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VOLUME 1: AQUATIC RESOURCES

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1.0 Introduction

This report describes 2010 aquatic resource monitoring conducted for the Kensington Project, near Juneau, Alaska, as required by the National Pollutant Discharge Elimination System Permit (Permit No. AK-005057-1). Annual monitoring is conducted on Sherman, Johnson and Slate Creeks, adjacent to the project area, and includes toxicity testing of stream sediment, benthic invertebrate surveys, resident fish population estimates, counts of out-migrating salmon fry and returning adult salmon, analysis of spawning gravel quality, and aquatic vegetation surveys.

2.0 Study Area

Sherman Creek drains an area of 10.59km^2 (4.09 mile^2) that ranges from 0 to 1,693m (5,552ft) in elevation (Konopacky 1992). It consists of four upper tributaries, Ivanhoe, Ophir, Upper Sherman and South Fork Sherman, which converge into a single channel approximately 1,500m from the stream mouth on the east shore of Lynn Canal (Figure 1). A permanent barrier to fish migration in the form of vertical falls exists 360m from the stream mouth. A tunnel connecting Kensington Mine with Jualin Mine on the Berners Bay side of the project was completed in July 2007. Mine drainage from the tunnel enters a water treatment facility before being discharged into Sherman Creek at permitted outfall 001, upstream of the confluence with Ivanhoe and Ophir tributaries (Figure 1).

Slate Creek and Johnson Creek drain into the north side of Berners Bay (Figure 1). Slate Creek drains an area of 11.61km^2 (4.48 mile^2) and has vertical fall barriers that prevent fish passage on both East and West forks approximately 1000m from the stream mouth. The East Fork of Slate Creek is unique among the streams in containing two lakes upstream. Johnson Creek drains an area of 19.97km^2 (7.71 mile^2) and has impassable barrier falls approximately 1,200m upstream from the confluence with Berners Bay. Fish species present in anadromous reaches, downstream of falls barriers include pink salmon (*Onchorhynchus gorbuscha*), coho salmon (*Onchorhynchus kisutch*), Cutthroat trout, Dolly Varden etc.

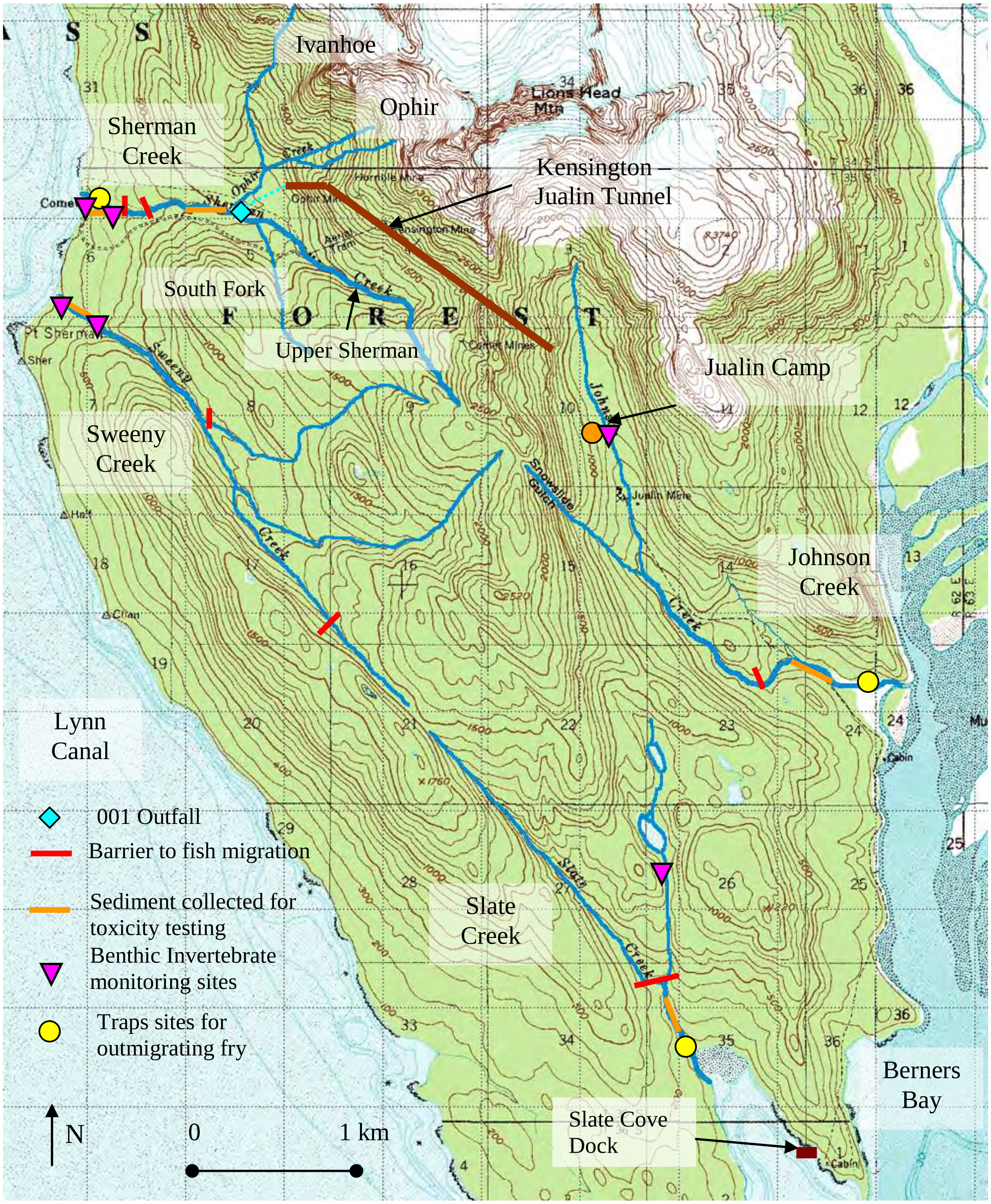


Figure 1: Location of streams near Kensington Mine included in 2010 Aquatic Resource Monitoring. Sediment toxicity testing, benthic invertebrate surveys, resident and anadromous fish surveys, analysis of spawning gravel and aquatic vegetations surveys were conducted in Sherman, Johnson and Slate Creeks. Benthic invertebrates were also collected from two reaches of Sweeny Creek.

Sediment Monitoring

3.1 Introduction

Stream sediment samples were collected in August 2010 and tested for biological toxicity and physical composition. Specific tests performed included: (1) 10-day whole sediment toxicity tests on the amphipod *Hyalella azteca,* and the midge *Chironomus dilutus* (formerly known as *Chironomus tentans*), (2) measures of total organic carbon, total solids, total volatile solids, total sulfide, (3) particle size analysis of sediment, and (4) analysis of metals in the sediment. Deposited stream sediment was collected in lower and middle reaches of Sherman Creek, lower and middle Slate Creek and lower Johnson Creek (Figure 1). Metals tend to adhere to fine clay particles, but there a very few areas of fine sediment deposition in any of the streams. Samples were collected from fine deposits of mud trapped behind boulders on the stream margins.

3.2 Methods

At each site, a sediment sample was collected by personnel using stainless steel scoops. The sediment was shaken through sieves with perforations of 1.68, 0.42 and 0.15mm to remove course material. The fine sediment that passed through the smallest diameter sieve was then poured into an Imhoff cone and allowed to settle for 10 minutes. Water was decanted off the top and the finest sediment left in the bottom of the cone was collected for the sample. This process was repeated until approximately 2L of fine sediment was collected at each site.

100ml of the sediment was placed in pre-cleaned glass containers provided by the laboratory (AECOM, formerly ENSR, Fort Collins, Colorado). These samples were analyzed to determine the physical composition of the sediment including metal concentration, grain size, total organic carbon content, etc). The remainder of the sample was placed in 2L pre-cleaned high-density polypropylene containers for toxicity testing. Sampling equipment (stainless steel scoops, sieves) was cleaned between sites by rinsing with site water and wiping with ethyl alcohol.

Particle size was determined for each creek using ASTM D422: Standard Test Method for Particle-Size Analysis of Soils. The distribution of particle sizes larger than 75 µm (retained on the No. 200 sieve) was determined by sieving, while the distribution of particle sizes smaller than 75 µm was determined by a sedimentation process using a hydrometer (Table 1).

Table 1: Physical Composition of Sediment Samples.

Particle Size %	Lower Slate	Middle Slate	Lower Johnson	Sherman Creek
Sand	34	28	50	78
Silt	34	44	32	15
Clay	32	28	18	7
Coarse material (>2mm)	5.58	3.03	4.05	7.16
Texture	Clay loam	Clay loam	Loam	Loamy sand
Total Solids %	16.8	16.1	46.9	66.6
Total Volatile solids %	30.12	27.30	13.03	3.87
Total Sulfide (umoles/g)	9.90	5.79	2.08	1.93
Total Organic Carbon %	17.6	18.9	7.86	3.10

Samples were collected from Lower and Middle Slate, Lower Johnson and one sample was made up from sediment collected from Lower and Middle Sherman. 2010 was the first year the sufficient sediment could be collected from Middle Slate for testing to be done. Sediment from the four sites varied in composition, ranging from 28% sand at Middle Slate to 78% sand at Sherman Creek (Table 1). Clay content was lowest at Sherman (7%). Total Solids, Total Volatile Solids and Total Sulfide were analyzed using Standard Methods 2540B, 2540E. Total Organic Carbon was determined using the Organic Matter-Walkley Black Method. Concentrations of total organic carbon ranged from 3% in Sherman Creek sediment to 19% in Middle Slate sediment. Total volatile solids ranged from les than 4% in Sherman sediment to 30% in Slate Creek samples. Sulfide varied from around 2umoles/g at Sherman to almost 10umoles/g at Lower Slate. The laboratory reports are included as Appendix 1a and b.

3.3 Sediment Metal Concentration

Total metals (aluminum, chromium, zinc) were determined using EPA method 6010B, inductivity-coupled plasma-atomic emission spectrometry (ICP-AES). Solid sample analysis of the metals arsenic, cadmium, copper, nickel, silver, lead and selenium was carried out using method 6020, inductivity-coupled plasma-mass spectrometry (ICP-MS) and mercury was determined by method 7471B, manual cold-vapor technique. Table 2 summarizes metal concentrations in the sediment collected from each stream.

Table 2: Concentrations of metals in stream sediment, (mg/kg)

Analyte	Lower Slate	Middle Slate	Lower Johnson	Sherman Creek
Aluminum	17,800	22,300	17,400	18,100
Arsenic	38.5	48.8	25	74.3
Cadmium	34.8	32	0.454	0.424
Chromium	37.5	45	35.9	37.4
Copper	174	203	155	103
Lead	13.6	16.6	16.4	18.7
Mercury	0.188	0.179	0.156	0.0757
Nickel	152	168	32.7	38.7
Selenium	6	8.7	0.296	0.585
Zinc	1,920	2,140	126	126
Silver	0.416	0.534	0.746	0.328

Eight out of the eleven metals appeared to be of highest concentration at either Lower or Middle Slate (aluminum, cadmium, chromium, copper, mercury, nickel, selenium and zinc) while arsenic and lead were highest in Lower Sherman. Six metals showed lowest concentrations in Johnson Creek, while four metals had lowest concentrations at Sherman Creek. All four sites had high concentrations of aluminum (over 17,000 mg/kg). Zinc and copper were the next most abundant metals after aluminum (Figure 2). Zinc made up 80% of the metal content (excluding aluminum) in the Lower and Middle Slate samples. Zinc made up around 30% of the metal concentration at Johnson and Sherman. Copper made up 39% of the sample at Lower Johnson and 26% at Sherman; arsenic was almost 20% of the Sherman sample

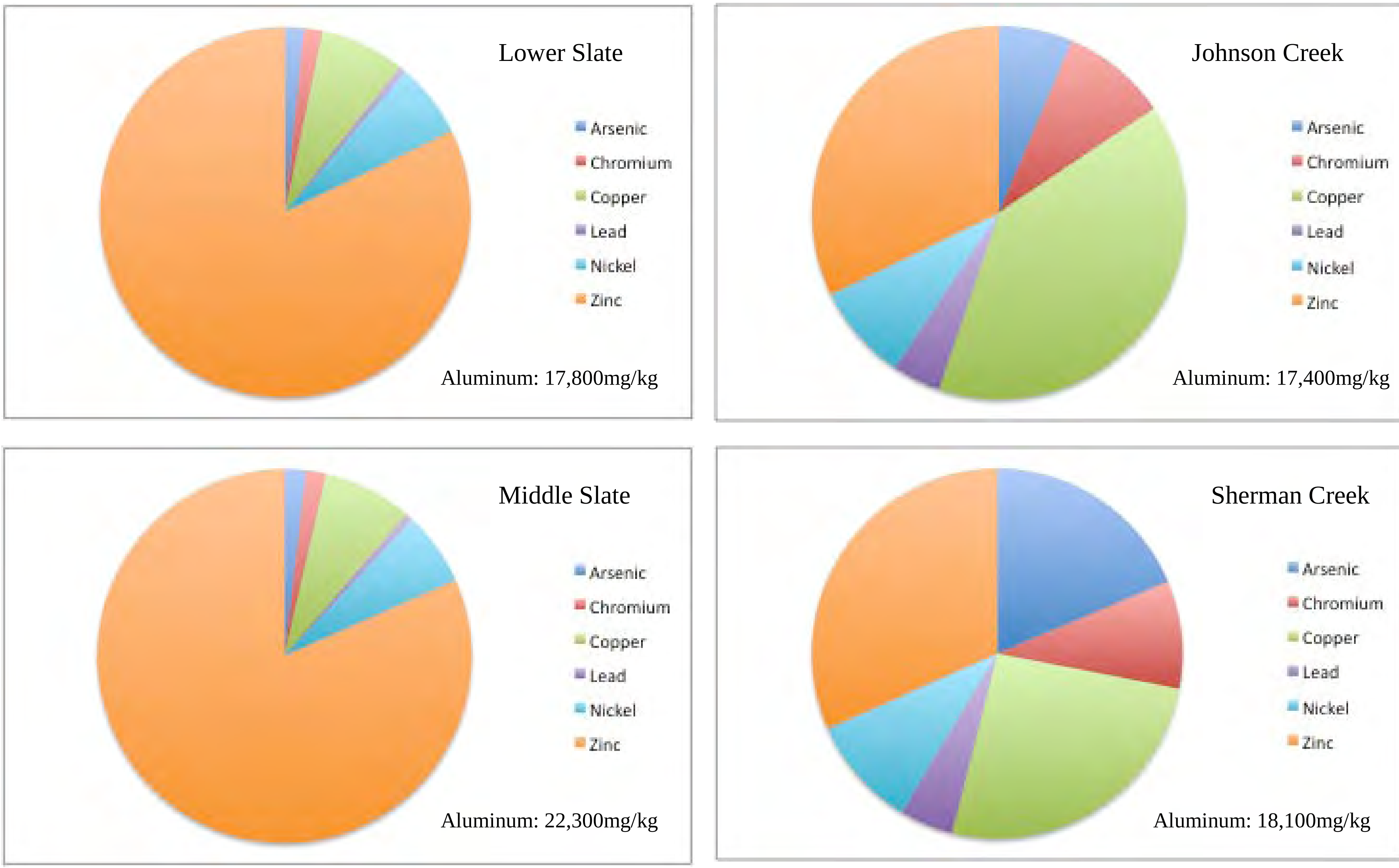


Figure 2. Metal content of stream sediment (aluminum not included in pie charts).

3.4 Sediment Toxicity Testing

Short-term toxicity testing was conducted using the amphipod *Hyalella azteca* and 3rd instar midge *Chironomus dilutus* (formerly known as *Chironomus tentans*). Any endemic organisms in the sediment were removed prior to testing. Eight replicates of stream sediment were used per treatment. The primary lab control sediment was silica sand and secondary control sediment was formulated with a smaller grain size and higher organic matter content (Appendix 1a, 1b).

