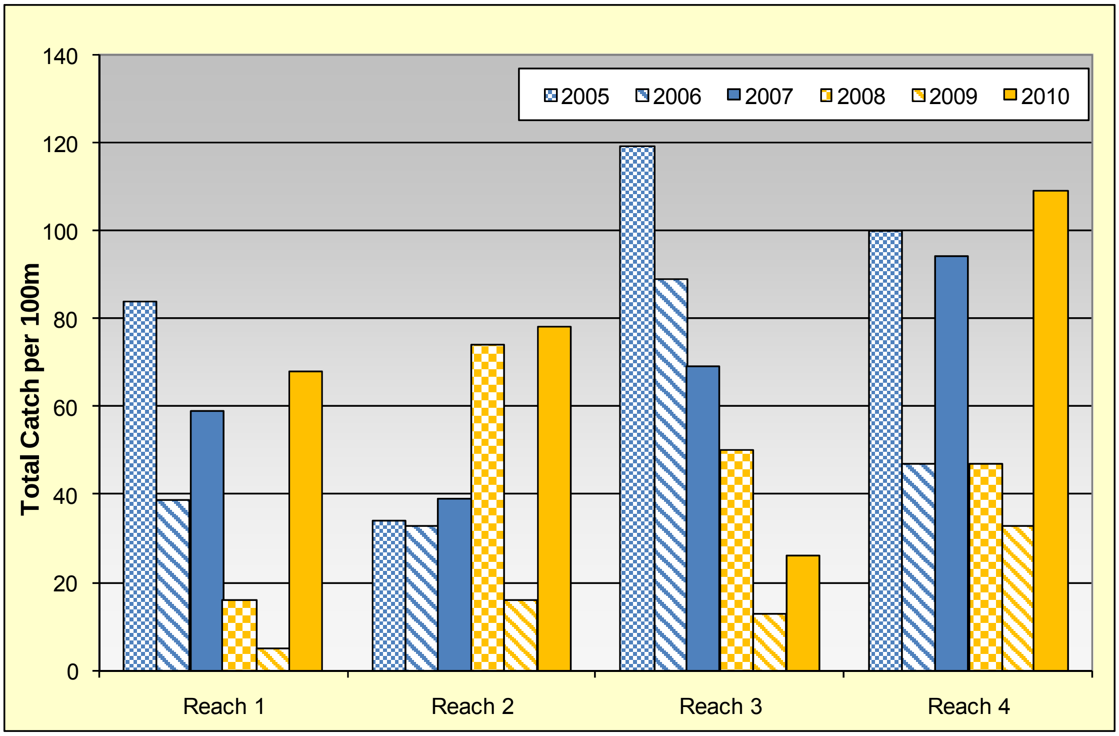


Figure 4.5-10: Total catch per 100 meters, reaches 1, 2, 3, and 4, 2005 through 2010

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 or 2010. Smallmouth bass were the most abundant in 2009 and 2010 while they accounted for a relatively small proportion of the catch in three of the four other years. Utah sucker were collected all six-years and comprised 4% to 13% of the catch. 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.

In reach 3, total biomass was much greater in 2007 (9132 g), 2008 (3574 g), and 2009 (2586 g) than in 2005 (474 g), 2006 (780 g), or 2010 (232 g). For 2007, a majority of the total biomass can be attributed to the collection of one large adult common carp (4960 g, 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, 2006, or 2010 and only 2 juvenile carp were collected in 2008. Redside shiner comprised a majority of the biomass in 2005 (83%, 392 g) while rainbow trout made up a majority of the biomass in 2006 at 294 g (38%). Common carp accounted for the highest proportion of the biomass in 2007 at 54% (4960 g), and Utah sucker made up the majority of the biomass in 2008 and 2009 at 93% and 72%, respectively. In 2010, smallmouth bass comprised a majority of the biomass at 57%, and Utah sucker accounted for 32%.

Total catch in reach 3 decreased each year of the study before increasing slightly in 2010. In 2005, total catch was highest at 119 fish, 89 fish in 2006, 69 in 2007, 50 fish in 2008, 13 in 2009, and 26 fish in 2010. Following the same trend as total catch, CPUE was highest in 2005 at 10.26 fish/minute, 5.88 fish/minute in 2006, 4.15 fish/minute in 2007, 3.27 fish/minute in 2008, 0.83 fish/minute in 2009, and 1.45 fish/minute in 2010.

Table 4.5-8: Fish density and biomass for reach 3, October 2005 through 2010

	Species	2005			2006			2007		
		N	Weight (g)	CPUE	N	Weight (g)	CPUE	N	Weight (g)	CPUE
Baseline 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
Variable Flows	Longnose Dace	0	0	0	0	0	0	0	0	0
	Small Mouth Bass	10 (20%)	64 (2%)	0.65	10 (77%)	84 (3%)	0.65	21 (81%)	132 (57%)	1.17
	Mottled Sculpin	1 (2%)	14 (<1%)	0.07	1 (8%)	22 (1%)	0.06	3 (12%)	26 (11%)	0.17
	Common Carp	2 (4%)	20 (1%)	0.13	0	0	0	0	0	0
	Redside Shiner	35 (70%)	146 (4%)	2.29	0	0	0	0	0	0
	Utah Sucker	2 (4%)	3330 (93%)	0.13	1 (8%)	1872 (72%)	0.06	2 (8%)	74 (32%)	0.11
	Rainbow Trout	0	0	0	1 (8%)	608 (24%)	0.06	0	0	0
	Cutthroat Trout	0	0	0	0	0	0	0	0	0
	Total	50	3574	3.27	13	2586	0.83	26	232	1.45

Reach 4 had five fish species collected in 2005 and 2006 but only four in 2007, 2008, 2009 and 2010 (Table 4.5-9). Longnose dace, mottled sculpin, and rainbow trout were all collected in all six-years of the study, and redside shiner were collected in five of six-years. Utah sucker were collected in small numbers in 2005 and 2006 only, and smallmouth bass were collected in 2010 only.

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 and 2010 they comprised only 6% and 5% of the total catch, respectively. Mottled sculpin were the next most abundant in the first four years (27%, 15%, 32%, and 38%), while they made up a majority of the catch in 2009 at 58% and in 2010 at 89%. Rainbow trout accounted for 22% of the catch in 2005, 13% in 2006, 5% in 2007, and 19% in 2008, 15% in 2009, and 6% in 2010. Redside shiner comprised a small to moderate amount of the catch in the initial five years at 10% in 2005, 13% in 2006, 26% in 2007, 6% in 2008, and 21% in 2009, however, they were not collected in reach 4 in 2010.

Total biomass in reach 4 was considerably greater in 2005 (6901 g) than in all other years (1910 g in 2006, 2175 g in 2007, 2494 g in 2008, 948 g in 2009, and 1800 g in 2010). This decrease in total biomass was consistent with a decrease in the number of rainbow trout collected in 2006 (6), 2007 (5), 2008 (9), 2009 (5), and 2010 (6) verses the 22 collected in 2005. Rainbow trout accounted for a large majority of the biomass during all six-years of this study at

91% in 2005, 84% in 2006, 67% in 2007, 91% in 2008, 80% in 2009, and 70% in 2010. The remainder of the biomass in reach 4 was typically comprised of small proportions of longnose dace, mottled sculpin, redside shiner, and Utah sucker.

Table 4.5-9: Fish density and biomass for reach 4, October 2005 through 2010

	Species	2005			2006			2007		
		N	Weight (g)	CPUE	N	Weight (g)	CPUE	N	Weight (g)	CPUE
Baseline 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
Variable Flows	Longnose Dace	18 (38%)	164 (7%)	1.04	2 (6%)	18 (2%)	0.12	5 (5%)	70 (4%)	0.22
	Small Mouth Bass	0	0	0	0	0	0	1 (1%)	4 (<1%)	0.04
	Mottled Sculpin	18 (38%)	106 (4%)	1.04	19 (58%)	100 (11%)	1.10	97 (89%)	466 (26%)	4.20
	Common Carp	0	0	0	0	0	0	0	0	0
	Redside Shiner	2 (4%)	26 (1%)	0.12	7 (21%)	72 (8%)	0.41	0	0	0
	Utah Sucker	0	0	0	0	0	0	0	0	0
	Rainbow Trout	9 (19%)	2198 (88%)	0.52	5 (15%)	758 (80%)	0.29	9 (6%)	1260 (70%)	0.26
	Cutthroat Trout	0	0	0	0	0	0	0	0	0
	Total	47	2494	2.72	33	948	1.92	109	1800	4.72

In reach 4, total catch was much higher in 2005 (100 fish), 2007 (94 fish), and 2010 (109 fish) than in 2006 (47 fish), 2008 (47 fish), and 2009 (33 fish). Similarly, CPUE was also considerably greater in 2005 (6.65 fish/minute), 2007 (4.75 fish/minute), and 2010 (4.72 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 4.5-11). Mean relative weight of all rainbow trout collected was 104 in 2005, 89 in 2006, 87 in 2007, 94 in 2009, and 95 in 2010. 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 or 2010 in reach 4.

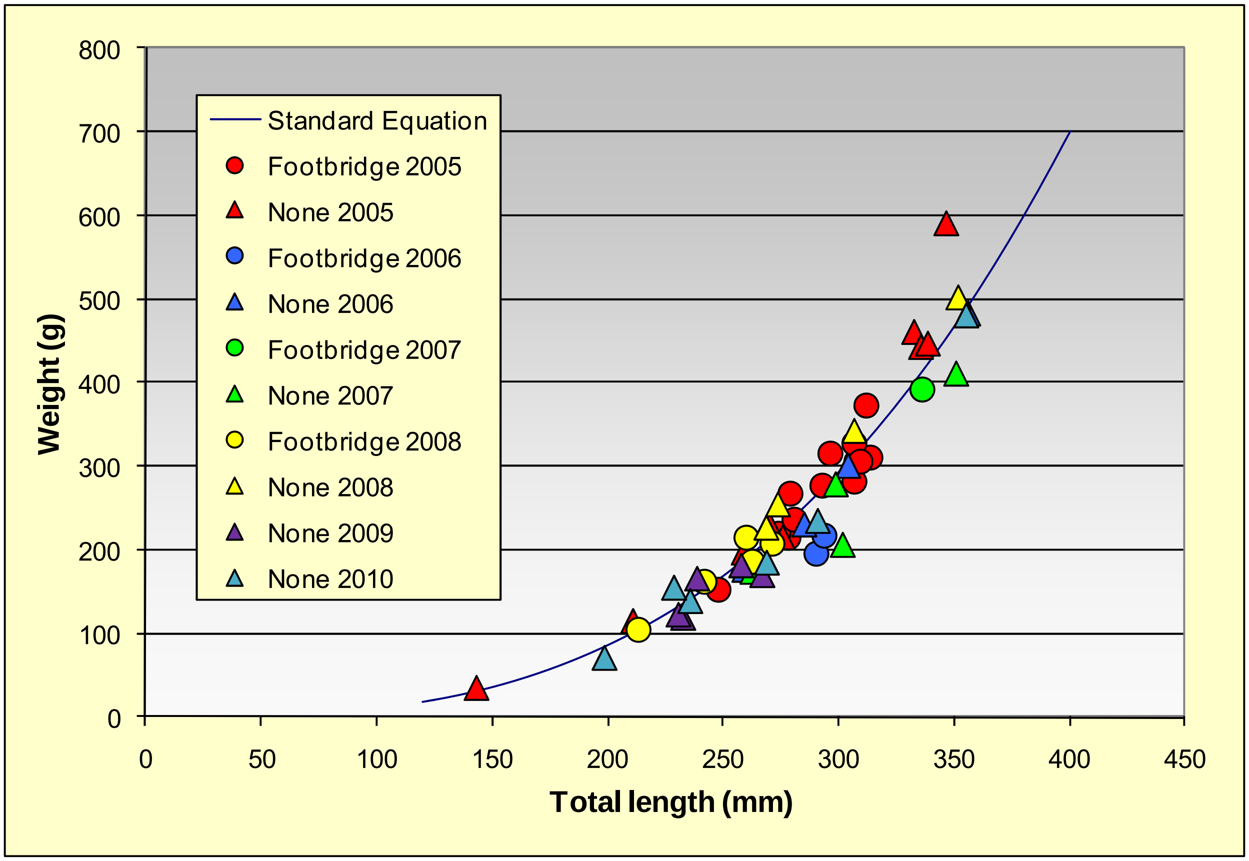


Figure 4.5-11: Length-weight relationship for rainbow, reach 4, 2005 through 2010