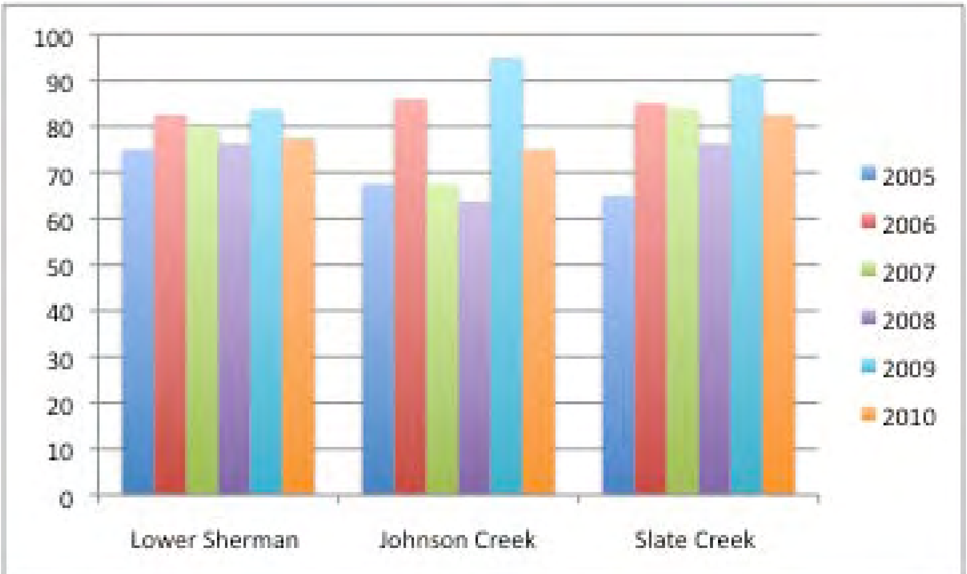
Short-term chronic screening toxicity tests were conducted on both organisms from September 24 to October 4, 2010 using survival and growth (ash-free dry weight per organism) as endpoints. Physical parameters including dissolved oxygen temperature, pH, hardness, alkalinity, conductivity, and ammonia were monitored throughout the tests (Appendix 1a, 1b). For each test the sand and formulated sediment were compared using a t-test. If there was no significant difference between the two, the controls were pooled and comparisons made against the pooled data. If there was a significant difference, all statistical comparisons were made against the formulated sediment since the amount organic matter content in this material was closer that of the test sediments. Survival of *Hyalella azteca* was high in sediment from all sites (over 90%) while that of *Chironomus dilutus* was 80% or higher for Slate Creek and 75% or higher for Johnson and Sherman (Table 3). Survival of both organisms was not significantly different from control sediment.

Table 3: Survival of organisms after 10-day exposure to sediment.

Biological Data			
Collection Date and Time	**Sample ID**	***Chironomus dilutus* Survival (%)**	***Hyalella azteca* Survival (%)**
8/11/10 17:00	Lower Slate	82.5	92.50
8/11/10 11:30	Middle Slate	80	90.00
8/18/10 14:15	Johnson Creek	75	91.25
8/16/10 15:30	Sherman Creek	77.5	96.25
	Sand - control	66.25	100.00
	Lab Sediment	70	81.25

Survival of *Hyalella azteca* has generally been higher than that of *Chironomus dilutus* since 2005 (Figure 3). Johnson Creek has seen the most variability in survival of Chironomus with some of the lowest and highest survival rates. There appears to have been general improvement in survival of both species at Slate Creek over time, with Sherman Creek showing no apparent change since 2005.

Chironomus survival



Hyalella survival

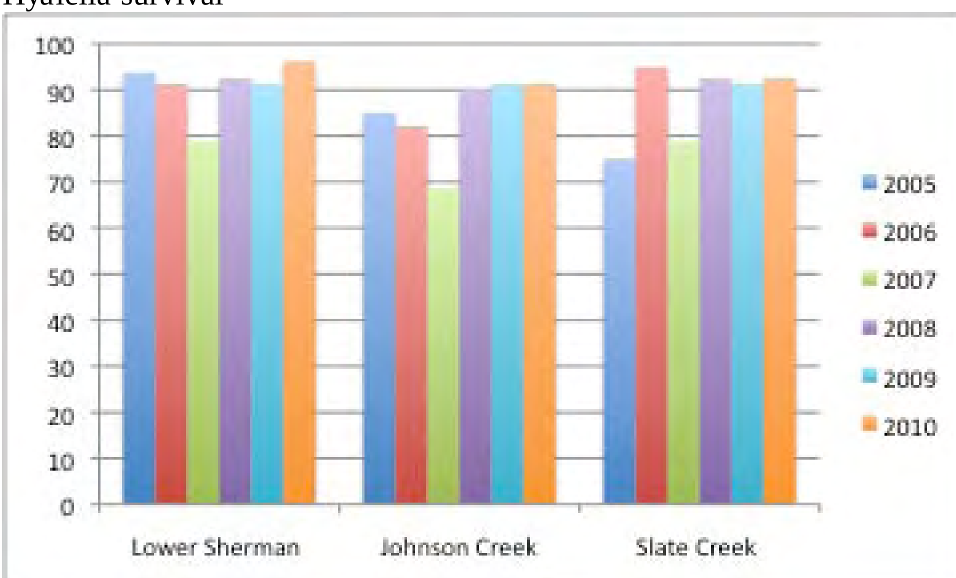


Figure 3: Comparison of toxicity tests with previous years

Growth of organisms is surmised from the remaining ash free dry weights at the end of the tests expressed per number of original organisms used at the start of the test and the number surviving at the end. *Chironomus dilutus* showed a significant reduction in growth in sediment from Lower and Middle Slate Creek compared to laboratory formulated sediment, but growth was not significantly different from control sediment for Sherman and Johnson sediment (Table 4). Growth of *Hyalella azteca* showed no significant difference compared to control sediment for all sites. Overall, 2010 results for growth were better than 2009 when growth of *Chironomus* showed significant reduction in sediment from all sites compared to control sediment and growth of *Hyalella* was affected at Johnson and Slate Creek sediment.

Table 4: Dry weights (growth) of organisms after 10-day exposure to sediment.

	Chironomus dilutus		***Hyalella azteca***	
	Ash free dry weight (mg)		Ash free dry weight (mg)	
Sample ID	per original organism	per surviving organism	per original organism	per surviving organism
Lower Slate	0.7501	0.9169[b]	0.106	0.115
Middle Slate	0.686[b]	0.8746[b]	0.106	0.117
Johnson Creek	1.0098	1.4277	0.119	0.131
Sherman Creek	0.7758	1.1517	0.142	0.148
Sand - control	0.5834	0.8836	0.150	0.150
Lab Sediment	0.8876	1.3018	0.072	0.088

b: significantly lower weight compared to lab sediment control.

Metal content of the sediments do not appear to explain differences in test results with previous years. The metal concentrations found in 2010 were in many cases higher than 2009 levels, particularly at Slate Creek, but survival of organisms was still high. Total organic carbon (TOC) levels were almost three times higher at Slate Creek and almost 4 times higher at Johnson in 2010 than the previous year. TOC can often offset toxicity, but this may only hold for Hyallela, which showed similar rates of survival to those in 2009. Johnson Creek showed lower survival for Chironomus despite higher TOC and growth appeared reduced in Slate Creek sediment despite high TOC there.

4.0 Benthic Invertebrates

4.1 Site Description

Benthic invertebrates were collected from established sampling sites on Slate, Johnson, Sherman and Sweeny Creeks in March and April of 2010 (Figure 1). Samples were collected on March 31 from Reach 1 of Sherman Creek 1 and on April 14 from Reach 2 of Sherman and from Sweeny Creek at sites used by Konopacky in 1995 (Konopacky 1996). Reach 1 of Sherman Creek lies between 3 and 29m upstream from the mouth while Reach 2 lies between 288 and 315m. Reach 1 of Sweeny Creek lies between 38 and 60m upstream and Reach 2 lies between 236 and 260m. Samples were collected from Johnson Creek on April 3 and from Slate Creek on April 15. At Slate Creek, the sampling site is 400m downstream from Lower Slate Lake, while at Johnson Creek samples are collected at the JS-1 flow monitoring site, upstream of the upper bridge crossing.

4.1 Sample Collection

Each reach was examined for all possible sampling sites, namely riffles with substrate particles greater than 20cm and water depth less than 0.5m. Every 3rd or 4th potential site was sampled until a total of 6 samples were obtained for the reach. Samples were collected using a 0.093m^2 Surber sampler equipped with 300μm mesh (Figure 4), placed in labeled whirlpak bags and preserved with 70% ethyl alcohol.

4.2 Invertebrate identification

Sorting and identification of invertebrates was conducted by personnel from Aquatic Science Inc. Juneau, Alaska, with quality control performed by Elizabeth Flory PhD. who has performed previous invertebrate identification for Kensington Mine samples. Invertebrates were identified to genus level using appropriate taxonomic keys (Merritt & Cummins 1996, Thorp 2001, Clarke 1981) and numbers of each genus recorded for each sample. The number of genera at each site is given in Table 5 and the species composition of samples is given in Table 6. Appendix 2 gives the numbers of each species found in each sample at each site.

4.3 Data Analysis

The area of streambed enclosed by the Surber sampling frame is 0.093 m^2. The density of invertebrates expressed as total numbers of invertebrates per m^2 was calculated by dividing the number of invertebrates per sample by 0.093. Shannon Diversity (H) and Evenness (E) indices were calculated using the following equations:

$$H = \text{sum} (Pi \log10 \{Pi\})$$

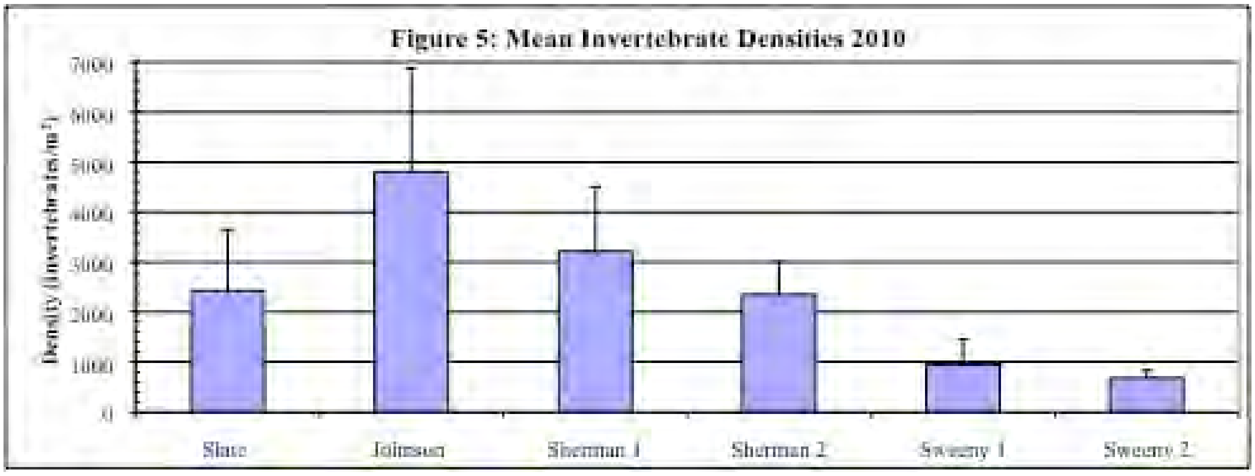
$$E = H/\log10 (S)$$

Where Pi is the number of organisms of a given species divided by the total number of organisms in the sample (the proportion of the sample comprised of species i), and S is the number of species or genera present in the sample. Diversity indices are presented in Table 7. The relative abundance of the EPT taxa, Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddis flies), in each sample was counted and the number of EPT taxa was expressed as a proportion of the total number of taxa present.

Figure 4: Surber sampling net is being used to gather invertebrates at Sherman.

4.4 Densities and Taxa Present

Densities of invertebrates in Slate Creek samples varied widely, ranging from 333 invertebrates per m^2 to $5,785/m^2$ with a mean of $2,438/m^2$ (Figure 5, Table 5). Johnson Creek densities were significantly higher than all other sites except Reach 1 of Sherman ($p < 0.05$) and ranged from 2,710 to $8,290/m^2$ with a mean of $4,808/m^2$. Sherman Creek densities ranged from 1,591 to $5,258/m^2$ over both reaches with a mean density of $3,219/m^2$ in Reach 1 and $2,350/m^2$ in Reach 2. Sweeny Creek densities ranged from 387 to $1,742/m^2$ over both reaches with mean density of $953/m^2$ for Reach 1 and $683/m^2$ for Reach 2.



2010 Site	Density (inverts/m^2)	Mean # Taxa	Mean # EPT	Mean Ratio
Slate	2433.7	13.7	8.3	0.62
Johnson	4808.2	20.7	14.2	0.69
Sherman 1	3218.6	16.5	10.3	0.63
Sherman 2	2349.5	15.0	11.5	0.77
Sweeny 1	953.4	10.8	6.8	0.63
Sweeny 2	682.8	9.3	6.5	0.70

Table 5: Invertebrate Densities and Mean Number of Taxa.

The mean number of taxa was significantly higher in Johnson Creek (20.7) than all the other sites (16.5 or less). Both Sherman Creek (Reaches 1 and 2) and Slate Creek had more taxa than either reach of Sweeny Creek. Johnson and Sherman Creek samples also had the highest mean number of Ephemeroptera, Plecoptera and Trichoptera (EPT taxa).

Overall, Slate Creek samples contained a total of 1,358 invertebrates from 26 genera, including 16 EPT taxa (Table 6). The overall ratio of EPT to non-EPT taxa was 0.62. Non-EPT taxa included two Chironomidae genera (non-biting midges), the common pea clam *Psidium*, two Tipulidae (crane fly), another diptera (true flies) larvae, a Collembola (springtails), a Simulidae, a Coleoptera (beetle larvae) and an Oligochaetae. Johnson Creek samples contained 2,683 invertebrates from 31 genera composed of 22 EPT taxa, five Chironomidae taxa, one Tipulidae, a Simulidae, a water mite and an Oligochaetae, giving a ratio of EPT to non-EPT of 0.71.

Sherman Creek samples contained 1,796 individuals at Reach 1 and 1,311 individuals at Reach 2. Reach 1 samples contained 29 genera with 18 EPT taxa while Reach 2 samples contained 30 genera including 19 EPT taxa giving EPT ratios of 0.62 and 0.63 respectively. Non-EPT taxa included five Chironomidae taxa, three Tipulidae, two Empididae, a Collembola and an oligochaetae. Sweeny Creek samples contained 532 individuals at Reach 1 and 381 individuals at Reach 2. Sweeny Creek samples from Reach 1 contained 22 genera, of which 13 were EPT taxa, while Reach 2 samples contained 18 genera, with 10 of these belonging to EPT taxa. Johnson and Sherman Creeks had the highest number of genera overall (29-31) and also the highest number of EPT taxa (18-22). Sherman Creek samples also contained the highest number of non-EPT taxa (11), just exceeding that of Slate Creek (10), which typically has the highest number owing to the presence of lakes upstream (Table 6).

Site	# Ephem.	# Plecop	# Trichop	# EPT	# non-EPT	# Total taxa	EPT ratio
Slate	6	7	3	16	10	26	0.62
Johnson	8	8	6	22	9	31	0.71
Sherman 1	6	8	4	18	11	29	0.62
Sherman 2	7	8	4	19	11	30	0.63
Sweeny 1	6	5	2	13	9	22	0.59
Sweeny 2	5	5	0	10	8	18	0.56

Table 6: Total number of genera in each taxonomic group.

Class	Order	Family	Genus	Slate	Johnson	Sherman 1	Sherman 2	Sweeny 1	Sweeny 2
Insecta	Ephemeroptera	Baetidae	Baetis	24.8	179.0	173.7	148.5	44.8	28.5
			Diphetor		2.0			0.2	
		Heptageniidae	Epeorus	4.8	3.4	7.7	6.3	0.8	1.0
			Cinygmula	25.7	68.2	9.2	4.8	2.3	4.6
			Rithrogena	0.5	4.5	0.2	0.5	3.0	2.8
		Ephemerellidae	Attenella			0.8			
			Drunella	0.7	32.0	5.3	5.8		
			Caudatella		6.6		1.5	0.3	
		Leptophlebiidae	Paraleptophlebia	2.5	0.5		0.2		0.2
	Plecoptera	Chloroperlidae	Triznaka		0.8				
			Alaskaperla	10.3		1.0	1.2	0.2	
			Haploperla						0.5
			Suwallia	0.2					
			Plumiperla		3.3	6.7	6.8	5.8	10.3
		Capniidae	Paracapnia		0.2	1.5	0.2		2.5
		Nemouridae	Nemoura	17.7	0.2	0.2		0.5	0.3
		Perlidae	Zapada	1.3	15.8	4.0	5.2		
			Shipsa		0.8	2.7	0.3		
		Perlodidae	Agnetina	2.4					
			Salmoperla	0.2					
			Megarcys		0.8	1.3	1.2		
		Leuctridae	Perlomyia	0.5	1.8	0.2	0.2		
			Despaxia				0.2		3.3
	Trichoptera	Hydropsychidae	Parapsyche		1.5			0.2	
			Arctopsyche		2.0				
		Glossosomatidae	Glossoma		19.7	0.2	0.3		
		Polycentropidae	Cernotina	0.2					
		Rhyacophilidae	Rhyacophila	1.3	11.5	0.5	3.3	0.5	
		Limnephelidae	Moselyana	0.2	0.7		0.2		
			Grensia		0.3	0.3	0.5		
			Ecclisomyia			0.2			

Table 7: Mean numbers of each taxa present at each site in 2010: EPT taxa

Class	Order	Family	Genus	Slate	Johnson	Sherman 1	Sherman 2	Sweeny 1	Sweeny 2
	Diptera								
Insecta	Chironomidae	Orthocladiinae	Eukiefferiella	14.3	42.3	18.3	19.8	21.0	8.0
			Tvetenia		8.5	1.3	2.0	0.8	
			Parachaetocladius		1.2				
		Diamesinae	Pagastia		7.0	0.2	0.2		
		Tanytarsini	Tanytarsus	25.5	27.2	1.2	0.3	0.2	0.5
		Podominae	Paraboreochlus			0.5			0.2
	Nematocera	Tipulidae	Dicranota	2.8	3.2	3.7	3.3	1.3	0.5
			Tipula	1.0					
			Brachypremna				0.2		
			Hesperoconopa			0.2			
			Hexatoma			0.7	1.0		0.2
			Antocha					0.3	
		Empididae	Clinocera			4.0	2.7		
			Oreogeton			0.2	0.2		
	Brachycera	Ceratopogonidae	Probezzia	2.0					
		Empididae	Clinocera					0.2	
	Collembola	Entomobryidae	Tomocerus	0.2					0.2
	Coloeptera		Unidentified	0.2					
	Simuliidae	Simuliidae	Prosimulium	11.3	0.8				
	Collembola		Tomocerus				0.2	0.2	
Arachnida	Hydrachnidae	Hydrodromidae	Hydrachna		0.2			0.2	0.2
Annelida	Oligochaetae	Tubificidae		0.5	6.0	53.7	2.8	2.3	0.5
Bivalva	Sphaeriidae	Psidiinae	Psidium (pea clam)	91.0					

Table 7 cont: Mean numbers of each taxa present at each site in 2010: non-EPT taxa

The most abundant genera in Slate Creek were the mayflies *Baetis*, *Cinygmula*, and *Epeorus*, the stoneflies, *Alaskaperla* and *Nemoura*, the pea clam *Psidium*, the blackfly larvae *Prosimulium* and the midge *Tanytarsus* (Table 7). In Johnson Creek, the mayflies *Baetis*, *Cinygmula*, and *Drunella*, the stonefly *Zapada* and the caddis flies *Glossoma* and *Rhyacophila* and chironomids Eukiefferiella and Tanytarsus were the most numerous. In Sherman Creek the most abundant taxa were the mayflies *Baetis*, *Cinygmula*, *Drunella* and *Epeorus*, the stoneflies *Plumiperla*, *Zapada* and *Shipsa* and chironomid Eukiefferiella. Reach 1 of Sherman Creek also had a large number of oligichaetae. Sweeny Creek abundant fauna included the mayflies *Baetis*, and *Cinygmula*, *Rithrogena* and stoneflies *Plumiperla*, *Paracapnia*, *Despaxia* and midge *Eukiefferiella.* Most of these genera were also found to be numerous at the same sites in previous years with the exception of oligochaetes in Sherman Creek, which had not been seen in high numbers before.

4.5 Diversity Indices

The Shannon Diversity (H) and Evenness (E) Indices are commonly applied measures of diversity. The minimum value of H is 0, which would describe a community with a single species. The value increases as species richness (number of species) and species evenness (equal abundance of species) increase. A community with one very dominant species has low evenness and therefore lower diversity. Table 8 compares mean diversity and evenness indices between sites.

Diversity and evenness were highest at Johnson Creek and lowest at Sherman and Sweeny Creeks in 2010 (Table 8). Prior to 2009, Sherman Creek had high diversity, but relatively low diversity and evenness was observed in 2010. The low diversity at Sherman appeared to be due to dominance by large numbers of Baetis mayflies, chironomids and, in the case of Reach 1, oligochaetes, relative to other species present. Slate Creek had the second-highest diversity in 2010, but evenness was in between that of Sherman and Sweeny Creeks, as was seen in 2009. Diversity was low in one sample from Slate Creek due to few species present and dominance by Baetis mayflies and Nemoura stoneflies. Johnson Creek had large numbers of *Baetis*, but also had healthy numbers of other species present that increased diversity.

	Shannon-Weaver			Shannon-Weaver	
	Diversity	**Evenness**		**Diversity**	**Evenness**
Slate			**Johnson**		
1	0.830	0.594	**1**	0.805	0.569
2	0.754	0.533	**2**	0.841	0.658
3	0.996	0.712	**3**	0.948	0.741
4	0.566	0.400	**4**	0.913	0.680
5	0.769	0.544	**5**	0.715	0.581
6	0.693	0.502	**6**	0.816	0.617
Mean	**0.768**	**0.547**	**Mean**	**0.840**	**0.641**
Sherman 1			**Sherman 2**		
1	0.551	0.385	**1**	0.547	0.491
2	0.682	0.482	**2**	0.517	0.439
3	0.504	0.361	**3**	0.660	0.548
4	0.826	0.583	**4**	0.525	0.486
5	0.599	0.428	**5**	0.586	0.467
6	0.655	0.452	**6**	0.591	0.491
Mean	**0.636**	**0.449**	**Mean**	**0.571**	**0.487**
Sweeny 1			**Sweeny 2**		
1	0.656	0.573	**1**	0.725	0.578
2	0.651	0.603	**2**	0.722	0.575
3	0.456	0.456	**3**	0.714	0.569
4	0.810	0.751	**4**	0.820	0.653
5	0.689	0.689	**5**	0.629	0.511
6	0.522	0.618	**6**	0.535	0.426
Mean	**0.631**	**0.615**	**Mean**	**0.691**	**0.552**

Table 8: Shannon Indices of Diversity and Evenness.

4.6 Comparison with Previous Years

Densities were relatively high at Sherman Creek and Reach 1 of Sweeny in 2010. Densities were also fairly high at Johnson Creek at over 4,000 invertebrates per m^2 though not as high as 2009, which had significantly higher densities ($p < 0.05$) than all other years (Figure 6). Changes in density over time may be due to the timing of sampling with high flow events, which may scour invertebrates off rocks and reduce numbers. Total number of taxa in 2010 was similar to previous years (Table 9) and relatively high at Sherman and Reach 1 of Sweeny due to an increase in both numbers of EPT taxa (pollution–sensitive) and non-EPT taxa (pollution-tolerant). Reach 1 of Sherman had one more EPT taxa in 2010 and five more non-EPT taxa., while Reach 2 had five more EPT taxa and two more non-EPT taxa. Numbers of EPT taxa at Slate Creek in 2010 were similar to those in 2007 and 2008, though lower than 2005, 2006 and 2009. Numbers of non-EPT taxa at Slate and Johnson Creeks have actually remained more or less unchanged since 2004 (Aquatic Science 2004) with 2006/2007 being exceptions (Table 9).

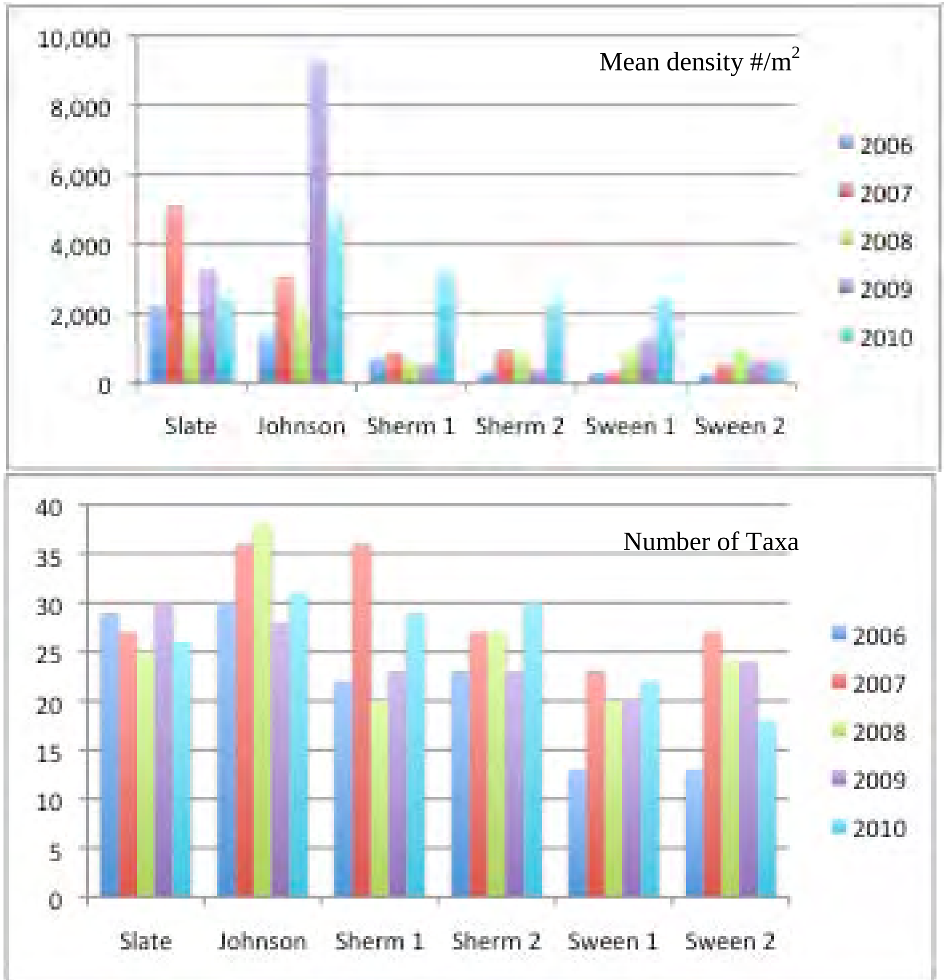


Figure 6: Invertebrate densities and number of taxa over time.

#EPT	2006	2007	2008	2009	2010
Slate	18	13	15	20	16
Johnson	26	32	30	20	22
Sherm 1	19	28	14	17	18
Sherm 2	21	22	18	14	19
Sween 1	10	16	14	14	13
Sween 2	11	16	16	16	10
#non-EPT	2006	2007	2008	2009	2010
Slate	11	14	10	10	10
Johnson	4	4	8	8	9
Sherm 1	3	8	6	6	11
Sherm 2	2	5	9	9	11
Sween 1	3	7	6	6	9
Sween 2	2	11	8	8	8

Table 9: Comparison of taxonomic groups over time.

4.7 Discussion

Generally, a higher water quality would be indicated by more EPT taxa (pollution sensitive species) and fewer non-EPT taxa (pollution tolerant species) or conversely, lower water quality would be indicated by loss of EPT taxa and gain of non-EPT taxa. Sherman Creek appeared to show some changes in 2010, namely, lower diversity, lower evenness, an increase in non-EPT taxa and large numbers of oligochaetes. This might suggest some lower water quality, but the pollution-tolerant taxa were only prevalent at Reach 1. Reach 2 actually had more EPT taxa in 2010 that might indicate improved water quality. Reach 1 of Sherman was sampled on March 1, two weeks earlier than Reach 2, but this short time period would not give rise to the change between the two sites. Reach 1 has a slightly lower gradient than Reach 2 so might naturally accumulate more sediment. The high number of EPT taxa, however, would indicate good water quality. Ephemeroptera (mayflies) tend to live mostly in unpolluted water, however, very small amounts of organic pollution can sometimes, initially, increase numbers of some species such as Baetis, which seems the most tolerant mayfly to pollution (Mandaville, 1999). The two reaches of Sherman Creek had relatively high numbers of Baetis compared previous years and to other sites. Baetis comprised 58 to 68% of the invertebrate community at Sherman in 2010 compared to 20-40% in previous years. A further 18% of the community at Reach 1 was comprised of pollution-tolerant oligochaete worms, however, several stonefly taxa and other mayfly taxa were still represented suggesting that if there was any impairment of water quality, it was only mild.

Slate Creek had around 75% fewer EPT taxa in 2010 than 2005, 2006 or 2009, but the same number of non-EPT taxa. Similarly lower EPT numbers were seen in 2007 and 2008. The diversion structure was first constructed in late 2006, removed in fall 2008 and rebuilt in fall 2009. Sampling is conducted in spring so this could have affected samples collected in 2007 and 2008 and 2010. Invertebrates may pass downstream through the diversion pipe from Upper Slate Lake, but having flow through a pipe versus outfall from Lower Slate Lake may alter the flow regime and consequently the invertebrate community downstream. The Slate Creek sampling site is only 200m downstream from the outfall from the pipe and almost 100% of the stream flow comes from the diversion. It will be interesting to see if the number of EPT taxa remains the same in future years with the diversion in place. Slate had roughly equal numbers of Baetis and Cyngmula, which is pollution-sensitive indicating good water quality.

5.0 Resident Fish Population

5.1 Stream Reaches

Resident fish surveys were conducted on the three main stream systems around the mine site, Sherman Creek that flows into Lynn Canal and Johnson and Slate Creeks that flow into Berners Bay (Figures 6, 7). Population surveys of resident fish were conducted in 2010 in lower, middle and upper reaches of each stream. Each reach is 360m in length. Sherman and Sweeny Creek reaches were designated during aquatic resource surveys in 1998 (Aquatic Science Inc. 1998) while Johnson and Slate reaches were delineated in 2005. All middle and upper reaches are located above barrier falls and are thereby inaccessible to sea-run fish. Dolly Varden char (*Salvelinus malma*), pink salmon (*Onchorhynchus gorbuscha*), chum salmon (*O. keta*), cutthroat trout (*O. clarki*) and coastrange sculpin (*Cottus aleuticus*) inhabit reaches below falls barriers. Dolly Varden are the only fish present above barrier falls and likely first arrived there when sea levels were higher.

Lower Sherman extends from the stream mouth to the barrier falls 360m upstream. Middle Sherman extends 360m downstream from the confluence of Sherman Creek and Ophir tributary. Upper Sherman extends 360m upstream from the road bridge across Upper Sherman Creek. Permanent markers are located at the start of strata if no permanent natural features occurred there (e.g. falls, stream confluence).

Lower Johnson begins at the forest/meadow border approximately 500m upstream from the confluence with Berners Bay. Middle Johnson begins at the confluence with the tributary draining Snowslide Gulch. Upper Johnson is located upstream of the mill site pad and above a braided section of river, in the Jualin basin. Lower Slate begins 400m upstream from the mouth; Middle Slate begins 400m downstream from the proposed dam at Lower Slate Lake; Upper Slate begins at the mouth of the north inlet to Upper Slate Lake. GPS points for the start of each reach are given in Table 10.