4.6 TEMPERATURE

Temperature data was analyzed for the three-year baseline period for the four study reaches (Figure 4.6-1). However, the absence of substantial changes in discharge in the summer season during the three-year baseline monitoring period made it difficult to detect correlations between discharge changes at Grace Dam and stream temperatures in reaches 2, 3 and 4. 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.

Constraints on the project budget regrettably prevented analysis and reporting of the temperature data for the three-year variable flow period from 2008 through 2010. Previous analysis and reporting of temperature data was outside the original scope of work.

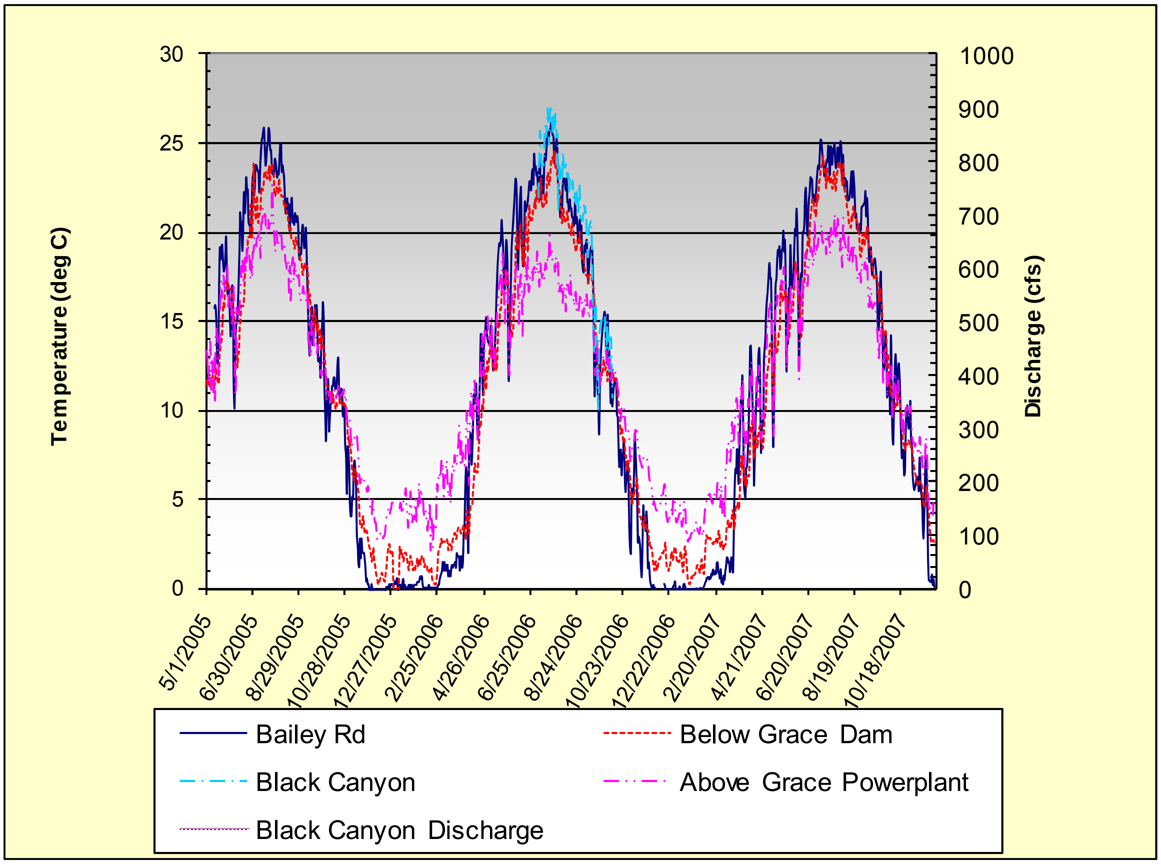


Figure 4.6-1: Maximum water temperatures in reaches 1, 2, 3 and 4, 2005 through 2007

4.7 BENTHIC MACROINVERTEBRATES

BMI density in 2010 exhibited similar densities to previous years in reaches 1, 2 and 3 (Figure 4.7-1). Reach 4, on the other hand, exhibited a substantial increase in BMI density in 2010 (859,592 organisms/m^2) compared to previous sample years (Table 4.7-1). In contrast, BMI density in reach 1 in 2010 was substantially less than previous sample years (8,504 organisms/m^2) whereas BMI density in reach 2 was the second highest density measured for this reach over the six-year study period (28,861 organisms/m^2). As in the previous five sample years, reach 3 contained the lowest BMI density for the 2010 sampling effort (7,360 organisms/m^2).

Comparisons across all six sample years within a single study reach indicate BMI densities were significantly different between years in reaches 1 and 4 only (p=0.08 and p=0.03 respectively, H-test). Comparisons between the baseline sampling period and variable flow regime found a significant decrease in BMI density in reach 1, the reference reach, during the latter three-year time period (p=0.07, ANOVA) (Figure 4.7-2). No significant differences in BMI density were observed between the baseline and variable flow periods in the three treatment reaches.

EPT density increased in the three treatment reaches in 2010 relative to the previous sampling years (Figure 4.7-3) but was significantly greater in reaches 2 and 4 only (p=0.005 and p=0.004 respectively, H-test). In contrast, the 2010 EPT density in reach 1 was the lowest recorded for the reference reach over the six-year study period (Table 4.7-2). In reach 3, EPT density was similar to densities observed in 2008 and substantially greater than densities observed in the baseline period but not significant. In reach 1, EPT comprised 86 percent of the overall BMI density compared to 25 percent, 47 percent and 1 percent in reaches 2, 3 and 4 respectively.

Table 4.7-1: Mean BMI density and taxa richness, October 2005 through 2010

Study Reach	Benthic Macroinvertebrate Density and Taxa Richness											
	Baseline Flow Period						Variable Flow Period					
	2005		2006		2007		2008		2009		2010	
	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	8,504	27
Reach 2	16,402	37	31,929	39	16,151	25	25,750	35	21,802	36	28,861	37
Reach 3	5,390	45	8,621	39	3,645	35	8,750	38	5,884	38	7,360	37
Reach 4	86,048	25	104,430	34	80,589	20	44,008	35	95,107	17	859,592	12

EPT density comparisons between the baseline sampling period and the variable flow regime found a significant decrease in reach 1 in the latter three-year period (p=0.06, ANOVA) but a significant increase in EPT density in the three treatment reaches during the variable flow period (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=0.0001, p=0.01 and p=0.007 respectively, H-test). EPT density in reach 2 was nearly six-times greater under the variable flow regime compared to the baseline period (3,059 compared to 654 organisms/m^2). In reach 3, EPT density was more than double the mean for the baseline period (2,859 compared to 1,226 organisms/m^2). In reach 4, EPT density was more than three-times the mean for the baseline period (3,604 compared to 987 organisms/m^2).

BMI taxa richness in 2010 ranged from a low of 12 taxa in reach 4 to a high of 37 taxa in reaches 2 and 3 while reach 1 contained 27 taxa (Figure 4.7-5). Comparisons across all six-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=0.0001, p=0.10 and p=0.00000004 respectively, ANOVA). Reach 4 contained the least BMI diversity of all four reaches over the six-year study period; 12 taxa in 2010. In contrast, reach 4 contained 35 taxa in 2008, the first year of variable flows. Reach 3 contained the greatest BMI diversity in the six-year study period, 45 taxa in 2005, and typically contained the highest BMI diversity relative to the other three reaches for respective sample years. BMI taxa richness comparisons between the three-year baseline sampling period and the variable flow regime found no significant differences in the three treatment reaches (Figure 4.7-6). BMI taxa richness in reach 1, on the other hand, was significantly lower during the latter variable flow regime period (p=0.05, ANOVA)