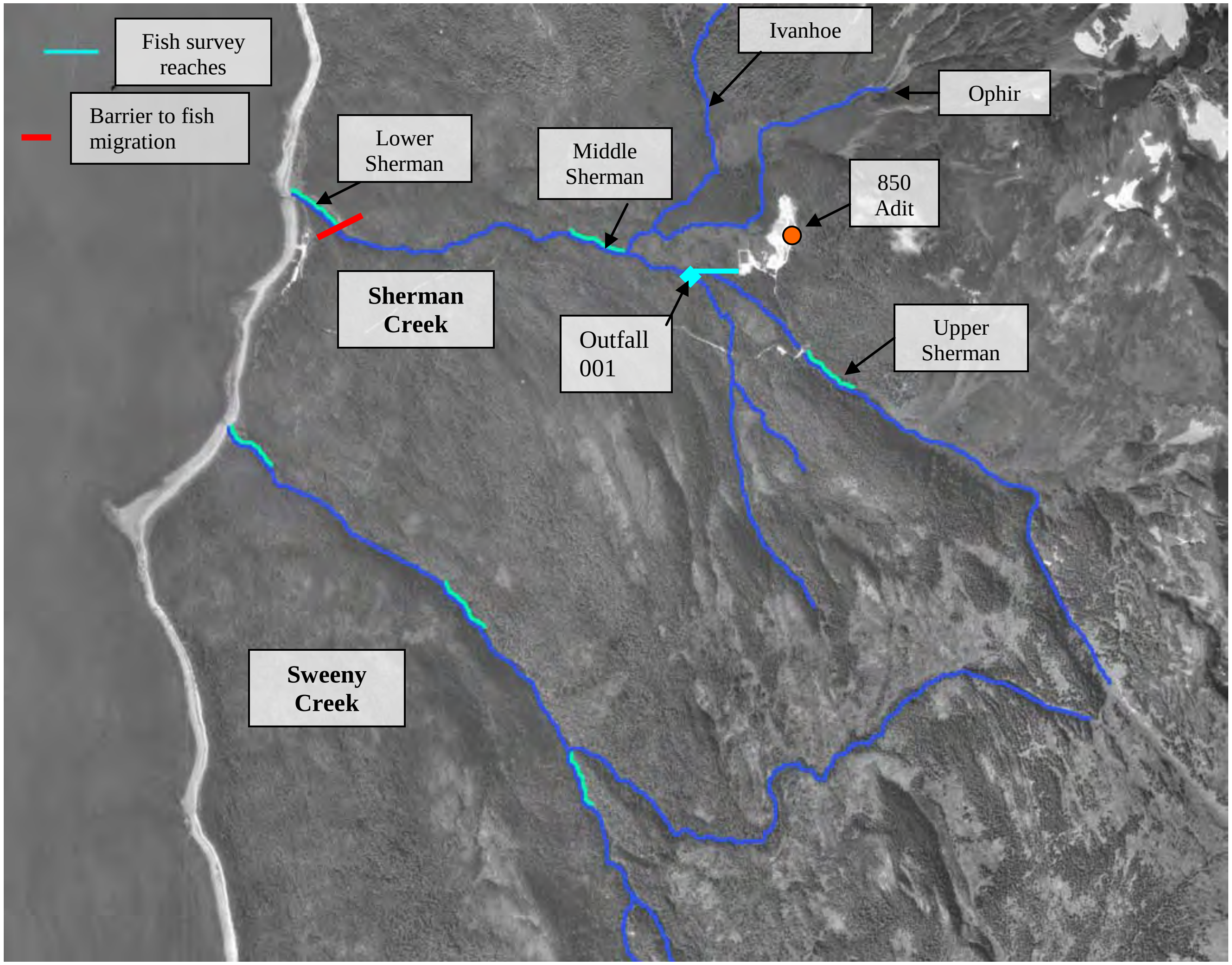


Figure 7A: Sherman Creek reaches used in 2010 Resident Fish Surveys.

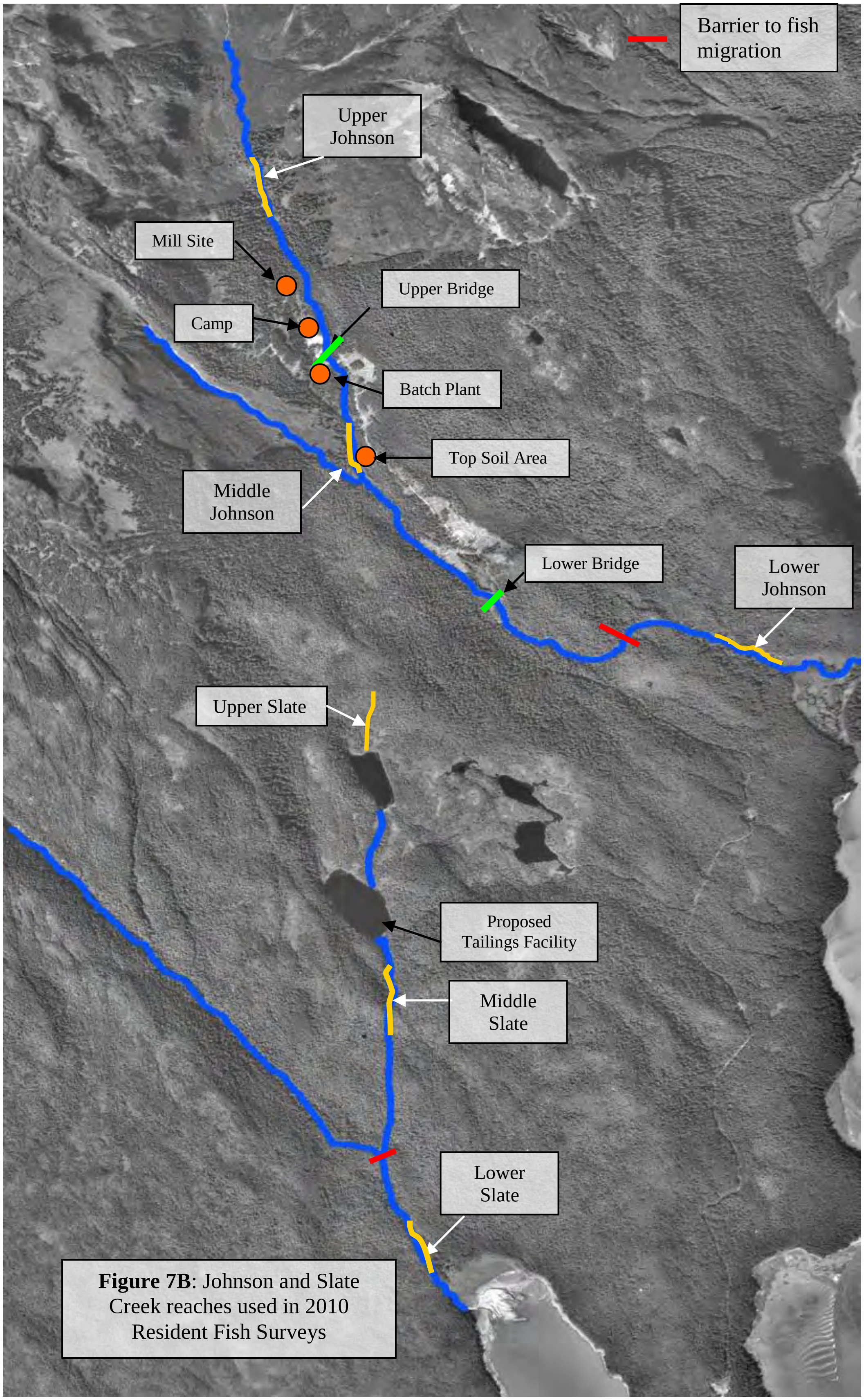


Figure 7B: Johnson and Slate Creek reaches used in 2010 Resident Fish Surveys

Table 10: GPS Coordinates (NAD 27) for resident fish strata.

	Stream Reach	Survey Date	Latitude	Longitude
1	Lower Sherman	7/23/10	58.86908	-135.14005
2	Middle Sherman	8/12/10	58.86774	-135.1143
3	Upper Sherman	8/17/10	58.86342	-135.10025
4	Lower Johnson	7/22/10	58.82383	-135.99936
5	Middle Johnson	8/13/10	58.83113	-135.03711
6	Upper Johnson	8/14/10	58.85147	-135.04892
7	Lower Slate	7/26/10	58.79628	-135.03716
8	Middle Slate	8/9/10	58.8037	-135.03706
9	Upper Slate	8/10/10	58.81412	-135.0403

5.2 Resident fish population survey methods

The number of fish within each stratum was estimated using the methods of Hankin and Reeves (1988) as in previous surveys (Aquatic Science 1998-2008). Resident fish surveys were conducted between July 22 and August 17, 2010. Lower reaches were surveyed first prior to adult pink salmon entering streams to spawn in late July. Electro-fishing gear is not permitted in the presence of spawning salmonids, as stipulated in the Alaska Department of Fish and Game Fish Resource Permit (Appendix 3a).

In each reach, stream habitat units were first categorized as riffle, pool, glide or cascade following the classifications of Bisson et al (1981). At least every third riffle, pool and glide was selected for snorkeling. A fisheries biologist, equipped with dry suit and snorkel, quietly entered the water at the downstream end of a selected unit and proceeded upstream observing fish underwater. Two field technicians, following behind to minimize disturbance to fish, measured the length of each habitat unit to the nearest 0.1m using a metric hip chain, and recorded the fish counts. Habitat unit width was measured using a 15m measuring tape and meter stick.

The accuracy of visual counts was verified by electro-fishing at least three units (if present) of each habitat type previously snorkeled. A three-member team proceeded upstream using a Smith-Root gasoline-powered backpack electro-fishing unit with output waves designed to minimize impact on fish. All stunned fish were counted and as many as possible captured using dip nets to allow length and weight measurements to be taken. Minnow traps baited with cured salmon eggs were set in high density fish areas identified by snorkeling. This allowed some fish to be removed and counted prior to electro-fishing, thereby minimizing effects of the electric current on the fish population. Captured fish were anesthetized in a solution of MS222 (Tricanemethane sulphonate), weighed to the nearest 0.1g and their total length measured to the nearest 1mm. The fish were then placed in a container of fresh stream water with a battery-powered aerator to recover before being returned to the habitat unit from which they were captured.

5.3 Data analysis methods

The number of fish within a reach was estimated by first applying a correction factor to the visual counts based on electro-fishing counts. It is assumed that electro-fishing counts are more accurate than snorkel counts since fish hiding between rocks might remain undetected by a diver, but can be captured by electro-fishing. The corrected counts for sampled units were then extrapolated over the total number of habitat units within a reach to give a total population estimate. Standard deviations and 95% confidence intervals for the population estimates were determined using equations (5) through (11) in Dolloff, Hankin & Reeves (1993). The precision of population estimates was calculated by expressing the 95% confidence intervals as a percentage of the estimated population size.

Definitions for equations used:

y_i = true number of fish in each unit; $i = 1,2,\ldots,N$,

Y = total number of fish in all units, d_i = count of fish by diver in unit i,

n' = number of units for which both diver and electrofishing counts are made

n = number of units for which diver counts only are made ($n>n'$).

The number of fish present is firstly estimated by $y_i = d_iR$ (for i not in n') where R is the ratio of actual numbers present to diver counts, estimated by $R = \Sigma\, y / \Sigma\, d$ (for i in n') or the total electro-fishing counts to diver counts. The estimate is then extrapolated over all units using: $Y = N/n\,(\Sigma y_i)$.

An estimation of error is then made using the equation:

$$V(y_{d,r}) = \frac{s^2y - 2Rs xy + R^2 s^2 x}{n'} + \frac{2Rs xy - R^2 s^2 x}{n} - \frac{S^2 y}{N}$$

where $s^2y = \Sigma(yi - y')^2 / n' - 1$,

$s^2x = \Sigma(xi - x')^2 / n' - 1$, and

$s xy = \Sigma(xi - x')\,(yi - y') / n' - 1$

The dimensions of each habitat unit in each reach are given in Appendix 3b. The total area of each habitat type was calculated and used in the computation of fish densities (number of fish per m^2). The minimum detectable difference (δ) in mean numbers of fish in each habitat unit or reach was calculated using the previously calculated estimation of error with the equation:

$$\delta = \sqrt{\frac{V(y_{d,r})}{n}}\,(t_{\alpha(2),v} + t_{\beta(1),v})$$

Where $v = n$-1

A significance level (α) of 0.05, and a statistical power β of 0.01 were specified for the analysis, to determine the smallest difference in mean numbers of fish that are detectable 90% of the time with a 95% significance level. The t values were read from tables giving critical values of the t distribution depending on sample size.

5.4 Population estimates

Population estimates by habitat type and by reach are presented in Table 11 and illustrated in Figures 8A and B. Actual numbers of fish counted by snorkeling and captured by electro-fishing and minnow trapping are summarized in Table 12. Dolly Varden were found in all stream reaches, while cutthroat trout were only present in the lower stream reaches. Dolly Varden numbers were highest in all reaches of Johnson Creek and Upper Sherman Creek, particularly in pools. Cutthroat numbers were highest in Lower Slate Creek.

Sherman Creek Dolly Varden				
Reach	Habitat Type	Estimate	C.I.	Precision (%)
Lower	Riffles	15	1.54	10.3
	Pools	46	2.73	5.9
	Glides	0	-	-
	All Units	**60**	**3.78**	6.3
Middle	Riffles	6	0.88	14.7
	Pools	62	2.56	4.1
	Glides	0	-	-
	All Units	**68**	**2.46**	3.6
Upper	Riffles	11	1.88	17.1
	Pools	95	4.84	5.1
	Glides	14	3.36	24.0
	All Units	**122**	**4.42**	3.6

Johnson Creek Dolly Varden				
Reach	Habitat Type	Estimate	C.I.	Precision (%)
Lower	Riffles	10	8.23	82.3
	Pools	203	45.2	22.3
	Glides	6	0.55	9.2
	All Units	**242**	**30.05**	12.4
Middle	Riffles	6	1.45	24.2
	Pools	138	25.39	18.4
	Glides	12	-	-
	All Units	**168**	**39**	23.2
Upper	Riffles	2	1.12	56.0
	Pools	147	35.4	24.1
	Glides	0	-	-
	All Units	**171**	**27.76**	16.2

Slate Creek Dolly Varden				
Reach	Habitat Type	Estimate	C.I.	Precision (%)
Lower	Riffles	5	2.63	52.6
	Pools	66	6.2	9.4
	Glides	17	9.31	54.8
	All Units	**93**	**8.16**	8.8
Middle	Riffles	10	1.08	10.8
	Pools	20	4.98	24.9
	Glides	9	1.3	14.4
	All Units	**40**	**2.9**	7.3
Upper	Riffles	5	1.27	25.4
	Pools	43	1.4	3.3
	Glides	11	1.08	9.8
	All Units	**79**	**2.96**	3.7

Cutthroat Trout				
Creek	Habitat Type	Estimate	C.I.	Precision (%)
Sherman	Riffles	7	1.54	22.0
Lower	Pools	10	0.82	8.2
	Glides	0	-	-
	All Units	**16**	**0.74**	4.6
Johnson	Riffles	0	-	-
Lower	Pools	2	1.41	70.5
	Glides	1	0.79	79.0
	All Units	**3**	**0.44**	14.7
Slate	Riffles	3	2.79	93.0
Lower	Pools	44	7.39	16.8
	Glides	21	5.6	26.7
	All Units	**72**	**6.78**	9.4

Table 11: Numbers of resident fish observed snorkeling and captured fishing.

Stream Reach	Habitat Type	Total Units (N) in stratum	Snorkeling			Electrofishing/Trapping		
				Numbers Observed			Numbers Captured	
			Units (n) snorkled	Dolly	Cutthroat	Units (n') fished	Dolly	Cutthroat
Lower Sherman	Pool	33	25	22	8	8	7	3
	Riffle	12	8	10	5	4	6	3
	Glide	1	1	0	0	1	0	0
	All Units	46	34	32	13	13	13	6
Middle Sherman	Pool	58	47	48	-	17	20	-
	Riffle	17	14	5	-	5	2	-
	Glide	1	1	0	-	1	0	-
	All Units	76	62	53	0	23	22	0
Upper Sherman	Pool	62	51	75	-	15	26	-
	Riffle	27	20	8	-	5	2	-
	Glide	6	5	12	-	4	7	-
	All Units	95	76	95	0	24	35	0
Lower Johnson	Pool	27	22	174	1	4	23	1
	Riffle	16	10	6	0	4	3	0
	Glide	9	7	5	1	5	2	1
	All Units	52	39	185	2	13	28	2
Middle Johnson	Pool	42	35	115	-	11	39	-
	Riffle	13	8	4	-	5	2	-
	Glide	1	1	11	-	1	12	-
	All Units	56	44	130	0	17	53	0
Upper Johnson	Pool	22	17	114	-	9	30	-
	Riffle	15	7	1	-	5	1	-
	Glide	6	5	0	-	4	0	-
	All Units	43	29	115	0	18	31	0
Lower Slate	Pool	19	16	40	37	5	12	13
	Riffle	14	9	3	2	6	3	2
	Glide	14	10	13	12	5	8	8
	All Units	47	35	56	51	16	23	23
Middle Slate	Pool	21	16	14	-	8	10	-
	Riffle	19	14	7	-	8	4	-
	Glide	9	6	4	-	4	6	-
	All Units	49	36	25	0	20	20	0
Upper Slate	Pool	33	29	31	-	12	22	-
	Riffle	46	18	2	-	8	2	-
	Glide	8	6	6	-	4	7	-
	All Units	87	53	39	0	24	31	0

Table 12: Resident Fish Population Estimates, 95% Confidence and Precision of Estimate.

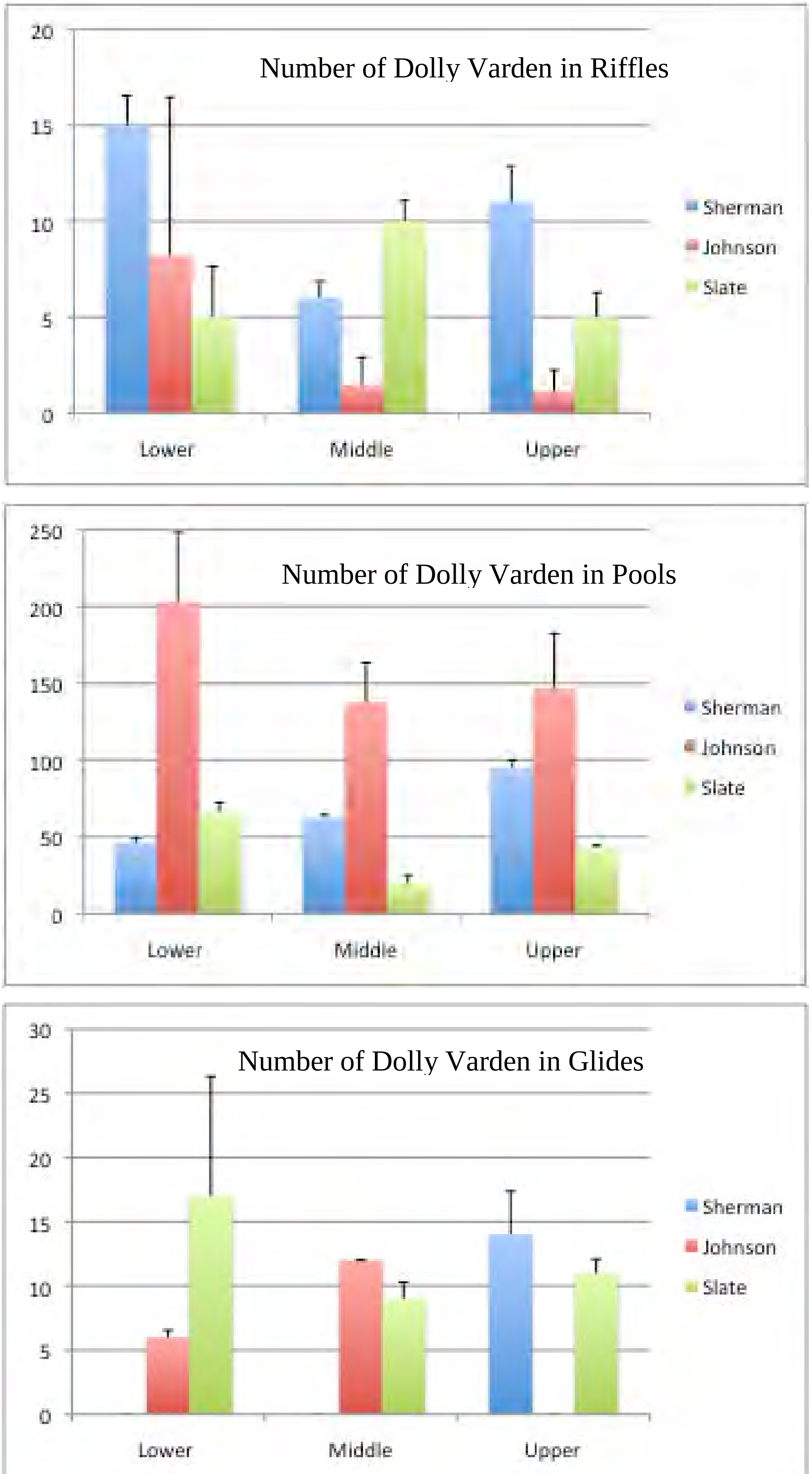


Figure 8A: Dolly Varden Population Estimates by Habitat Type.

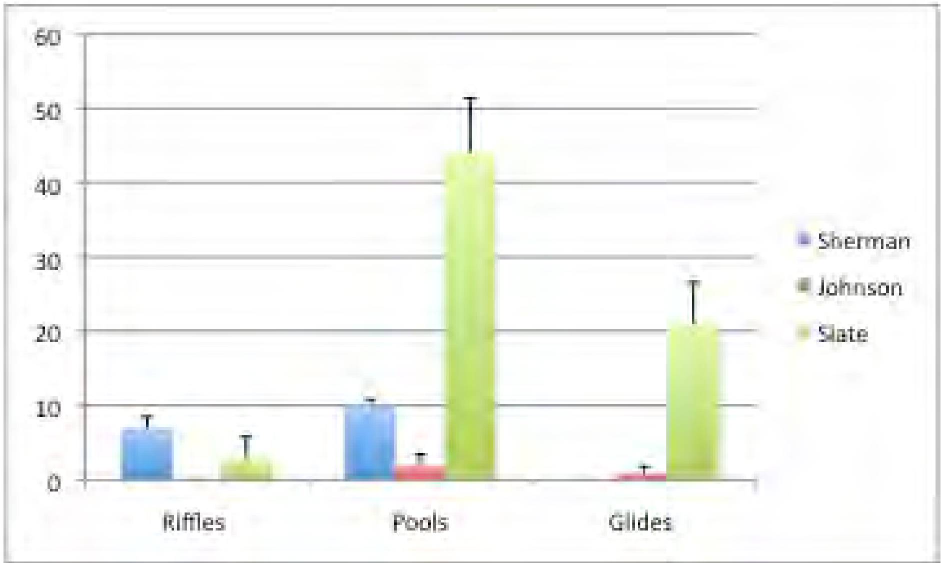
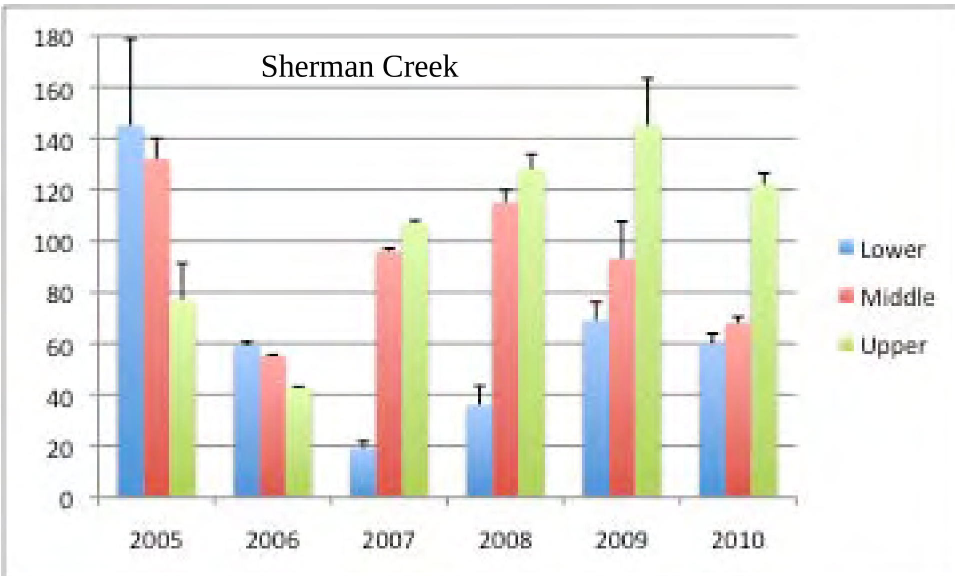


Figure 8B: Cutthroat Population Estimates by Habitat Type.

Comparison of Dolly Varden numbers over time (Figure 9A) shows that 2010 numbers appeared to be much higher in Lower Slate Creek (though lower at Upper Slate) and higher in Lower and Upper Johnson Creek than previous years. Large groups of over 50 fish were observed in large pools in Upper Johnson created by recent beaver activity, which might explain the increase there. A water shrew was also observed swimming underwater during snorkel surveys at this site. Many of the fish observed in lower reaches were of larger size than often observed in the streams and also bright silver in color suggesting they had migrated in from the ocean. High flow in 2004/2005 may have lead to passage of more fish downstream, explaining the high number in lower and middle reaches relative to the upper reach in 2005. Numbers have held fairly steady at Sherman Creek since 2007. Higher flows during surveys of Lower Sherman in 2007, likely lead to fewer fish being encountered. The number of cutthroats encountered in Slate Creek was greatest in 2009 with numbers in 2010 similar to previous years. Cutthroat numbers appear to have declined steadily at Sherman Creek (Figure 9B), but total fish numbers in lower Sherman increased slightly from 2007 (Figure 9C). The high number of fish found in Lower Sherman in 2005 was comprised of a high number of both cutthroats and dollies. If a large number of dollies were washed downstream from upper reaches, perhaps competition later drove out some cutthroats. Varying numbers of fish migrating in from the ocean also influence the total number of fish in lower reaches.

The number of total fish (Dolly Varden and cutthroat trout together) has increased steadily at Lower Johnson and was higher at Lower Slate in 2009 and 2010 than previous years. Fish may move in and out of lower reaches in response to changing stream flows or food availability. A large flood event in November 2005 followed by severe winter of 2006 may also have affected numbers in lower reaches. Numbers may still be recovering from this natural event. There is natural variability in the population from year to year as well as differences in the numbers detected by snorkeling and electro-fishing, which is affected by differences in stream flow and temperature at the time of sampling.



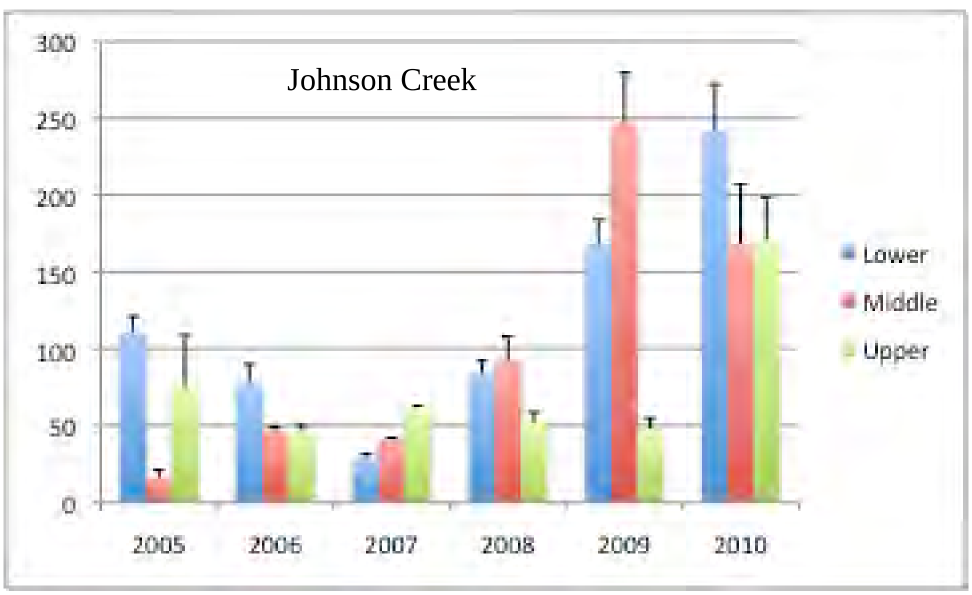


Figure 9A: Comparison of Dolly Varden numbers over time, 2005 to 2010.

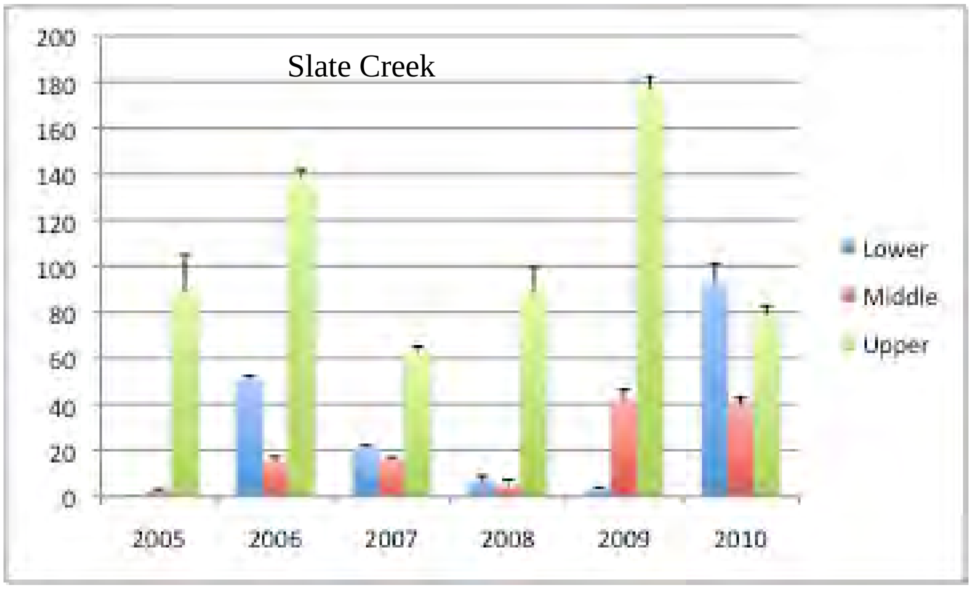


Figure 9A cont: Comparison of Dolly Varden numbers over time, 2005 to 2010.

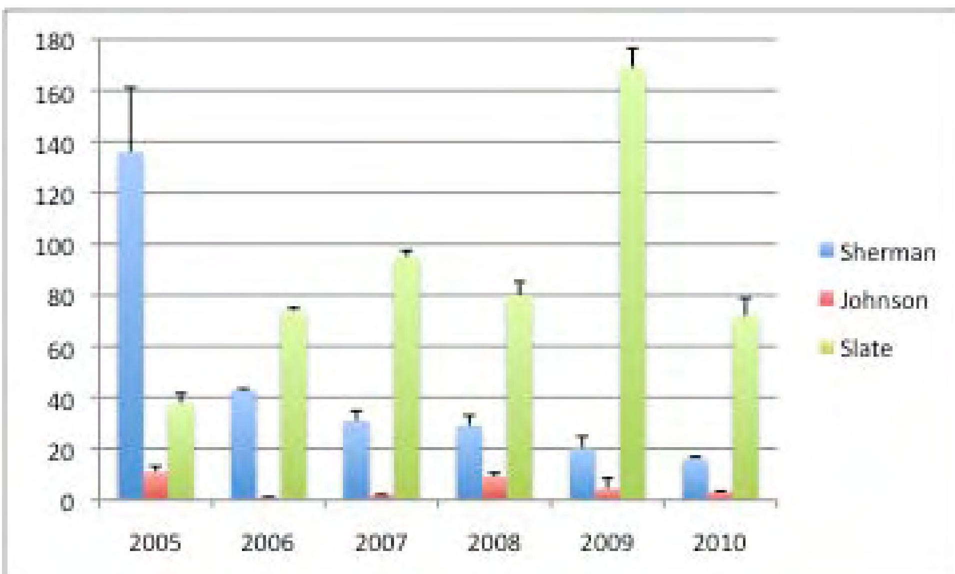


Figure 9B: Comparison of cutthroat trout numbers over time.