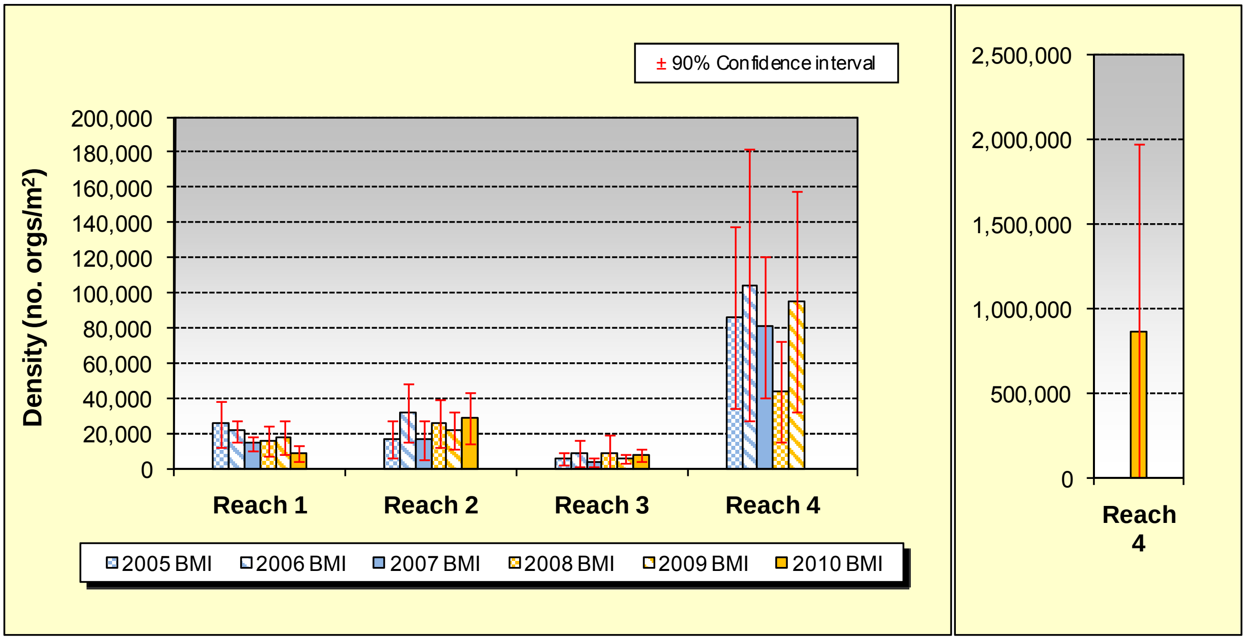


Figure 4.7-1: Average BMI Density in October, 2005 through 2010

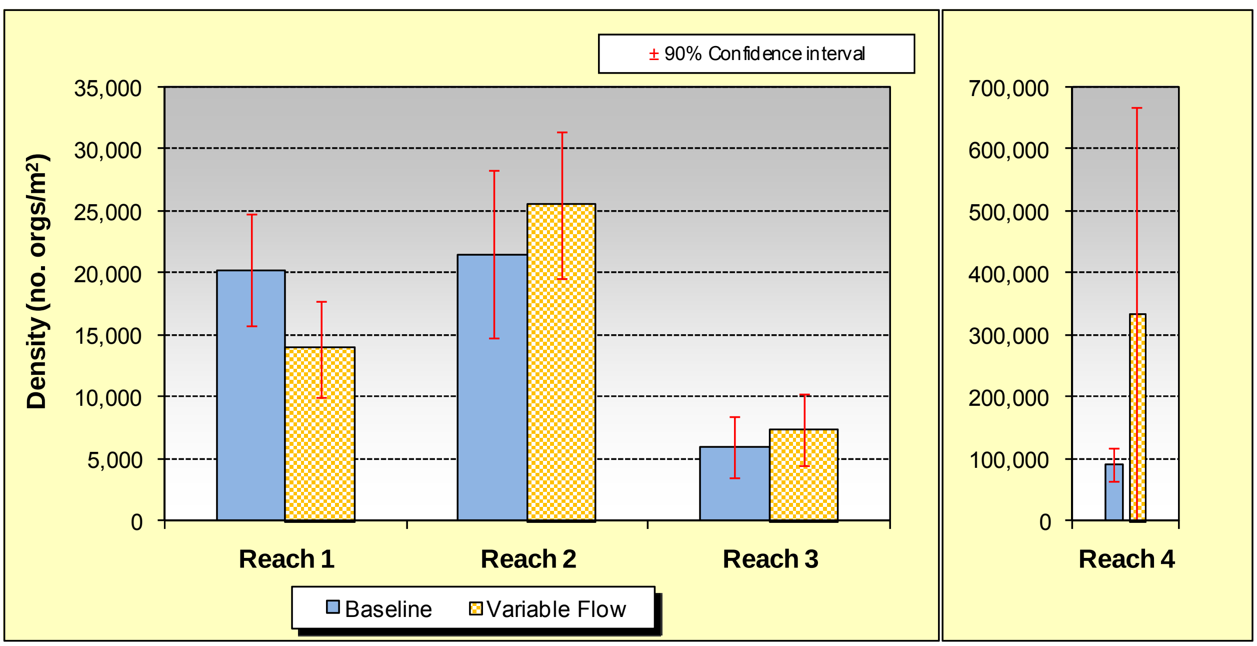


Figure 4.7-2: Average BMI Density, baseline period versus variable flow.

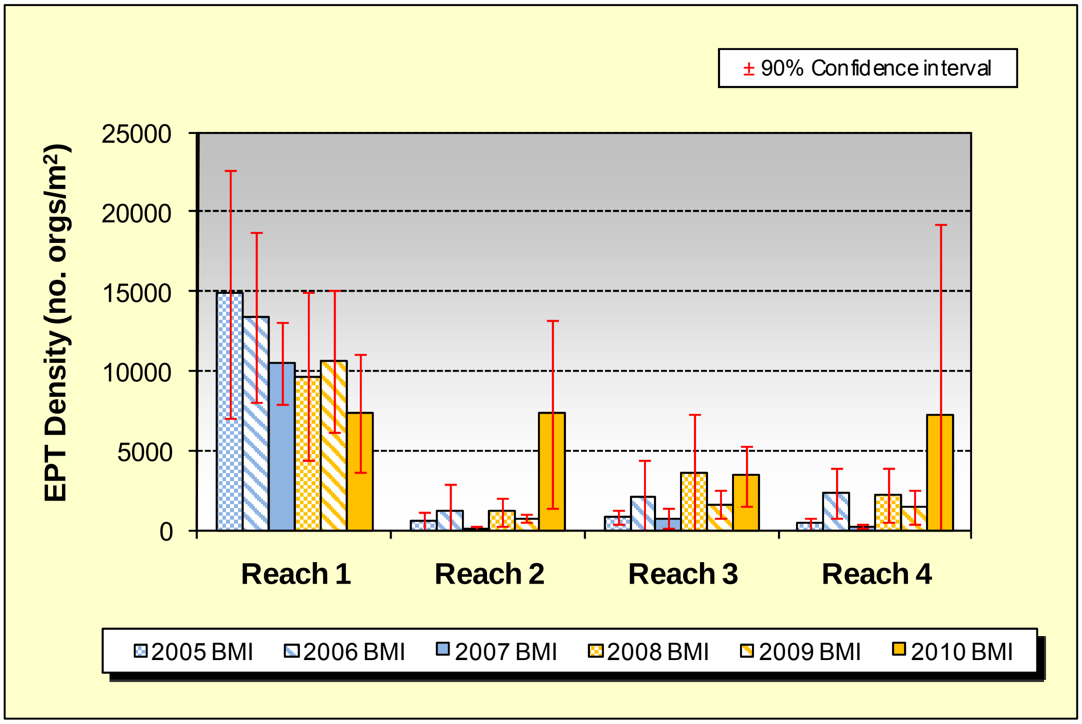


Figure 4.7-3: Mean EPT Density, October, 2005 through 2010

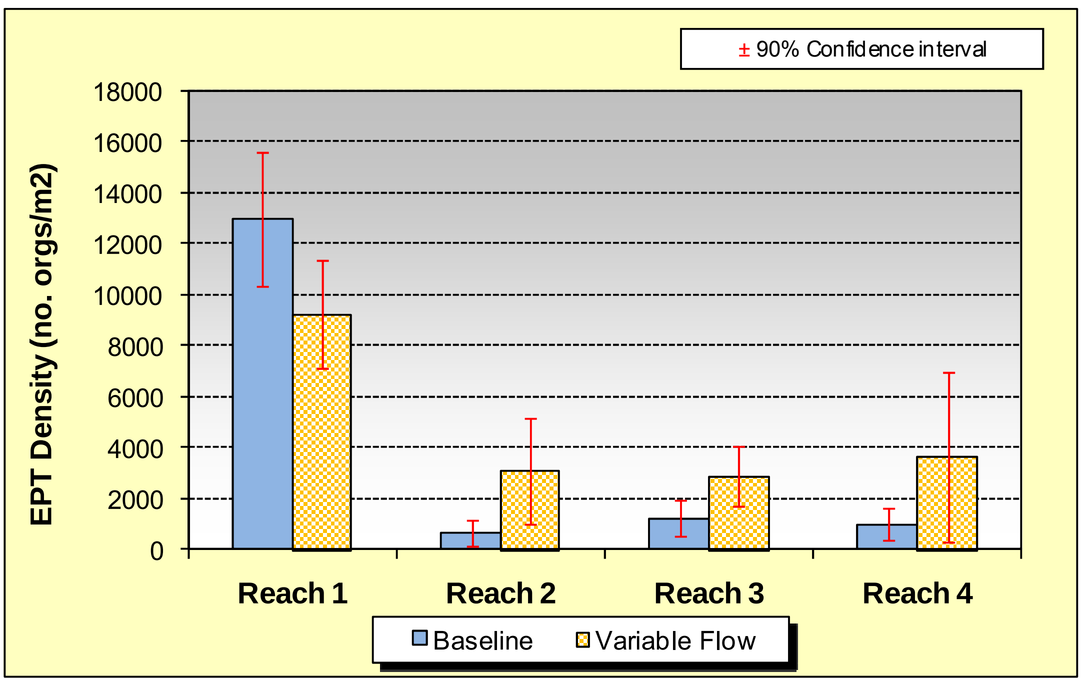


Figure 4.7-4: Mean EPT Density, baseline period versus variable flow

Table 4.7-2: Mean EPT density and taxa richness, October 2005 through 2010

Study Reach	Ephemeroptera, Plecoptera and Trichoptera (EPT) Density and Taxa Richness											
	Baseline Flow Period						Variable Flow Period					
	2005		2006		2007		2008		2009		2010	
	Density	No. taxa	Density	No. taxa	Density	No. taxa	Density	No. taxa	Density	No. taxa	Density	No. taxa
Reach 1	14,836	14	13,415	16	10,544	13	9,665	14	10,628	16	7,310	13
Reach 2	595	5	1,244	5	124	3	1,164	5	722	5	7,291	8
Reach 3	826	11	2,125	10	727	9	3,531	10	1,622	12	3,425	10
Reach 4	412	2	2,310	5	238	2	2,171	5	1,435	3	7,206	3

EPT taxa richness in 2010 ranged from a high of 13 taxa in reach 1 to a low of 3 taxa in reach 4 (Figure 4.7-7). Reaches 2 and 3 had eight and ten EPT taxa respectively in 2010. Reach 1 consistently had the highest EPT taxa richness over the six-year study period with the highest number of EPT taxa occurring in 2009, 16 taxa. Reaches 2 and 4 consistently had the lowest number of EPT taxa (2 to 5 taxa) each sample year. Comparisons across all six-years within a single study reach indicate EPT taxa richness was significantly different between years in reaches 1, 2 and 4 but similar in reach 3 (p=0.09, p=0.07 and p=0.00002 respectively, H-test). EPT taxa richness comparisons between the three-year baseline sampling period and the variable flow regime found a significant increase in EPT taxa richness in reach 2 under the variable flow conditions (p=0.07, ANOVA) but no significant differences in reaches 1, 3 or 4 (Figure 4.7-8).

Dominant taxa measures reveal the proportion of the dominant taxa relative to the larger BMI community. In 2010, the top three dominant taxa in reach 1 comprised 62.0% of the BMI community; dominant taxa 1—32.4%, dominant taxa 2—18.2% and dominant taxa 3—11.4% (Table 4.7-3). 2010 marked an increase in the dominant taxa relative to the previous five sampling years. The percentage of dominant taxa 1 (Figure 4.7-9) and dominant taxa 2 (Figure 4.7-10) increased in 2010 but remained similar for dominant taxa 3 (Figure 4.7-11).