The 70 Dolly Varden captured by electro-fishing and minnow trapping in the three reaches of Sherman Creek represented 28% of the total estimated Dolly Varden population of the three Sherman Creek reaches surveyed. The 6 cutthroat trout captured in Lower Sherman represented 37.5% of the estimated Sherman Creek cutthroat population. The 112 Dolly Varden captured in Johnson Creek represented 19.3% of the estimated population of Johnson Creek. Only 2 cutthroat trout was captured in Lower Johnson, representing 66.7% of the total estimate. The 74 Dolly Varden captured in Slate Creek comprised 34.9% of the Slate Creek population estimate and the 23 cutthroats captured represented 31.9% of the Lower Slate population. Counts of fish observed by snorkeling and captured by electro-fishing and minnow trapping in each habitat unit are presented in Appendix 3c.

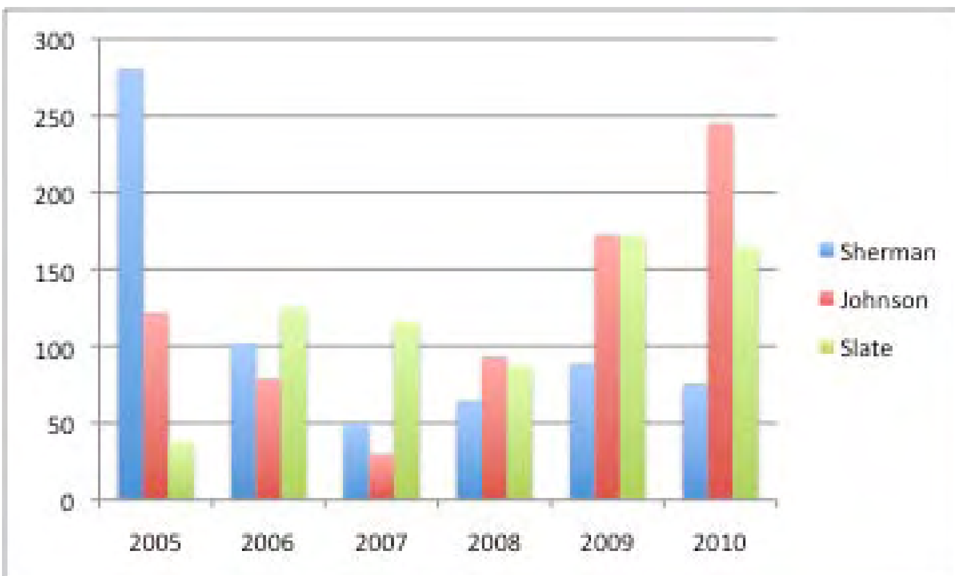


Figure 9B: Comparison of total fish numbers (cutthroats and dollies) over time.

5.5 Minimum detectable differences in mean numbers of fish.

Mean numbers of fish in each habitat unit were used to compute hypothetical minimum detectable differences that could be detected for each mean. Table 13 gives the mean number of fish in each habitat type and the minimum detectable difference (MDD) resulting from comparing habitat types in each stream reach. A difference in means of 1 to 3 fish per habitat unit was detectable for Dolly Varden and cutthroat trout in most habitat types with the exception of Lower Slate glides (MDD = 4.7 fish), Lower Johnson riffles (MDD = 5.7 fish), and Johnson Creek pools (MDD = 6.9 to 12.9 fish). In the case of Lower Slate glides, numbers of fish varied from zero to four, but only five of the fourteen glides present were fished. Similarly, Lower Johnson riffles contained zero to three fish, but only five of sixteen riffles were surveyed. Johnson Creek pools varied greatly in numbers of fish present from zero to sixty so that even surveying all pools would likely give a high minimum detectable difference. The ability to detect small differences in numbers of fish is important in detecting changes in the population from year to year.

Figure 10: Large group of Dollies in Upper Johnson Creek, August 2010.

Table 13: Mean number of fish per habitat unit and minimum detectable differences (MDD).

Sherman Creek Dolly Varden			
Reach	**Habitat Unit**	**Mean # Fish**	**MDD**
Lower	Riffles	1.500	2.737
	Pools	1.400	1.541
	Glides	0.000	-
	All Units	**1.318**	1.707
Middle	Riffles	0.357	0.609
	Pools	1.075	1.014
	Glides	-	-
	All Units	**0.896**	0.838
Upper	Riffles	0.400	1.305
	Pools	1.529	2.034
	Glides	2.400	2.919
	All Units	**1.287**	1.478

Slate Creek Dolly Varden			
Reach	**Habitat Unit**	**Mean # Fish**	**MDD**
Lower	Riffles	0.000	-
	Pools	3.500	2.407
	Glides	1.200	4.744
	All Units	**1.986**	3.322
Middle	Riffles	0.500	0.608
	Pools	0.972	2.210
	Glides	1.000	0.984
	All Units	**0.817**	1.059
Upper	Riffles	0.111	0.715
	Pools	1.307	0.655
	Glides	1.400	0.820
	All Units	**0.912**	0.990

Cutthroat Trout			
Creek	**Habitat Unit**	**Mean # Fish**	**MDD**
Sherman	Riffles	0.625	1.167
Lower	Pools	0.320	0.461
	Glides	-	-
	All Units	**0.318**	0.334
Johnson	Riffles	0.000	-
Lower	Pools	0.045	0.982
	Glides	0.143	0.548
	All Units	**0.054**	0.186
Slate	Riffles	0.222	1.794
Lower	Pools	2.313	2.866
	Glides	1.500	2.750
	All Units	**1.543**	2.762

Johnson Creek Dolly Varden			
Reach	**Habitat Unit**	**Mean # Fish**	**MDD**
Lower	Riffles	0.60	5.716
	Pools	7.53	11.813
	Glides	0.71	0.382
	All Units	**4.65**	7.467
Middle	Riffles	0.50	1.004
	Pools	3.29	6.934
	Glides	0	-
	All Units	**3.01**	9.588
Upper	Riffles	0.14	0.774
	Pools	6.71	12.872
	Glides	0.00	0.000
	All Units	**3.97**	8.407

5.6 Fish density

Due to differences in the size of habitat areas sampled, population estimates were converted to numbers of fish per unit area for comparisons between reaches and habitat types. Dolly Varden density was highest in upper reaches where there is less habitat area available so fish are more concentrated (Table 14). Upper Johnson and Upper Sherman Creeks had the highest fish densities, followed by Lower and Upper Slate and Middle Johnson. Middle Slate Creek had the lowest density and was identical to 2009 densities. The highest density of cutthroat trout was found at Lower Slate, despite a higher density of Dolly Varden being observed. There is evidence from literature that Dolly Varden densities are suppressed when stream habitat is shared with cutthroat trout (Hinder et al 1988, Hastings 2005), but this may not hold for larger dollies migrating in from the ocean.

Table 14: Densities of fish by species, reach and habitat type.

Fish Density (number of fish/m^2)									
		Dolly Varden				Cutthroat Trout			
Creek	**Strata**	**Riffles**	**Pools**	**Glides**	**All**	**Riffles**	**Pools**	**Glides**	**All**
Sherman	Lower	0.012	0.083	0.000	**0.033**	0.005	0.018	0.000	**0.009**
	Middle	0.009	0.154	0.000	**0.060**				
	Upper	0.024	0.290	0.170	**0.141**				
Johnson	Lower	0.011	0.571	0.021	**0.154**	0.000	0.003	0.003	**0.002**
	Middle	0.005	0.290	0.000	**0.099**				
	Upper	0.004	0.089	0.000	**0.074**				
Slate	Lower	0.007	0.295	0.031	**0.063**	0.016	0.211	0.032	**0.049**
	Middle	0.006	0.102	0.006	**0.012**				
	Upper	0.009	0.308	0.179	**0.101**				

Table 15: Densities of Dolly Varden and Cutthroat Combined.

		Dolly Varden and Cutthroat			
Creek	**Strata**	**Riffles**	**Pools**	**Glides**	**All Units**
Sherman	Lower	0.017	0.101	na	**0.041**
	Middle	0.009	0.154	na	**0.060**
	Upper	0.024	0.290	0.170	**0.141**
Johnson	Lower	0.011	0.573	0.024	**0.156**
	Middle	0.005	0.290	0.000	**0.099**
	Upper	0.004	0.089	0.000	**0.074**
Slate	Lower	0.011	0.492	0.069	**0.112**
	Middle	0.006	0.102	0.006	**0.012**
	Upper	0.009	0.308	0.179	**0.101**

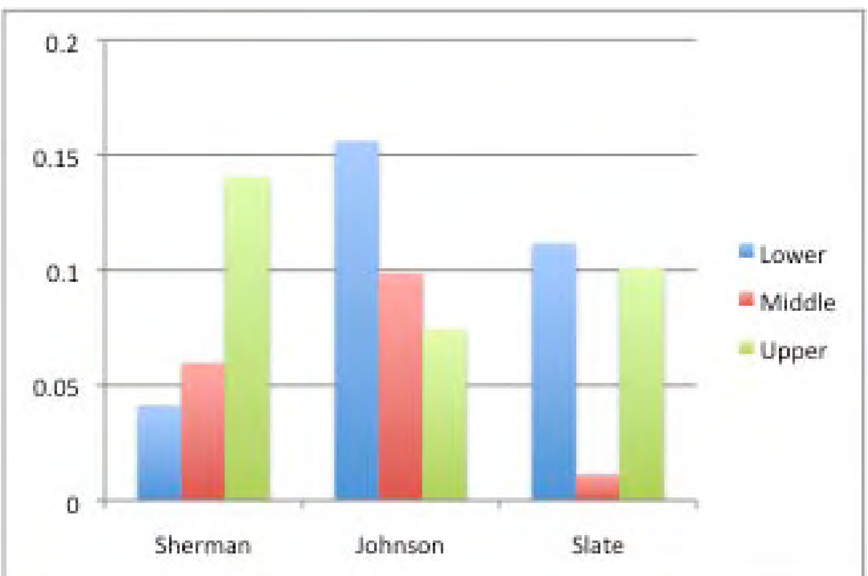


Figure 11: Densities of all salmonids combined (#/m^2) in Sherman, Johnson and Slate Creeks.

Densities were slightly lower in all reaches of Sherman Creek in 2010 compared to 2009, but this was at least partly due to habitat area being larger in 2010 due to higher flow during sampling. Lower Johnson Creek had higher densities in 2010 with the habitat area remaining the same. Upper Johnson densities were three times higher in 2010 with 600m^2 of pool habitat added in 2010 from beaver activity. Pools as large as 50 by 20 m here provide a large amount of rearing habitat. Middle Slate had the same number of fish (around 40) in 2010 as 2009, but density was lower in 2010 due to greater habitat area at higher flow. Upper Slate is thought to be a nursery area for Upper Slate Lake with lost of Dolly fry. Density was lower in 2010 than 2009, partly due to a greater habitat area due to higher flow, but also due to fewer fish encountered. Fish here have access to the lake so numbers may vary depending on fish movement to and from the lake. There could be some difference due to time of sampling as the 2010 survey of Upper Slate was conducted on August 8 compared to August 27 in 2009.

Overall fish density (numbers over total habitat area) can be very different from density in each habitat type as fish are both dollies and cutthroats are often concentrated in pools. The density of all salmonids combined was greatest in pools, particularly in middle reaches where gradient can be steepest and glide habitat limited (Figure 12). Lower Johnson and Lower Slate pools had the highest density at around 0.5 fish/m^2 followed by Upper Slate and Upper Sherman pools at around 0.3fish/m^2. Upper Slate and Upper Sherman glides had around 0.17 fish/m^2. Densities of Dolly Varden were highest in Lower Johnson pool habitat and decreased from downstream to upstream as pool area increased. Beaver activity has created larger pools in Upper Johnson and the fish population is likely still adjusting to the increased area. Middle Slate pools had rather low fish density perhaps due to the generally shallower pools in this bedrock-dominated reach. It is useful to examine changes in density by habitat type as well as total population estimates over time to determine true population changes.

Figure 12: Densities of all salmonids by habitat type.

5.7 Fish condition

Fish condition is an index based on the ratio of fish length to weight and was determined from field measurements of fish captured by electro-fishing and minnow trapping. The histograms in Figure 12 show the size range of fish captured in each creek. The largest Dolly Varden was found in Upper Johnson Creek and measured 223mm and 90.2g. Only five cutthroat were measured, but the largest was found in Lower Slate and was 137mm and 20.8g. A large number of small Dolly Varden were captured in Upper Slate Creek, which seems to provide a nursery and spawning area for Upper Slate Lake. Lengths and weights of fish were used to calculate Fulton's condition factor (K) using the equation given in Anderson & Neumann (1996):

$$K = W/L^3 \times 10{,}000$$

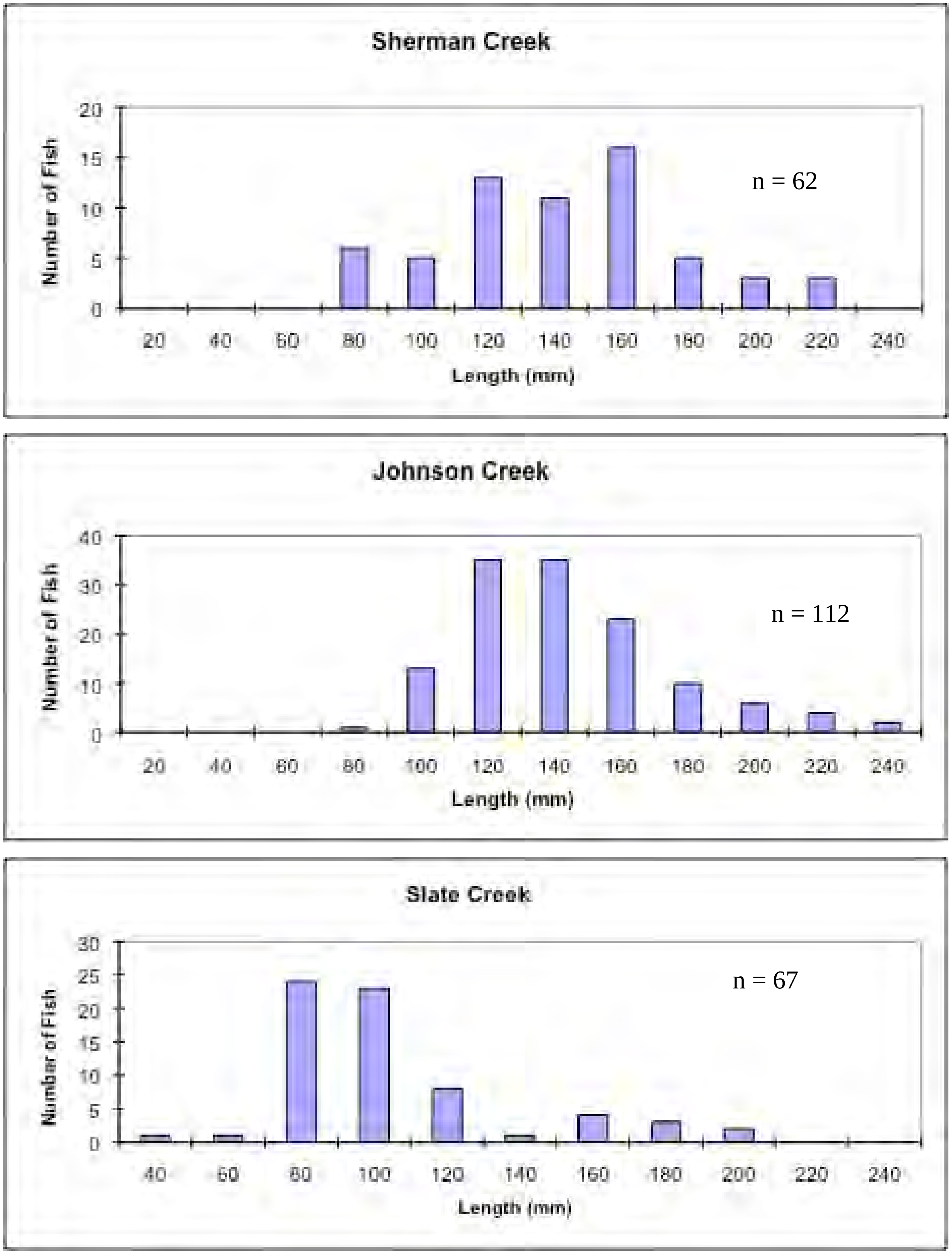
W = weight in g; L = total length in mm

The length, weight and condition factor of each fish are presented in Appendix 3d. Mean condition factors by stream reach are presented in Table 16 and Figure 13. Condition of Dolly Varden appeared slightly greater in Lower and Middle Sherman and slightly smaller in Lower Johnson than other reaches, but the differences are not significant (95% level). Mean condition factor of cutthroats was based on only five fish, but appeared relatively high and not significantly different from condition of Dolly Varden.

Table 16: Mean condition factor of Dolly Varden and cutthroats by reach.

		Sherman		Johnson		Slate	
Species	**Reach**	**Mean K**	**95% C.I.**	**Mean K**	**95% C.I.**	**Mean K**	**95% C.I.**
Dolly Varden	**Lower**	0.918	0.061	0.746	0.038	0.805	0.063
	Middle	0.915	0.033	0.806	0.016	0.854	0.033
	Upper	0.825	0.082	0.809	0.013	0.849	0.036
Cutthroat	**Lower**	0.932	na	na	na	0.907	0.189

Figure 12: Length-frequency histograms for Dolly Varden captured in all reaches in 2010.



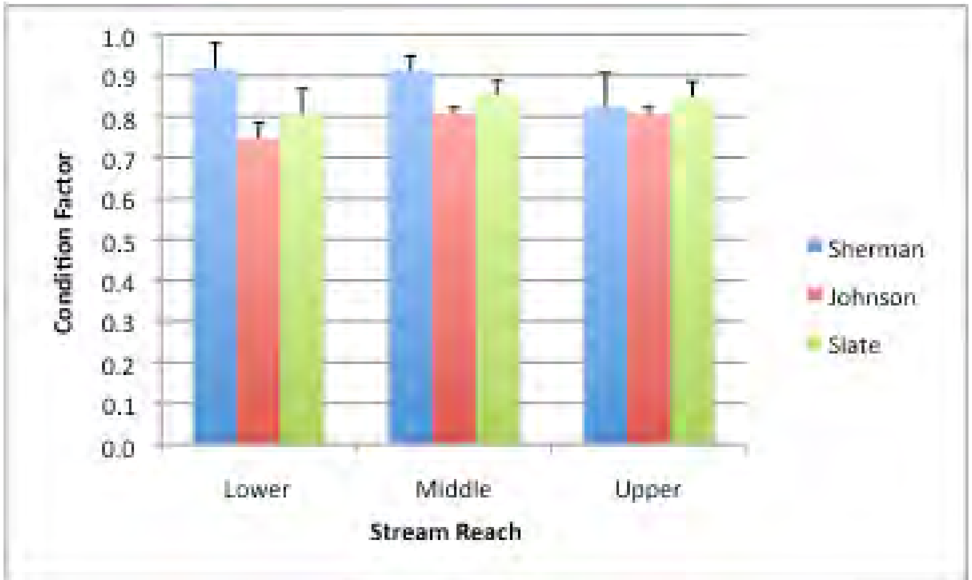
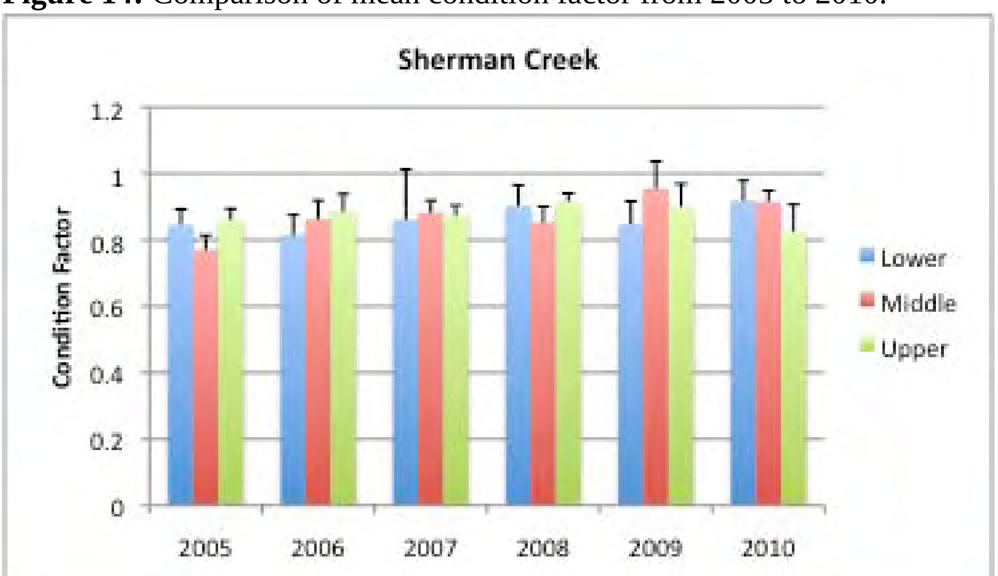
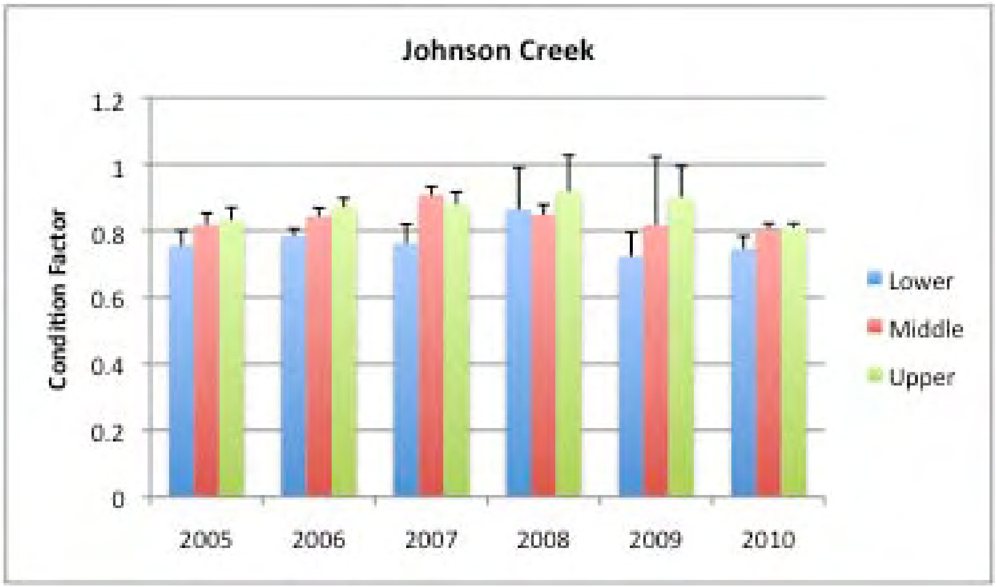


Figure 13: Mean Condition Factor of fish captured in 2010.

Comparison with previous years did not reveal any significant changes in mean condition factor (Figure 14). Dolly Varden condition appeared lower in Upper Johnson in 2010, but was not significantly different in other reaches. At Lower Slate Creek it appears that Dolly Varden are only found in even years, but this could be chance alone or perhaps a population of dollies is tuned to following even-year pink salmon into the stream to spawn. Cutthroat condition was not significantly different from previous years among the lower reaches.

Figure 14: Comparison of mean condition factor from 2005 to 2010.





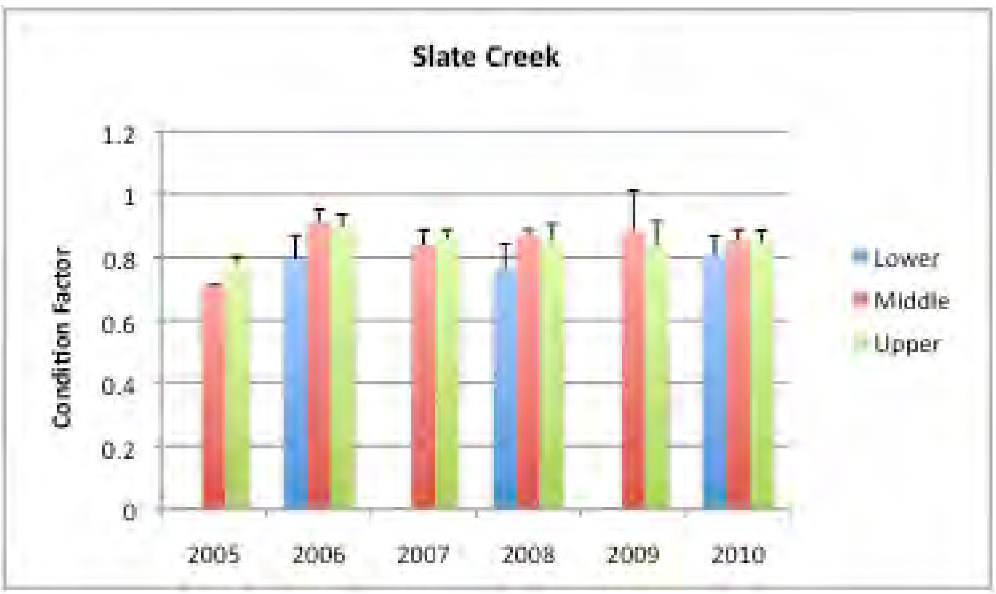


Figure 14 continued.

6.0 Anadromous Fish Monitoring

6.1 Pink Salmon Ecology

All pink salmon migrate to sea, are 2 years old at maturity and all die after spawning. This has resulted in two separate populations that do not interbreed using the same spawning habitat in alternate years (Quinn 2005). Around Southeast Alaska, even-year populations of returning adult salmon are generally larger than odd years. The differences between odd and even year populations may have originated during the last ice age when ice cover resulted in two distinct populations at northern (even) and southern (odd) glacial refuges. Odd-year populations are generally larger in the southern part of their range, perhaps being better adapted to warmer water. The out-migrating fry population for 2010 was expected to be smaller than the previous year, following the spawning of the odd-year smaller population.

Adult pink salmon migrate into Southeast Alaska streams to spawn from July through September. Pink salmon tend to spawn closer to the ocean than other species, although when large numbers of salmon return at the same time, accessible sites further upstream will be utilized. Fertilized eggs are buried in a nest or redd of gravel that is dug and guarded by the female for 10-13 days after construction (Heard 1991). The embryos develop over the fall and winter and fry emerge from the gravel between the end of March and beginning of June, predominately at night and immediately migrate downstream to the ocean. The night migration is considered to be an avoidance of predator adaptation (Godin 1980). At emergence, pink salmon fry are fully adapted for seawater and migrate directly to sea, making essentially no use of freshwater for rearing. Overall freshwater survival of pink salmon from egg to emergent fry averages 11.5% (Quinn 2005).

6.2 Trapping Procedures

Previous studies on Sherman and Sweeny Creeks used a fence trap system followed by fyke nets (EVS 1998, 2000, Coeur Alaska Annual Report 2005-2007). Fence traps set across the entire stream channel resulted in high mortality, particularly at times of high flow, due to fish being impinged against wire mesh by the current. Fyke nets have been more successful with much lower mortality since only a portion of the stream was sampled and the angle of the net against the flow was much reduced.

Due to the distance between streams and the necessity of checking traps daily, two teams of field personnel were used to conduct the study. In 2010, Sherman Creek was accessed by one team traveling through the mine tunnel from Jualin Camp, approximately 5 miles away, while a second team accessed Johnson Creek via a trail from the Jualin road at mile 3, and Slate Creek via kayak from the Slate Cove dock (Figure 1). Fyke nets with adjustable wings constructed from 1/8 inch mesh were used to trap out-migrating salmon fry at each creek (Figure 15). The width of each net opening was adjusted according to stream flow from 4 to 11 feet across by deploying the wings. The larger the proportion of stream sampled, the more accurate the population estimate should be, however, at high flow the pressure of water on the net wings when fully deployed resulted in some mortality of fry. The nets were therefore adjusted daily to minimize mortality as the flow increased or decreased. The percentage of stream flow sampled by the nets was estimated each day. Debris traps were also set in front of the nets in the form of 1 inch chicken wire set in a v-shape with rebar to reduce debris loading inside the nets (Figure 15).

Kate Kanouse of ADFG reported pink salmon fry emigrating from Auke Creek, Juneau approximately 2 weeks earlier than normal, therefore traps were set out earlier than previous years. One net was set in Slate Creek on March 24, 2010, approximately 25m above mean high water. A net was set in Johnson Creek on March 26 approximately 100m from the confluence with the Lace River. The Sherman Creek net was set on March 31 approximately 50m upstream of the creek mouth at mean high water. The GPS co-ordinates of each trap are given in Table 17. Each net was attached to a live holding box that contained a partition to deflect the flow and allow fry to pass underneath to a compartment of low flow. The live boxes were made of perforated aluminum and had adjustable legs that could be raised or lowered with stream flow so that moderate flow could be maintained inside the box.

Each net was visited at least once a day to identify, count and release fish from the trap using small hand nets. Every 3-4 days, a sample of 150 fish (if available) was stained with Bismarck Brown dye and released upstream of the trap to determine trap efficiency. All other fish were released downstream of the trap after identification. The total population of fry migrating from each creek was estimated using the average ratio of marked to unmarked fish from successive marking events.

6.3 Physical Data Collection

Water temperature and stream discharge were monitored throughout the sampling period on each stream by data-logging units that recorded measurements every 15 minutes. On Sherman Creek the data-logger was adjacent to the net; on Johnson and Slate Creeks the data-loggers were over 1km upstream, but still gave an indication of changes in flow and temperature when combined with measurements near the nets. Physical measurements of stream discharge were made at least once a week using a Pygmy flow meter. Measurements were taken at 12 to 15 intervals across the stream. Water level (stage) was also measured daily from a staff gauge in each stream. A stage-discharge relationship was developed to allow estimation of stream discharge on those days when it was not measured directly.

Figure 15: Fyke net and debris trap at Slate Creek.

Stream	GPS Co-ordinates (NAD27 Alaska)
Sherman	N 58.86908 W 135.14005
Johnson	N 58.82383 W 134.99936
Slate	N 58.79628 W 135.03716

Table 17: GPS Co-ordinates of the trap sites at each stream.

6.4 Fish Data Collection

Prior to the beginning of field operations, a Fish Resource Permit was obtained from the Alaska Department of Fish and Game (Appendix 4a), which authorized sampling fish in each creek. In addition, Coeur Alaska holds a Fish Habitat Permit from the Alaska Department of Natural Resources permitting use of a trap structure in each stream (Appendix 4b).

The outmigration count began at Slate Creek on March 25, Johnson Creek on March 27 and Sherman Creek on April 1 and continued until negligible numbers of fish were being captured. Daily sampling continued until May 15 at Slate Creek, May 19 at Sherman Creek and Johnson Creek. Before conducting the fish counts, a general assessment of the flow, debris accumulation, and number of dead fish in the traps was performed. Fish were scooped out of the holding box using 4 by 6 inch hand nets, identified using a field guide (Pollard et al 1997) and released back into the stream. Numbers of each fish species trapped were recorded every day.