Table 4.7-4 and 4.7-5 list the density per square meter and relative abundance for all taxonomic orders present at the four study reaches. In 2005, the BMI community composition in reach 1 consisted of Ephemeroptera (38%), Diptera (35%), Trichoptera (20%) and Annelida (4%). The remaining orders were less than 1 percent of the community composition. In 2006, the BMI community composition consisted of Diptera (35%), Trichoptera (32%) and Ephemeroptera

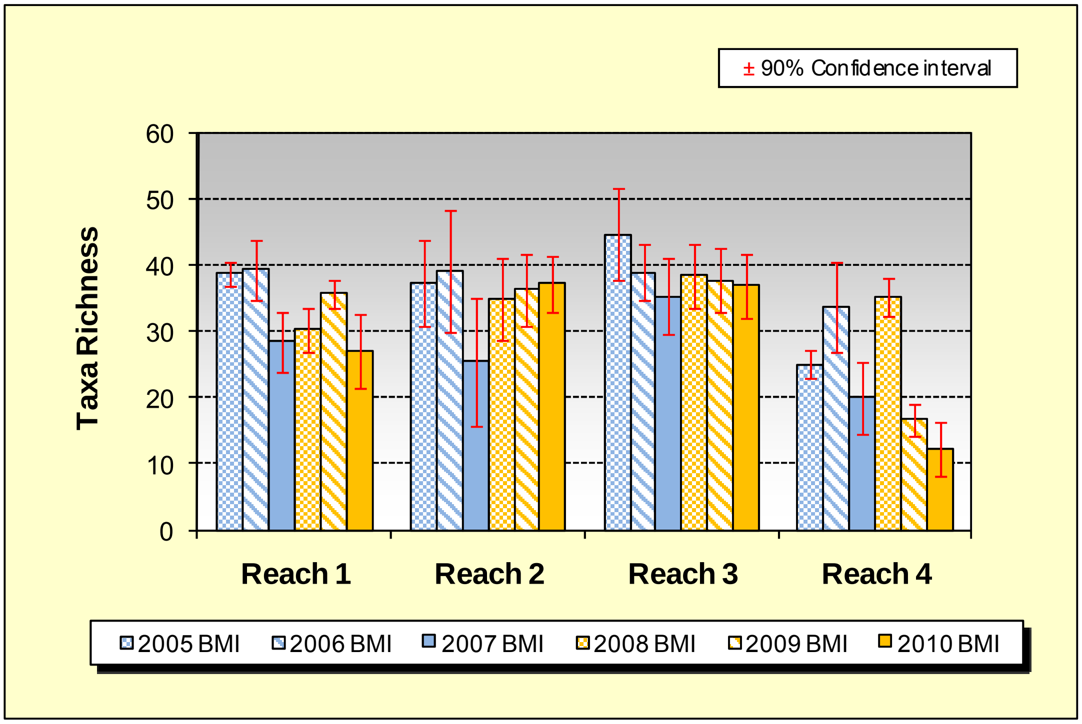


Figure 4.7-5: BMI taxa richness, October 2005 through 2010

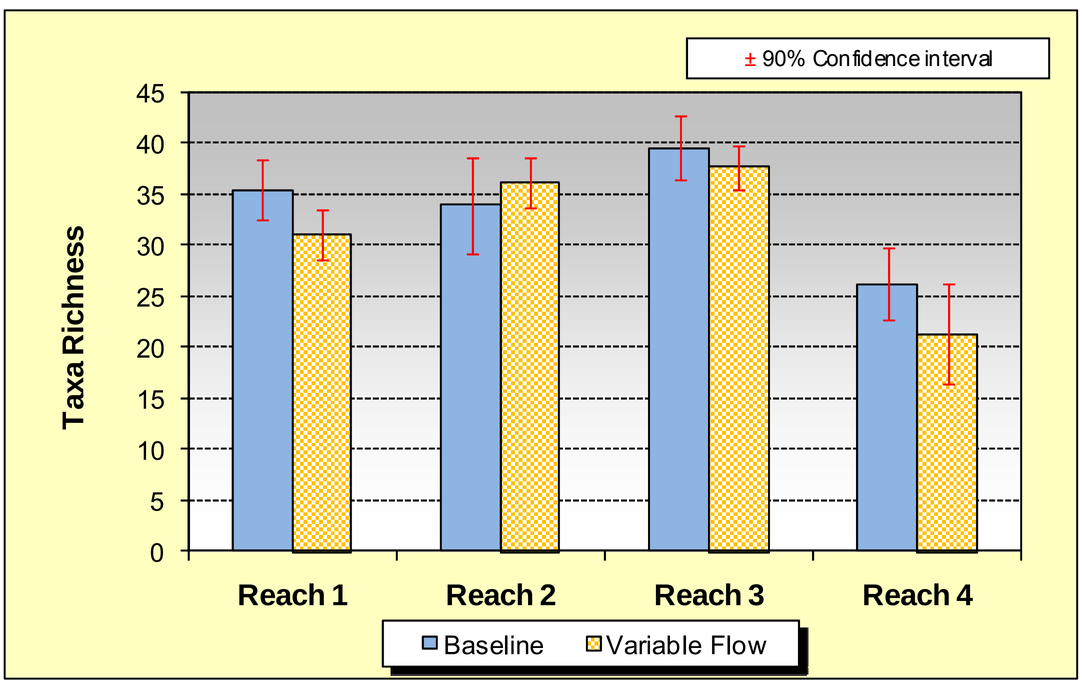


Figure 4.7-6: BMI taxa richness, baseline period versus variable flow.

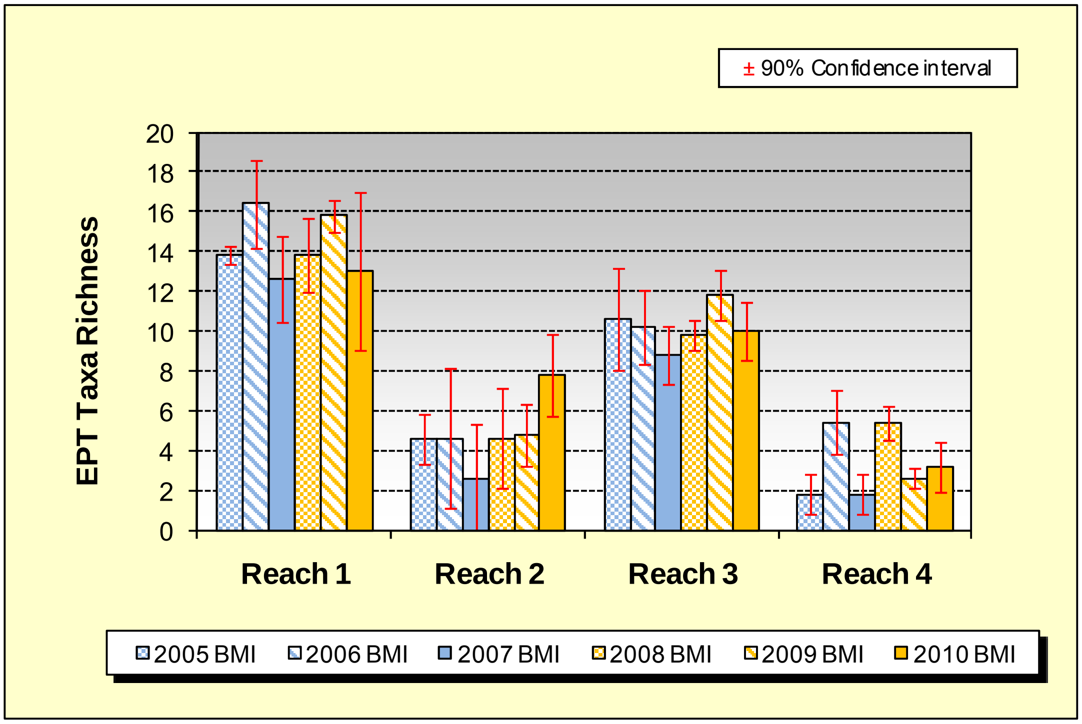


Figure 4.7-7: EPT taxa richness, October 2005 through 2010

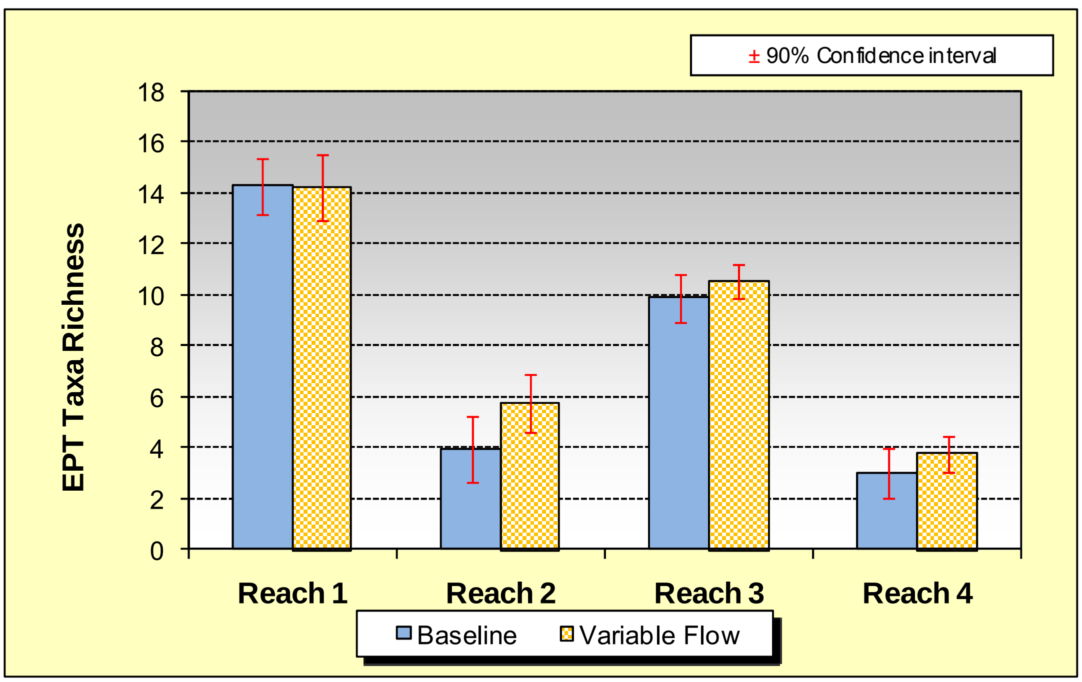


Figure 4.7-8: EPT taxa richness, baseline period versus variable flow.

(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 2010, reach 1 community composition consisted of Trichoptera (57%), Ephemeroptera (28%), Chironomidae (5%) and Diptera (5%).

Table 4.7-3: Top three dominant taxa percentages, 2005 through 2010

Study Reach	Dominant Taxa 1 (%)						Dominant Taxa 2 (%)					
	2005	2006	2007	2008	2009	2010	2005	2006	2007	2008	2009	2010
R1	20.2	17.3	19.3	18.0	21.4	32.4	12.5	12.6	15.1	12.2	15.3	18.2
R2	31.6	25.2	38.4	28.6	25.0	24.9	12.4	12.3	16.4	16.3	13.0	14.3
R3	21.7	13.4	23.0	32.2	24.1	24.1	9.8	10.4	14.0	16.5	11.6	13.8
R4	79.6	70.3	82.6	36.9	88.7	90.9	5.3	5.3	3.6	14.1	2.3	5.2
Study Reach	**Dominant Taxa 3 (%)**						**Totals (%)**					
	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
R1	8.9	10.6	12.3	10.6	11.2	11.4	41.6	40.5	46.7	40.8	47.9	62.0
R2	9.9	9.5	11.4	9.3	11.7	8.9	53.9	47.0	66.2	54.2	49.6	48.2
R3	8.4	9.7	9.4	8.2	9.4	10.9	40.0	33.5	46.4	56.9	45.1	48.8
R4	3.1	3.9	2.4	8.2	1.8	1.2	88.0	79.4	88.6	59.2	92.8	97.3

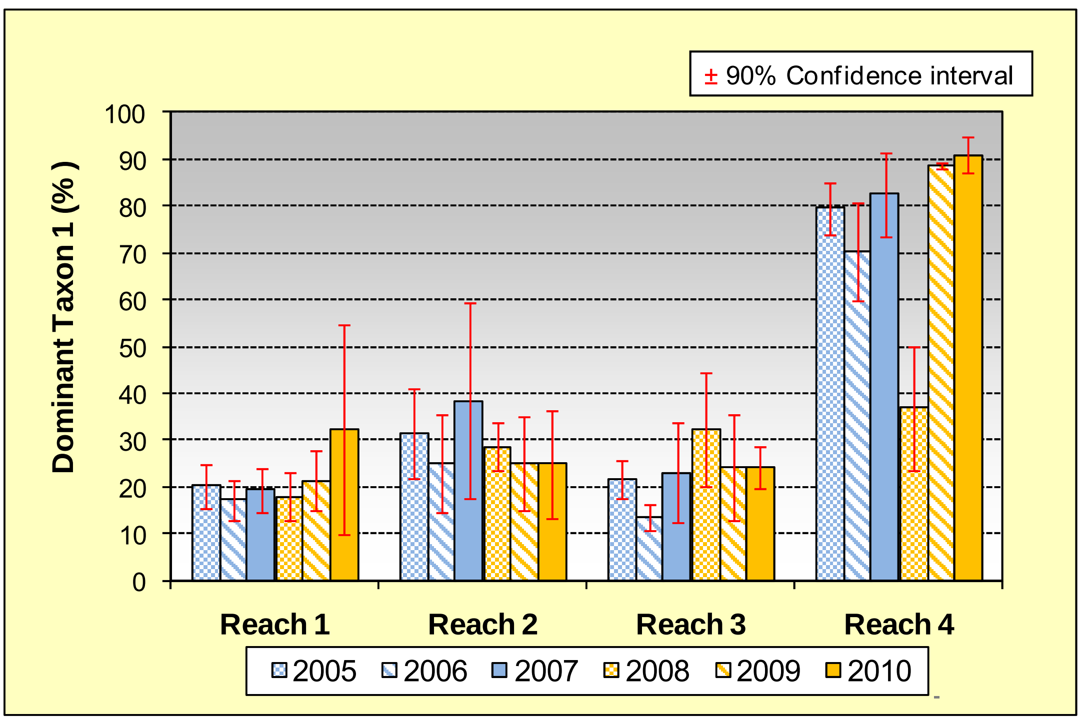


Figure 4.7-9: Dominant taxon percentage; October 2005 through 2010

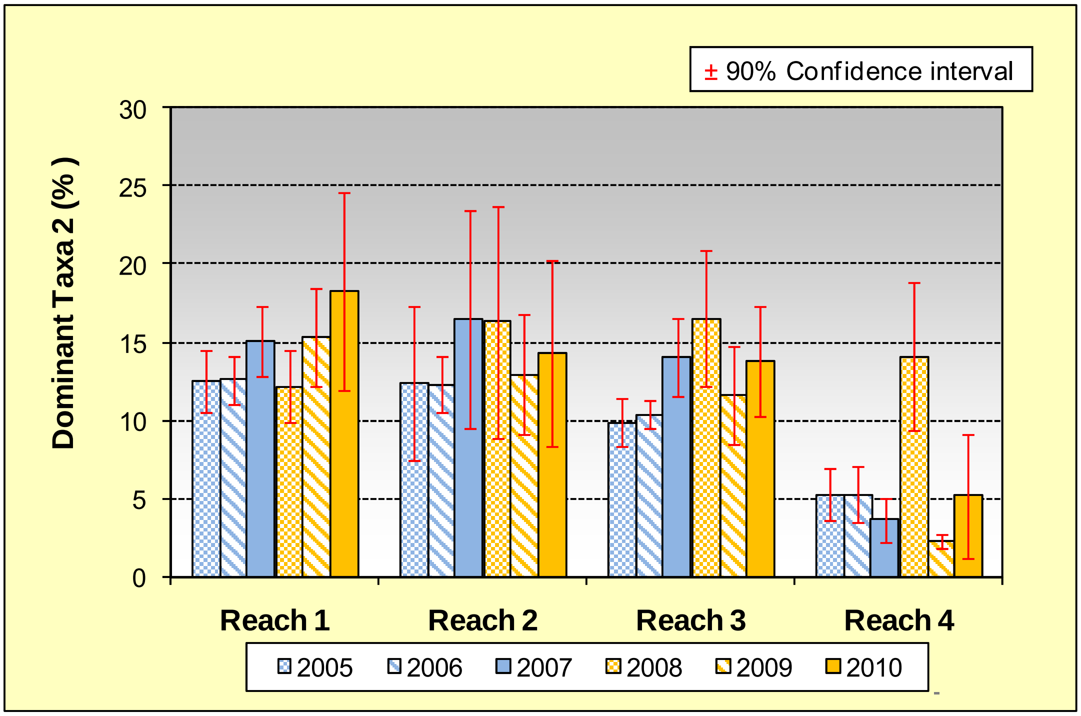


Figure 4.7-10: Second dominant taxon percentage; 2005 through 2010

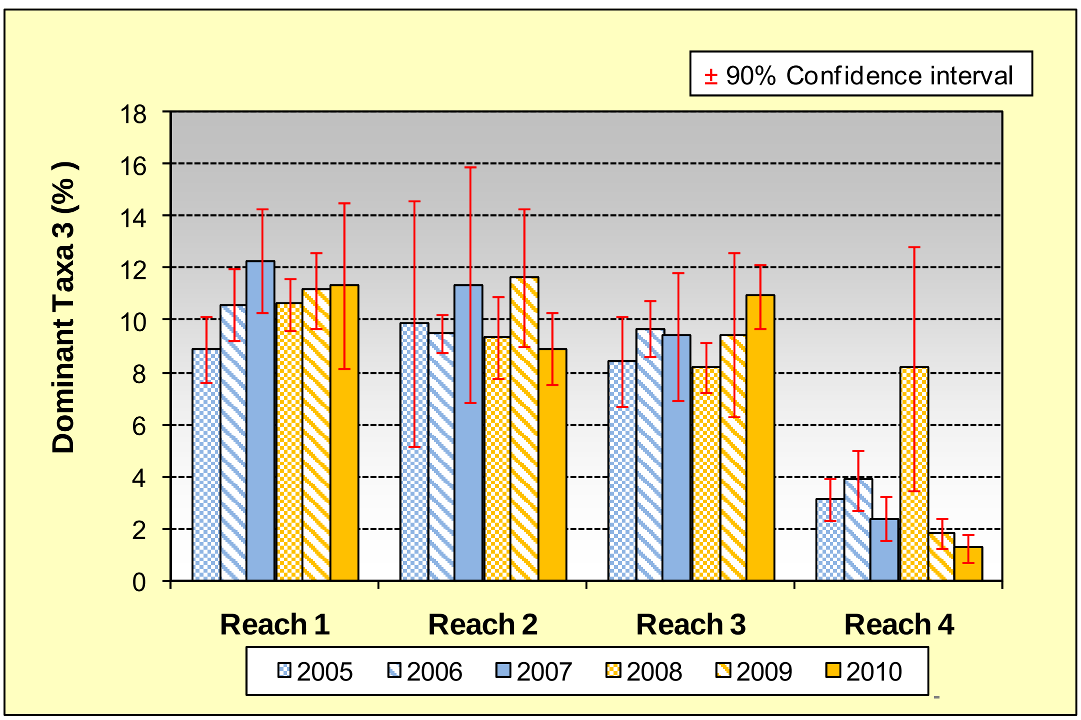


Figure 4.7-11: Third dominant taxon percentage; 2005 through 2010

In reach 2, Ephemeroptera, Plecoptera and Trichoptera, the orders typically used as indicators for healthy water quality and habitat conditions, were nearly non-existent in the community composition in five of the six study years. Trichoptera made up 4% of the BMI community composition in 2005 and 2006 respectively, 1% in 2007, 3% in 2008 and 2009 respectively and 23% in 2010. The order Ephemeroptera was 3 percent or less of the BMI community all six-years. The order Plecoptera was not present in reach 2 in any of the sample years.

The BMI community in reach 2 throughout the six-year study period was typically dominated by orders considered indicators of poor habitat and water quality. 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 six-years, followed by Acarina (15%), Crustacea (10%), other organisms (9%) and Diptera (3%). In 2010, Chironomidae occupied (31%) of the BMI community followed by Trichoptera (23%), Acarina (15%), Diptera (10%) Crustacea (9%), and other organisms (5%)

In reach 3, the BMI community composition in 2005 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%). In 2010, BMI community composition consisted of Trichoptera (31%), Acarina (28%), Ephemeroptera (15%), Chironomidae (8%), Coleoptera (7%), Diptera (3%), and Crustacea (3%).

In reach 3, the BMI community composition saw an increase in Ephemeroptera under the variable flow regime compared to the three-year baseline period (4%, 3% and 3% in 2005, 2006 and 2007 compared to 30%, 12% and 15% in 2008, 2009 and 2010). The percentage of Trichoptera in the BMI community increased substantially in 2010 (31% compared to 11%, 21%, 17%, 11% and 15% in the previous five-years respectively). Chironomidae, on the other hand, saw a dramatic decline under the variable flow regime compared to the three-year baseline period (24%, 28% and 27% in 2005, 2006 and 2007 compared to 8%, 13% and 8% in 2008, 2009 and 2010). Plecoptera were not present in reach 3 in 2007, 2008, 2009 and 2010 but comprised less than 1% in 2005 and 2006.

Reach 4 was dominated by the order Gastropoda in all six- years; 2005 (85%), 2006 (77%), 2007 (89%), 2008 (38%) 2009 (92%) and 2010 (97%). Declines in 2008 suggested a shift in the Gastropoda community potentially in response to variable flow conditions but the rebound to substantial dominance of this order in 2009 and 2010 indicates other factors may play a larger role 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 respectively in all six-years. Chironomidae was the second most dominant taxa in five of the six-years in reach 4; 2005 (8%), 2006 (11%), 2007 (5%), 2008 (36%) 2009 (3%) and 2010 (<1%). In 2008, Ephemeroptera increased to 4% of the BMI community, a substantial increase compared to the baseline period. However, in 2009 and 2010, the percentage decreased to 1% or less for Ephemeroptera.

In reach 1, functional feeding group composition was dominated by filter feeders, gatherers, scrapers and shredders over the six-year study period (Table 4.7-6). Filter feeders and gatherers tended to be the dominant functional feeding groups each year followed by shredders. Scrapers were typically ten percent or less of the functional group composition except in 2007 (34%).

In reach 2, functional feeding group composition was dominated by gatherers, predators and filter feeders in all six-years. Gatherers were the dominant group in all six-years; 2005 (54%), 2006 (35%), 2007 (45%), 2008 (42%), 2009 (36%) and 2010 (31%). Predators were the second dominant group throughout the study period (31%, 35%, 39%, 31%, 26% and 30% respectively in 2005, 2006, 2007, 2008, 2009 and 2010). In 2009, shredders increased to 24% of the functional feeding group composition compared to 7% in 2005, 10% in 2006, 11% in 2007 and 2008 and 7% in 2010. Filter feeder composition increased substantially in 2010 (30%) compared to 2005 (6%), 2006 (18%), 2007 (5%), 2008 (15%) and 2009 (14%). Scrapers were 1% or less of the community in all six-years.

In reach 3, predators and gatherers were the dominant functional groups followed by scrapers and filter feeders (Table 4.7-7). Predators dominated the functional feeding group community in 2005, 2009 and 2010 (44%, 40% and 40% respectively). Gatherers dominated the functional feeding group community in reach 3 in years 2006, 2007 and 2008 (35%, 38% and 41% respectively). Filterer feeders comprised 19% of the community in 2009 compared to 6%, 15%, 14% 12%and 6% in 2005, 2006, 2007, 2008 and 2010 respectively. Scrapers were the only group to exhibit a distinct difference between the baseline period and the variable flow conditions; 2005 (15%), 2006 (20%), 2007 (20%), 2008 (4%), 2009 (9%) and 2010 (6%).

In reach 4, scrapers comprised the largest percentage of the functional feeding group composition in all six-years, 83%, 73%, 84%, 42%, 92% and 96% 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, increased to 21% in 2008 and decreased to 2% in 2009 and 1% in 2010. Filter feeders comprised 1% in 2005, 5% in 2006, 2% in 2007, 17% in 2008 then decreased to 2% in 2009 and were undetected in 2010. Predators were the next most common group with 6% in years 2005 and 2006, 4% in 2007, increased to 14% in 2008 and decreased to 2% in 2009 and 2010 respectively.

Table 4.7-4: BMI relative abundance by taxonomic order, reaches 1 and 2

Taxonomic Order	Reach 1												Reach 2											
	2005		2006		2007		2008		2009		2010		2005		2006		2007		2008		2009		2010	
	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	%	No./m^2	%	No./m^2	%
Ephemeroptera	9508	38	6,544	31	2,680	19	4,805	31	7,304	42	2387	28	11	<1	116	<1	26	<1	281	1	79	<1	751	3
Plecoptera	354	1	81	<1	38	<1	50	<1	310	2	73	1	-	-	-	-	-	-	-	-	-	-	-	-
Trichoptera	4961	20	6,798	32	7,825	54	4,803	31	3,013	17	4850	57	584	4	1,128	4	98	1	882	3	643	3	6533	23
Odonata	3	<1	6	<1	-	-	-	-	-	-	3	<1	95	1	83	<1	77	<1	243	1	103	<1	83	<1
Coleoptera	52	<1	73	<1	112	1	65	<1	65	<1	89	1	58	<1	73	<1	40	<1	49	<1	20	<1	335	1
Chironomidae	6939	28	4,438	21	2,713	19	2,976	19	3,658	21	464	5	6425	39	11,444	36	3,518	22	13,795	54	11,902	55	8836	31
Diptera	1770	7	2,838	13	761	5	2,765	18	2,876	16	431	5	671	4	2,171	7	401	2	1,293	5	757	3	2829	10
Lepidoptera	266	1	83	<1	179	1	136	1	151	1	170	2	9	<1	24	<1	-	-	4	<1	5	<1	175	1
Gastropoda	5	<1	-	-	-	-	-	-	-	-	-	-	1	<1	17	<1	-	-	-	-	-	-	-	-
Bivalvia	145	1	90	<1	15	<1	10	<1	7	<1	7	<1	108	1	1,096	3	105	1	9	<1	162	1	415	1
Annelida	1042	4	158	1	4	<1	45	<1	27	<1	13	<1	300	2	1,683	5	1,095	7	589	2	521	2	311	1
Acarina	47	<1	72	<1	14	<1	9	<1	16	<1	20	<1	2029	12	6,502	20	4,326	27	5,356	21	3,360	15	4364	15
Crustacea	31	<1	14	<1	17	<1	15	<1	28	<1	2	<1	4221	26	3,383	11	4,167	26	1,412	5	2,225	10	2707	9
Other Organisms	-	-	8	<1	7	<1	5	<1	0	0	1	<1	1889	12	4,207	13	2,302	14	1,818	7	2,028	9	1514	5
Total Organisms/m2	25,123		21,202		14,366		15,685		17,455		8509		16,400		31,927		16,156		25,730		21,803		28853	

Table 4.7-5: BMI relative abundance by taxonomic order, reaches 3 and 4

Taxonomic Order	Reach 3											
	2005		2006		2007		2008		2009		2010	
	No./m²	%	No./m²	%	No./m²	%	No./m²	%	No./m²	%	No./m²	%
Ephemeroptera	216	4	295	3	123	3	2,585	30	731	12	1112	15
Plecoptera	3	<1	2	<1	-	-	-	-	-	-	-	-
Trichoptera	607	11	1,827	21	604	17	947	11	892	15	2314	31
Odonata	31	1	2	<1	4	<1	27	<1	16	<1	29	<1
Coleoptera	588	11	1,086	13	384	11	307	4	367	6	514	7
Chironomidae	1,309	24	2,453	28	976	27	674	8	756	13	622	8
Diptera	374	7	324	4	161	4	287	3	376	6	227	3
Lepidoptera	267	5	767	9	325	9	79	1	276	5	76	1
Gastropoda	12	<1	-	-	1	<1	-	-	-	-	-	-
Bivalvia	-	-	2	<1	18	<1	14	<1	2	<1	13	<1
Annelida	122	2	41	<1	9	<1	36	<1	59	1	18	<1
Acarina	1,427	26	1,431	17	748	21	2,926	33	1,824	31	2093	28
Crustacea	136	3	36	<1	230	6	321	4	182	3	209	3
Other Organisms	298	6	351	4	62	2	552	6	404	7	135	2
Total Organisms/m2	5,391		8,618		3,644		8,754		5,884		7362	

Taxonomic Order	Reach 4											
	2005		2006		2007		2008		2009		2010	
	No./m²	%	No./m²	%	No./m²	%	No./m²	%	No./m²	%	No./m²	%
Ephemeroptera	211	<1	1,188	1	157	<1	1,751	4	972	1	3,576	<1
Plecoptera	-	-	-	-	-	-	-	-	-	-	-	-
Trichoptera	199	<1	1,116	1	81	<1	422	1	471	<1	3,063	<1
Odonata	19	<1	59	<1	-	-	-	-	-	-	-	-
Coleoptera	478	1	1,040	1	52	<1	234	1	39	<1	65	<1
Chironomidae	6,829	8	11,744	11	4,042	5	15,856	36	2,410	3	3,313	<1
Diptera	1,027	1	3,484	3	1,013	1	3,242	7	804	1	1,250	<1
Lepidoptera	-	-	-	-	-	-	-	-	-	-	-	-
Gastropoda	72,841	85	79,890	77	71,841	89	16,784	38	88,457	92	780,693	97
Bivalvia	221	<1	341	<1	305	<1	32	<1	82	<1	871	<1
Annelida	491	1	227	<1	63	<1	138	<1	17	<1	186	<1
Acarina	2,664	3	1,554	1	1,274	2	4,213	10	1,143	1	3,970	<1
Crustacea	225	<1	497	<1	416	1	630	1	150	<1	1,640	<1
Other Organisms	994	1	2,991	3	1,220	2	765	2	1,091	1	4,610	1
Total Organisms/m2	86,201		104,131		80,465		44,068		95,637		803,237	

Table 4.7-6: Functional feeding group composition in reaches 1 and 2

Functional Feeding Group	Reach 1						Reach 2					
	2005	2006	2007	2008	2009	2010	2005	2006	2007	2008	2009	2010
	%	%	%	%	%	%	%	%	%	%	%	%
Filterers	31	43	32	37	29	63	6	18	5	15	14	30
Gatherers	34	36	20	40	34	26	54	35	45	42	36	31
Predators	8	3	3	2	8	4	31	35	39	31	26	30
Scrapers	8	7	34	11	4	6	1	1	0	0	0	1
Shredders	19	11	11	9	23	1	7	10	11	11	24	7
Piercer-Herbivores	0	0	0	1	1	1	1	0	0	0	0	1
Unclassified	0	0	0	0	0	0	0	0	0	0	0	0

Table 4.7-7: Functional feeding group composition in reaches 3 and 4

Functional Feeding Group	Reach 3						Reach 4					
	2005	2006	2007	2008	2009	2010	2005	2006	2007	2008	2009	2010
	%	%	%	%	%	%	%	%	%	%	%	%
Filterers	6	15	14	12	19	6	1	5	2	17	2	0
Gatherers	30	35	38	41	24	29	8	13	6	21	2	1
Predators	44	27	26	35	40	40	6	6	4	14	2	2
Scrapers	15	20	20	4	9	6	83	73	84	42	92	96
Shredders	2	2	2	4	7	12	1	2	2	3	1	1
Piercer-Herbivores	1	0	1	4	1	8	0	1	0	1	0	0
Unclassified	2	0	0	0	0	0	0	0	2	2	0	0

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5. DISCUSSION

5.1 HYDROLOGY

Reach 1 differed 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 and a peak of 1300 cfs on July 22. In 2010, the daily average flows remained above 1000 cfs from June 28 through August 28 with the peak daily average flow of 1780 cfs on July 13, 2010. Consequently, the annual manipulation of the flow regime in reach 1 to meet downstream water demands should be taken into consideration when comparing affects of the variable flow regime on reaches 2, 3 and 4.

Reaches 2, 3 and 4, located in the Black Canyon of the Bear, were fully regulated by upstream irrigation and power generation diversions. Instream flows below Grace Dam remained relatively stable year round. Groundwater upwellings and springs just upstream of reach 4 contributed 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 one of which was equivalent to the discharge volume in the variable flows (965 cfs instantaneous peak flow on April 17, 2005). It is uncertain what effect the instantaneous peak flow or the other releases from Grace Dam during the baseline period had on the fish and benthic macroinvertebrate community. No change was detected in the channel shape and structure based on initial survey data from Van Every and Mladenka (2004). 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. In 2010, four variable flow events occurred between April and mid-July ranging from 877 to 1080 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.

5.2 CHANNEL SHAPE AND SUBSTRATE

The mean bankfull width in reach 2 for the baseline period and the variable flow conditions was nearly the same, 62.9 and 63.0 meters respectively. The mean bankfull depth was also similar between the baseline period and variable flow conditions, 0.39 meters compared to 0.43 meters. 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 difficult to accurately locate in a single year let alone relocate bankfull elevation indicators between years. The channel in reach 2 has not changed shape during the six-years of monitoring as evidenced in the nearly identical annual channel cross sections for reach 2. The small change in mean bankfull width was well within the margin of error for measuring bankfull width in the field particularly given the lack of bankfull indicators in this reach. The most noticeable change was observed in R2TA where beavers dammed the river left channel causing ponding and changes in wetted perimeter width but the channel shape remained unchanged.

In reach 2, the substrate composition was similar for all three-years in the baseline sampling period with fines being the dominant substrate followed by sand, 40 and 14 percent respectively of the overall substrate composition. Under the variable flows, the percentage of fines and sand were reduced to 4 and 6 percent respectively of the substrate composition. 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, 21.8 and 21.7 meters respectively. The mean bankfull depth remained the same over the two study periods; 0.79 for the three-year baseline period and 0.80 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 and 2010, deposition of fine material and sand was again observed resulting in a more defined floodplain feature on the inside meander bend. 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 (66 versus 54 percent) and an absence of fines (0 versus 8 percent). Field staff noted the ocular decrease in fines and sand in reach 3 compared to previous years while gathering periphyton and benthos samples. Gravels and cobbles, previously heavily embedded with fines and sand, were more clearly visible and contained more interstitial spaces free of sand and fines.

5.3 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 and light (Sheath et al. 1986). Consequently, the periphyton community is likely to change over short periods of time as well as seasonally based on changing environmental conditions. The fall sampling event associated with the Black Canyon Monitoring Study provided a snapshot of the periphyton community in the respective reaches. Three-months elapsed between the last variable flow release in reaches 2, 3 and 4 and the annual sampling event. Identifying the environmental factors influencing the periphyton community in a given reach requires systematic sampling where periphyton is sampled on a weekly or biweekly basis. This approach enables researchers to track periphyton growth rates while simultaneously monitoring biotic and abiotic factors (Biggs 1990; Biggs 1996; Biggs and Kilroy 2000). Consequently, this study does not single out the factors contributing to differences in the periphyton community over the six-year study period within a single reach. The Black Canyon Monitoring Study was designed to assess long-term differences in the periphyton community through comparative analysis of annual sampling events during the baseline period and variable flow conditions. Accordingly, the report focuses on inter-annual differences and differences between the baseline and variable flow periods where they exist.

The periphyton community response to the variable flow releases was not consistent across the three treatment reaches. AFDW was higher in all three treatment reaches during the variable flow period but significant in reaches 2 and 4 only. Chlorophyll a, on the other hand, responded inconsistently across the three treatment reaches. In reach 2, chlorophyll a was similar between the baseline and variable flow periods. In reach 3, chlorophyll a was significantly lower during the variable flow period while in reach 4, chlorophyll a was significantly higher during the variable flow period. Both AFDW and chlorophyll a for respective reaches exhibit a substantial amount of variability across the individual sample years.

In reach 1, the reference reach, chlorophyll a and AFDW were lower during the variable flow period but not significant. Chlorophyll a values and AFDW in reach 1 appear to show a weak inverse relationship with water withdrawals from Bear Lake for downstream irrigation. The highest chlorophyll a values in reach 1 occurred in 2006 and 2009 corresponding to years when summer water withdrawals for irrigation were lower or shorter in duration compared to other years. For most of the six-year study period, water deliveries for downstream irrigation resulted in elevated discharge (>1000 cfs) in reach 1 for much of July and August. In 2006, discharge was less than 1000 cfs in reach 1 for the summer season. In 2009, flows greater than 1000 cfs occurred for a two week period only in July. Periphyton AFDW also showed a positive response in 2006 and 2009 in reach 1. The reach 1 periphyton community appears to have more growth in years when the discharge magnitude and duration is lower. The combination of scour, increased water depth and turbidity may impede periphyton growth in years with higher discharge in July and August. Consequently, flow fluctuations from regulated releases in reach 1 may confound results and should be considered prior to any comparisons with trends in the respective variable flow treatment 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 six October sampling events, the four study reaches exceed the normal AI range indicating 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 significantly higher in reaches 2, 3 and 4 relative to the baseline period indicating there was even more non-photosynthesizing organic matter than previous years. The elevated AI values in the treatment reaches may be the result of increased biological productivity associated with mobilization of fine sediments and silt containing elevated nutrient levels. AI values in reach 1 were similar between the baseline period and the variable flow period.

5.4 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. In 2008 and 2010, elevated discharge volumes in reach 1 were scheduled later in August and had higher peaks which may account for the decreased filamentous coverage observed.

Initially, it was anticipated the variable flows would reduce filamentous algae coverage in reaches 2, 3 and 4 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 under baseline conditions 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 to attach; 3) Mobilization of nutrients during the variable flow release may have stimulated algal growth; or 4) Variable flow volumes lacked the power to scour filamentous algae from bedrock surfaces. The lack of a consistent response in the filamentous algae coverage in the treatment reaches suggests other environmental factors beyond changes in discharge alone influence filamentous algal growth.

5.5 FISHERIES

Fish sampling results in October 2009 may have been affected by problems with the Halltech backpack electrofishing unit. The lowest total catch and accordingly, the lowest catch rates were recorded for all four study reaches in 2009. The Halltech unit showed a few signs of problems during sampling including blown fuses and an occasional electrical burning smell. The field crew worked on the unit in the field. The unit was subsequently sent into the manufacturer for diagnosis / repair. The manufacturer determined 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. Data collected in 2010 supports this idea as both catch rates (CPUE) and total catch were considerably greater than in 2009. Accordingly, the metrics calculated for 2009 (total catch, catch rate, species composition, and biomass) may be imprecise and the results should be interpreted with this in mind.

Within reach comparisons of total fish catch between the baseline period and variable flow phase were different for each of the four study reaches. In reach 1, total catch in 2010 was on par with numbers collected during the baseline period whereas 2008 was well below those numbers. In reach 2, total catch was substantially greater in the variable flow period (2008 and 2010) compared to the three-years of baseline. In reach 3, total catch appeared to decline in the variable flow period, particularly 2010, compared to the baseline period. In reach 4, total catch was similar between the baseline and variable flow phases. Comparisons of total catch in reach 4 were confounded by the rainbow trout stocking schedule. Lastly, total catch data from 2009 was not included in this analysis due to problems with the electrofishing unit.

Species richness in reaches 2, 3 and 4 was similar between the baseline and variable flow periods. In nearly all cases, when an additional species was detected in a sample, they were only collected in small numbers (1 to 4 fish per 100 meters), and therefore had low relative abundances. Similarly; when a species went undetected in a sample, they had only been collected in small numbers during past sampling years. Thus, while it was possible the apparent changes in species richness were a result of a species not being present in a reach during the sampling period, it was likely 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 sample years 2005, 2006, 2007 and 2008 (101, 73, 52, and 35 respectively) but none were collected in 2009 or 2010.

Total fish biomass comparisons within each reach did not detect substantial differences between the baseline period and variable flow conditions. Reaches 1, 3, and 4 had considerable variability between individual sample years. Reach 2 had considerably less variation. A large amount of the total biomass variation between years was the result of a few large bodied adult carp, suckers, or trout in some year(s) while none were collected in other years. In reach 3 for example, 1 large carp accounted for 4.96 kg of the 9.12 kg (54%) of the biomass in 2007 despite being only 1.4% of the catch in terms of abundance. 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.

5.6 TEMPERATURE

Temperature data for the three-year baseline monitoring period at the four study reaches revealed distinct seasonal patterns. 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 2, under MIF conditions, water temperature 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. 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 summer water temperatures with daily averages consistently below 20 ºC and a single day each summer when a maximum water temperature exceeded 20 ºC; 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 as well as an increase in air temperatures resulting in the call for increased irrigation water exceeding the capacity of the Grace flume and triggering spill over the dam. 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.

Similar water temperature analysis should be undertaken for the variable flow regime period particularly in reaches 2, 3 and 4 to determine the influence of surface water releases on downstream temperatures. Stream temperatures in reaches 2 and 3 already reflect summer meteorological conditions similar to Grace Reservoir surface water temperatures and exceed the salmonid threshold. Consequently, it is unlikely that variable flow releases will cause thermal loading in reaches 2 and 3. In reach 4, surface water releases have the potential to raise water temperatures above the 20 ºC threshold for salmonids.

Analysis of the 2008 - 2010 temperature data will help determine the potential of variable flow releases to increase stream temperatures in reach 4 and the duration of the temperature change. This 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. At present, reach 4 offers the only summer coldwater refugia in the bypass reach below Grace Dam for coldwater organism to flourish.

5.7 BENTHIC MACROINVERTEBRATES

Changes in the BMI community composition in reaches 2, 3 and 4 during the variable flow phase indicated improvements in habitat quality and/or water quality. EPT density comparisons within respective reaches indicate a significant increase in reaches 2, 3 and 4 during the variable flow phase. EPT taxa richness also increased in reach 2 during the variable flow phase. BMI density and taxa richness, on the other hand, for reaches 2, 3 and 4 showed no differences between the baseline period and the variable flow phase. In reach 1, the BMI metrics exhibited nearly the opposite patterns. BMI density, EPT density and taxa richness in reach 1 were all significantly lower during the variable flow phase compared to the baseline period. EPT taxa richness remained similar between the two periods in reach 1.

The increased EPT densities in reaches 2 and 3 signify a change in habitat conditions under the variable flow releases although still a small percentage of the overall BMI community composition. This was particularly evident in reach 3 where EPT comprised 41 percent of the BMI community composition in 2008, 27 percent in 2009 and 51 percent in 2010 compared to 15 percent, 24 percent and 20 percent in 2005, 2006 and 2007 respectively. In reach 2, on the other hand, the small percentage of EPT taxa suggests that a combination of habitat and water quality conditions are the overriding limiting factors.

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 and water 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.

Reach 4 supported a substantially higher BMI density than the other three study reaches in all six-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 *Potamopyrgus antipodarum,* NZMS, demonstrates the invasive was at a competitive advantage over other BMI taxa for food resources in reach 4. In fact, NZMS was the dominant taxa in reach 4 for all six October sampling events; 2005 (81%) 2006 (74%), 2007, (83%), 2008 (37%), 2009 (89%) and 2010 (91%). In 2010, mean NZMS density reached 706,088 orgs/m^2, considerably greater than densities observed by Kerans et al. (2005) in the Madison River of 300,000 orgs/m^2. This also represents a seven-fold density increase over the six-years of monitoring in reach 4. The presence of this invasive species in reach 4 likely exerts a larger influence on the BMI community composition than the variable flow releases.

Reach 4 was dominated by scrapers in all six 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 and 2010, similar disturbance events were introduced in reach 4 with a slightly lower flow threshold. NZMS density rebounded with numbers greater than previously observed in the baseline period.

The dramatic decline in NZMS in 2008 under the variable flow phase initially reflected positive changes in the BMI community composition for reach 4 and potential tool for controlling the invasive. However, the dramatic increase in NZMS density in 2009 and further increase in 2010 suggest no effect on NZMS densities from variable flow releases in the volumes spilled in 2009 and 2010. Variable flow volumes were approximately 200 cfs greater in 2008 than 2009 and 2010 suggesting a potential, although unlikely, flow threshold for NZMS between 1100 and 1300 cfs.

Mobilization of fine sediments in 2008, the initial year of the variable flows, could have been a potential factor resulting in a lower density of NZMS that year. 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 and 2010 may not have mobilized as much fine sediment as 2008 due to limitations on supply and/or discharge thresholds. Turbidity measures during the variable flow phase should be analyzed to discern differences between years. Clearly, variable flows alone are not sufficient to account for the dramatic decline in NZMS observed in 2008.

The presence of NZMS in reach 4 raises concerns for fisheries managers potentially far greater than issues associated with variable flows. NZMS is an invasive species first discovered in the Black Canyon in March 2000 (Richards et al. 2003). Density was documented as “sparse” at the time of discovery in the Black Canyon. NZMS is now distributed throughout southeast Idaho as well as other Rocky Mountain states. Kerans et al. (2005) found a decrease in colonization of other macroinvertebrates on substrate containing high densities of NZMS. Furthermore, Vinson et al. (2007) found that fish diets high in NZMS may not meet the energy requirements for salmonids resulting in reduced growth and weight loss. The dominance of NZMS in reach 4 and potential expansion into upstream sections of the Black Canyon may limit these reaches as mainstem recovery areas for Bonneville cutthroat trout. From a fishery management perspective, the conditions in 2008 that lead to the significant decrease in NZMS density in reach 4 should be further investigated to determine if discharge is a potential tool for controlling NZMS. Furthermore, preventative measures for removing NZMS from gear should be established in reach 4 of the Black Canyon, particularly for boaters and anglers traveling to upstream reaches.

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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 on an interannual time scale as opposed to immediate responses following a variable flow release. Specifically, the Black Canyon Monitoring Plan included 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 comprised four study reaches. Reach 1, partially regulated by Bear Lake, served as the reference reach. Reaches 2, 3 and 4, subjected to the variable flow regime below Grace Dam, served as the experimental reaches. The monitoring study spanned six-years of data collection. The first three-years served 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, served as the experimental phase when reaches 2, 3 and 4 were subjected to flows ranging from 800 to 1344 cfs, approximately 700 to 1300 cfs greater than the minimum instream flow of 65 cfs below Grace Dam. Field sampling occurred once annually in October. Field sampling was initiated in October 2005 and concluded in October 2010.

This report compares the results from the baseline monitoring effort, years 2005 through 2007 with three-years of variable flows in 2008, 2009 and 2010. 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 the distinct differences in community composition and habitat, the comparative analysis between sample years and treatments examined changes within respective study reaches over time rather than comparisons between reaches. Furthermore, the annual summer flow fluctuations in reach 1 for downstream irrigation must be taken into consideration prior to comparing ecological effects on reaches 2, 3 and 4 subjected to variable releases.

Channel morphological characteristics remained largely unchanged in reaches 2 and 3 under the three-years of variable flow conditions compared to baseline monitoring period. The variable flow releases mobilized silt and sand deposited in the channel resulting in high turbidity levels during the releases (Mark Stenberg, personal communication). The suspension and 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 reach 3, field staff observed less silt and sand in the active channel and increased deposition of these materials in the floodplain margins above the MIF wetted perimeter particularly along the river left meander bend. After the first year of variable flow releases in 2008, field staff sampling reach 3 noted a visible increase in the percentage of gravels and cobbles available for spawning as well as an increase in interstitial spaces for benthic macroinvertebrates. These habitat features were less evident in previous sampling years under baseline conditions. Reach 2 also saw a decrease in silt and sand during the variable flow period based on Wolman pebble counts but was less obvious on site due to the dense macrophytes and algae present in reach 2.

Surface water releases from Grace Dam have the potential to cause thermal loading to surface waters in the bypass, in particular, reach 4 where summer coldwater refugia exists. Water temperature monitoring was not included as part of this study. Nonetheless, thermistors deployed by Idaho DEQ staff in study reaches 1, 2, 3 and 4 were analyzed during the initial three-year baseline period. Based on the analysis of baseline temperature data it was determined that reaches 2 and 3 were already thermally impacted under existing MIF conditions and not likely to be further impacted from variable flow releases. Reach 4, on the other hand, consistently maintained temperatures below the salmonid threshold of 20 ºC. Water temperature data in reach 4 associated with the variable flows in 2008, 2009 and 2010 should be analyzed to determine the magnitude of the temperature changes, if any, associated with releases from Grace Dam. Temperature is considered one of the primary factors influencing the longitudinal distribution of aquatic organisms particularly in reaches regulated by hydroelectric projects (Ward and Stanford 1979).

The contrasting responses in the periphyton community between treatment reaches suggests other environmental factors, biotic and abiotic, beyond the physical disturbance of the variable flow releases may be influencing periphyton growth. Biotic factors include grazing by benthic macroinvertebrates while abiotic factors include shifts in substrate composition and changes in nutrient concentrations (Shortreed and Stockner 1976; Hunter 1980; Lamberti and Resh 1983; McAuliffe 1984). Periphyton growth resulting from increased nutrient concentrations associated with mobilization of fines and sand during variable releases should affect reaches 3 and 4 equally but the data reflects confounding results for chlorophyll a and AFDW. The dominant BMI taxa in reach 4, *P. antipodarum,* is classified as a grazer and likely plays a key role influencing the periphyton community in this reach (Lamberti and Resh 1983). The substantial increase in *P. antipodarum* population over the course of this study likely has a stronger influence on the periphyton community in reach 4 than the variable flows. Consequently, the periphyton community in the Black Canyon of the Bear River appears to be more strongly affected by other reach specific environmental factors rather than variable flow released from Grace Dam.

Filamentous algae coverage was significantly higher in reaches 2 and 3 during the variable flow sampling period but significantly lower in reaches 1 and 4. 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. However, substantial growth in the three-months between the last whitewater release and the annual sampling event would likely obscure effects associated with scour. Dense mats of filamentous algae were observed on adjacent unregulated streams and rivers indicating that local geology and land-use practices likely influence these conditions. Because of the contrasting response between reaches variable flows are not believed to be affecting filamentous algae in the Black Canyon of the Bear River.

Species richness and the distribution of species did not differ considerably between the baseline and variable flow periods in reaches 1, 2, 3, or 4, with perhaps the exception of redside shiner in reach 3. In 2010, a total of 6 fish species were collected throughout the combined four reaches compared with eight species in 2008, seven species in 2005, 2006, and 2007, and six species in 2009. Redside shiner and cutthroat trout were the two species not collected in 2010 that had been collected previously. Only one single cutthroat trout (reach 1, 2008) had been collected from all reaches during all years of the study, so it was not surprising that they were not collected in 2010. On the other hand, redside shiner had been collected from at least one reach in all previous years, and they were collected from all four reaches on at least one occasion. While 2010 was the only year where redside shiner were not collected, both their presence and relative abundance was inconsistent during both the baseline and variable flow sampling periods, in both the reference reach and the 3 experimental reaches. In addition, redside shiner were collected in all three experimental reaches (reaches 2, 3, and 4) in 2008 and in reaches 2 and 4 in 2009 following variable flow years. Accordingly, it is inconclusive whether their relative abundance and distribution was influenced by the variable flow regime. However, redside shiner is known to prefer slow water habitats in streams and thus it is plausible that their distribution may be affected by the increased velocities associated with the variable flow regime.

Total catch and catch rates (CPUE) for all species combined showed a large degree of variability during both the baseline and variable flow periods, in the reference and experimental reaches. Reach 1 showed a decrease in total catch and CPUE in 2008 that was congruent with implementation of the variable flows, but reach 1 was the reference reach not subjected to these flows, thus indicating natural variability and / or other environmental conditions were influencing the fishery. Furthermore, within site variability between baseline flow years was apparent in reaches 1, 3, and 4 and to a lesser degree in reach 2. Accordingly, the variability shown in reaches 2, 3, and 4 was consistent with the reference reach, and the baseline flow years, and thus should be considered expected variability.

Total biomass and biomass by species also showed a large degree of inconsistency during both the baseline and variable flow periods, in the reference and experimental reaches. The observed variability was greatest during the baseline flow period and was typically the result of collecting just one or a few large bodied adults in a single sampling year. Overall, fish biomass was not influenced by the implementation of the variable flow regime.

Reach 4 was the only reach where rainbow trout were collected in all six 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, 2009, or 2010 (Table 4.5-9). This was likely due to 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, approximately 1 hour prior to the fish sampling in reach 4. As a result, some of the fish collected that day were likely hatchery fish just stocked from the truck. In 2006, the most recent stocking prior to sampling occurred on September 12, in 2007 and 2008 it occurred on August 29th, in 2009 on September 21st, and in 2010 the most recent stocking was on September 23rd. Accordingly in 2006, 2007, 2008, 2009, and 2010 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, 2009, and 2010 compared to 2005 suggests a strong relationship between catch rates in this study and the rainbow trout stocking schedule. Similarly, the relative weights of 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. In summary, the relative abundance, catch rates, biomass, and condition of rainbow trout in reach 4 were not reliable indicators of conditions in the river as they are heavily influenced by the stocking program.

BMI density showed no significant response to the variable flow periods in the three treatment reaches (reaches 2, 3 and 4). EPT density, on the other hand, exhibited a significant increase in reaches 2, 3 and 4 under the variable flow conditions which coincided with shifts in community composition for reaches 2 and 3. Increased EPT density in reaches 2 and 3 was likely the result of changes in the substrate composition evidenced by a decrease in silt and sand and increase in interstitial spaces in gravel and cobbles particularly in reach 3. Overall, variable flows appear not to affect overall BMI density in the Black Canyon of the Bear but may have a positive effect on habitat quality thereby influencing the BMI community composition and increasing EPT density.

The invasive NZMS was first discovered in the Black Canyon in March 2000 and described as sparse in numbers (Richards et al. 2003). In 2005, the first year of the Black Canyon Monitoring Study, NZMS densities had reached approximately 100,000 orgs/m^2. By 2010, NZMS densities had increased to approximately 700,000 orgs/m^2, a seven-fold increase in six-years. NZMS clearly dominate the BMI community in reach 4 and likely displace other macroinvertebrates through competition for food and space. NZMS have limited nutritional value for fish resulting in reduced growth. NZMS were not collected in reaches 1, 2 or 3 over the six-year study period. 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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