6.5 Mark-Recapture Trials

Since fish are not randomly or evenly distributed within streams, estimates of total counts cannot be based simply on the percent of total discharge being sampled by the nets. The total number of daily migrants was estimated by firstly capturing and marking individuals from the migrating population, releasing marked fish upstream of the trap, and then re-sampling to determine the fraction of marked fish out of the total number captured. This allows calculation of the sampling efficiency of the nets in terms of the number of fish caught in the net verses the number passing by downstream.

Mark-recapture trials were conducted every 3-4 days to determine the total number of out-migrating fry based on the ratio between marked and unmarked individuals. Repeated trials were conducted since trap efficiency is likely to vary with fluctuating stream flow, with fish having less chance of capture at higher flows. The trials were separated by at least three days to avoid capturing marked fish from an earlier marking episode. Bismark Brown Y dye was used to mark fry because it is easily visible amongst large numbers of fish, does not harm fish, and is fast and simple to apply. Fish were immersed for 10 minutes in 1.5 gallons of water in which 0.6g of dye had been dissolved. A battery-operated aerator was placed in the water with the fry to ensure they had sufficient oxygen. After immersion, fish were transferred to a container of fresh water for a few minutes to recover from the staining process and released approximately 30 to 50 m upstream of the nets. Marked fish were released by spreading them evenly across the current. Many marked fish were found in the live holding box immediately after release, so these were counted and released downstream the same day. Thirteen mark-recapture trials were conducted at Sherman Creek, twelve at Slate Creek and fifteen at Johnson Creek with 150 fish marked (if available) on each occasion (Table 14).

6.6 Calculation of Population Estimate

The total daily number of out-migrating pink salmon fry was calculated using the ratio of marked to unmarked fish captured in the net. Marking experiments were conducted every 3 days and an average recapture rate calculated for every two successive experiments. The average recapture rate was then applied to the actual numbers captured each day. For example, at Sherman Creek on April 16, 149 marked fish were released and 40 were recaptured (27% of total released). A catch of 1,654 fish on April 16 divided by 0.27 gives a total estimate of 6,126 fish for that day. The lowest recapture rate used for Sherman Creek was 15% to avoid over-estimating the population as some fry may hold close to stream banks for cover rather than migrating in mid-stream where the trap was located. On April 1 there was already a catch of 1,465, therefore the four days prior to this were given estimated catch figures of 200, 400, 600 and 1,000 fish respectively, assuming a bell curve distribution of numbers of fry captured over time. Mean capture rates were calculated for the period between two successive recapture trials and these rates used to calculate a daily estimate (Table 18). The estimated total catch was calculated in this way for each day and then a final total summed for the entire survey period.

6.7 Physical Data

Flow data was used to develop stage-discharge relationships for each stream based on manual discharge measurements, staff gage readings near the fyke nets and transducer data. These relationships were then used to calculate discharge for each day of the fry study (Figure 19). The flow at each creek was relatively low at the end of March, with Sherman Creek less than 20cfs, Johnson less than 10cfs and Slate Creek mostly less than 5cfs. Flows increased gradually with warming temperatures to over 30cfs at Sherman and Johnson Creeks, but only 5-7cfs at Slate Creek with the exception of a few days over 10cfs. Flows increased to around 60cfs at Sherman and 60-100cfs at Johnson after May 19 presumable due to snowmelt. Flows continued to be mellow at Slate Creek at the same time likely because the lakes, now thawed, were buffering flow.

Peaks in flow occurred on April 18-22 reaching 58cfs at Sherman Creek, 74cfs at Johnson Creek. These peak flows were only around half of those observed in 2009 around the same time. Slate Creek only peaked at 15cfs, which was around ¼ of the peak flow observed in 2009 during the same time period. There was a later peak in flow on May 27 at Sherman and Johnson reaching 69 and 107cfs respectively.

The proportion of the flow sampled by the nets varied with discharge and creek, affecting the number of salmon fry captured. At Sherman Creek around 10% to 60% of the flow was sampled during the study (average 28%), while at Johnson Creek 10 to 25% of the flow was sampled (average 15%). At Slate Creek 20% to 70% of the flow was sampled (average 37%). High flow may flush more salmon fry out of the gravel or result in a lower catch because the net had to be moved out of main channel.

Figure 18A: Chum salmon with parr marks mingle with pink fry in Johnson trap.

Figure 18B: Eulachon in the Slate Creek fish trap.

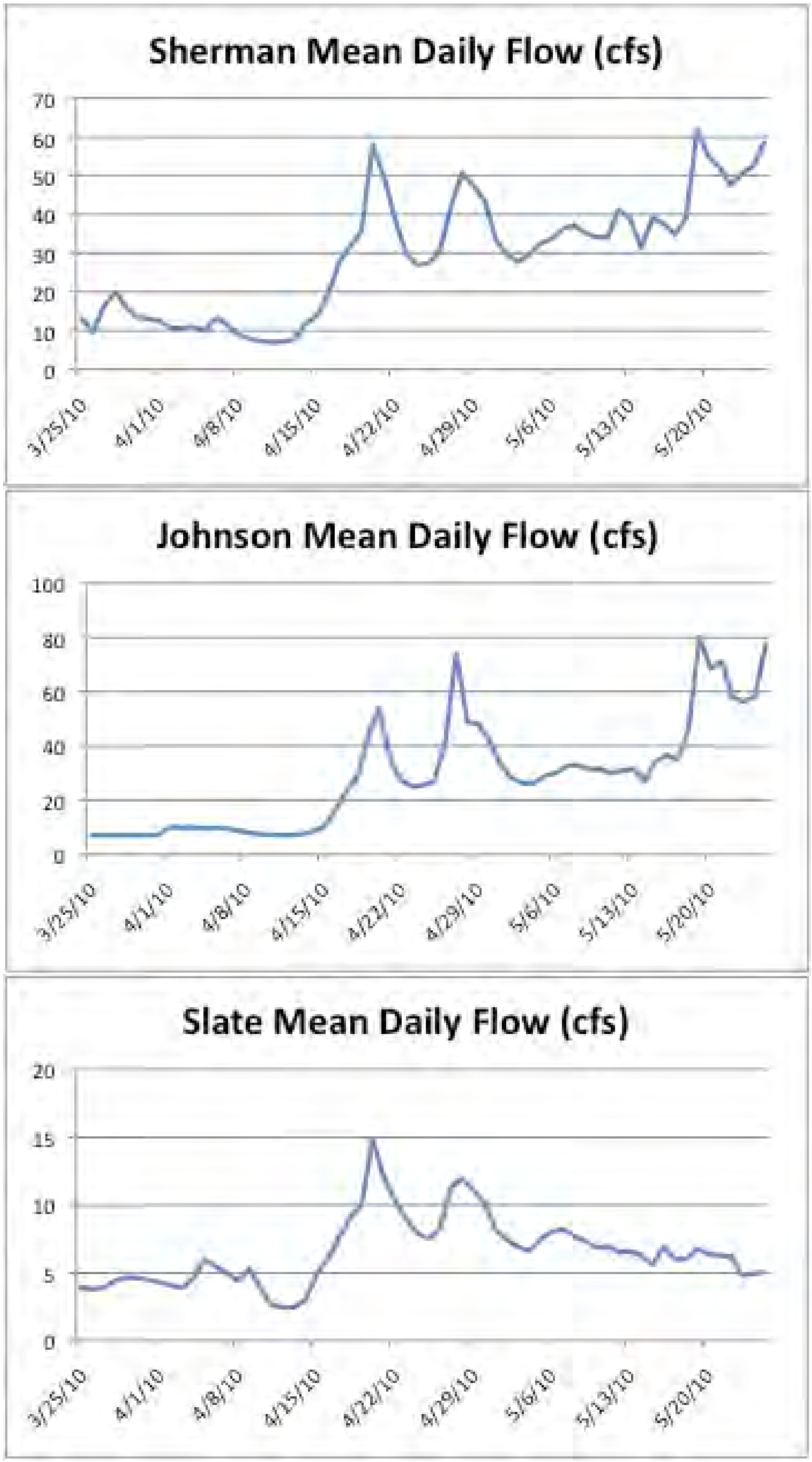


Figure 19: Mean daily stream flow in cubic feet per second (cfs).

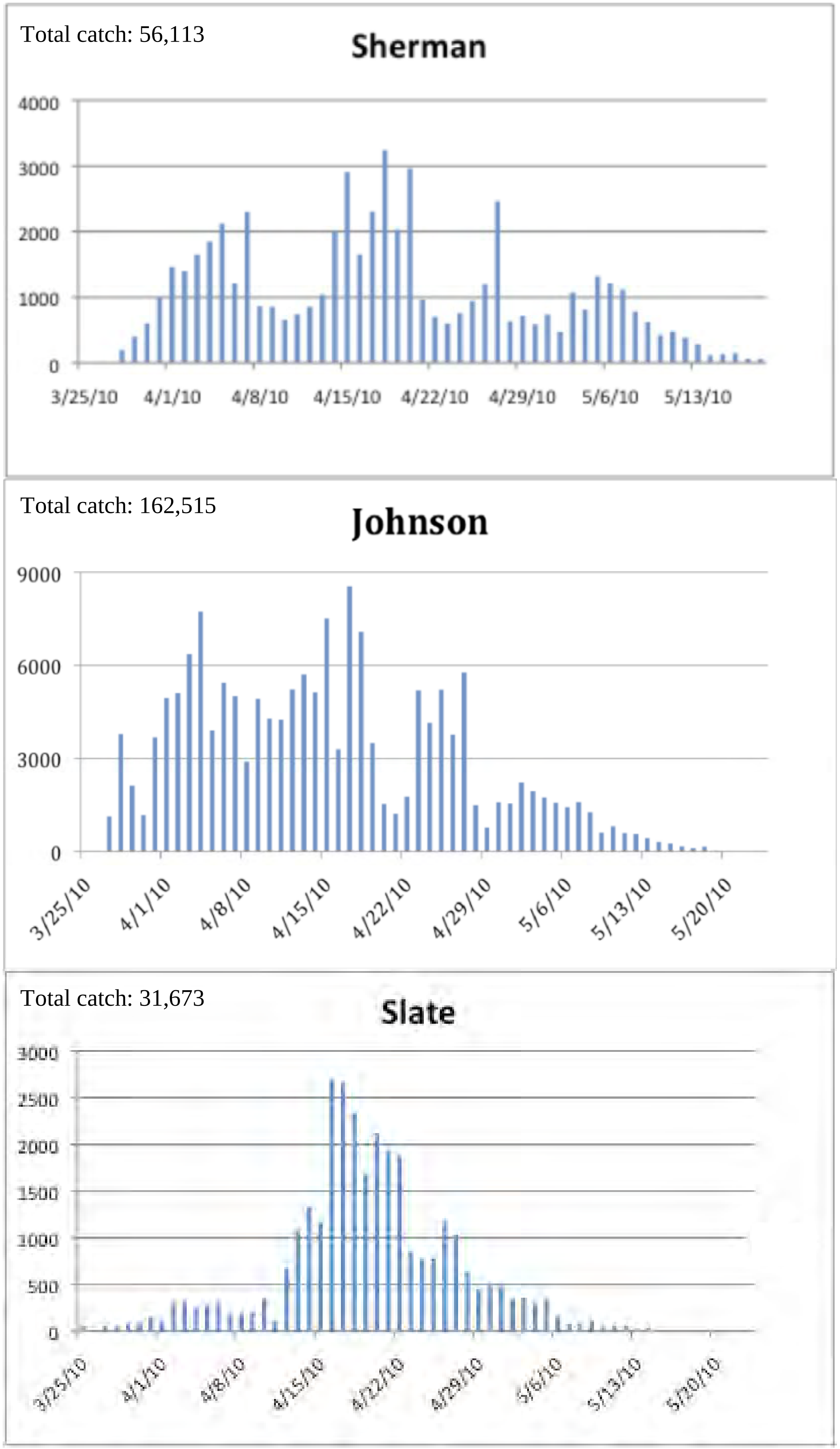


Figure 20: Daily catch of pink salmon fry 2010.

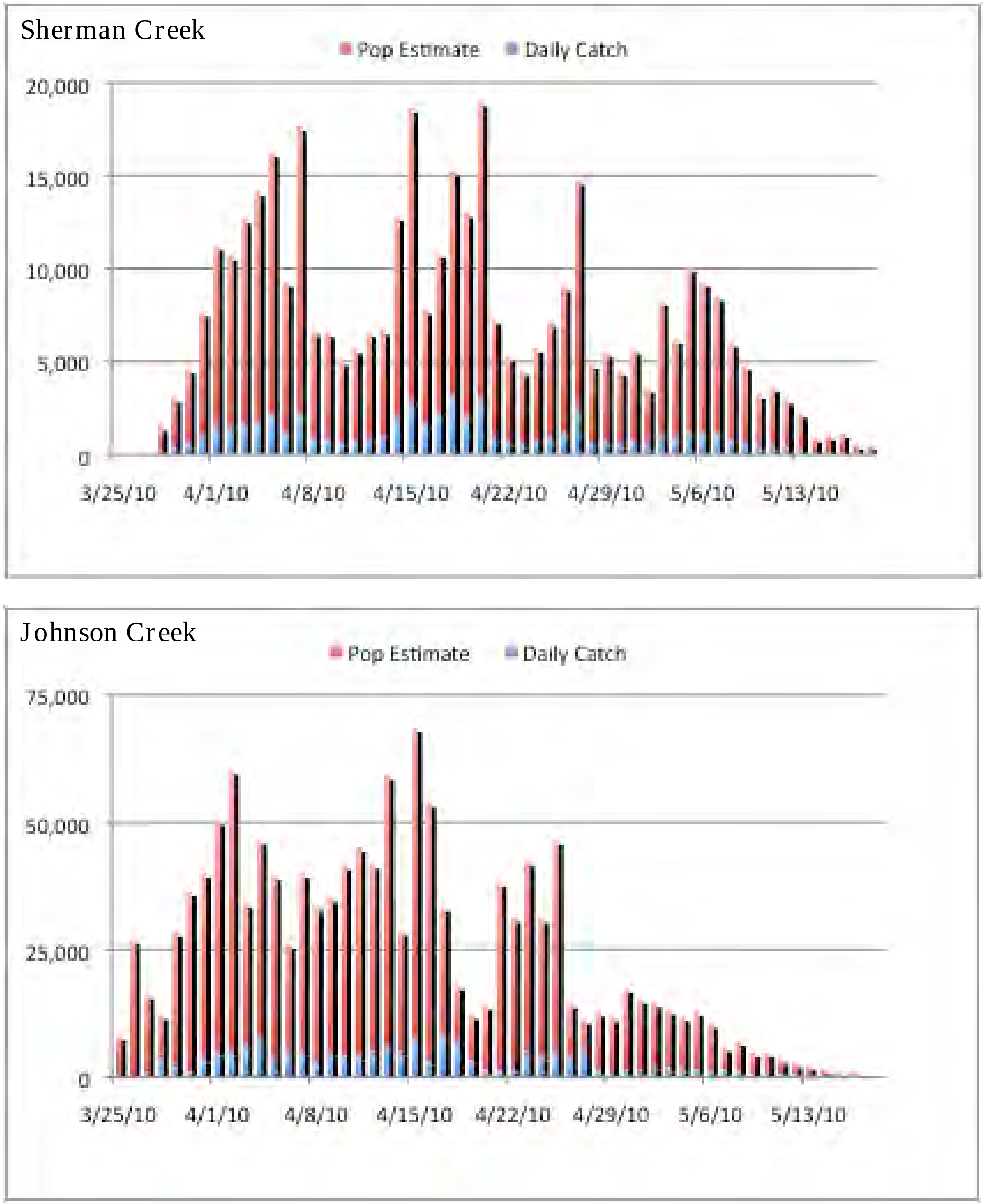


Figure 21: Estimated daily total pink fry migrating downstream.

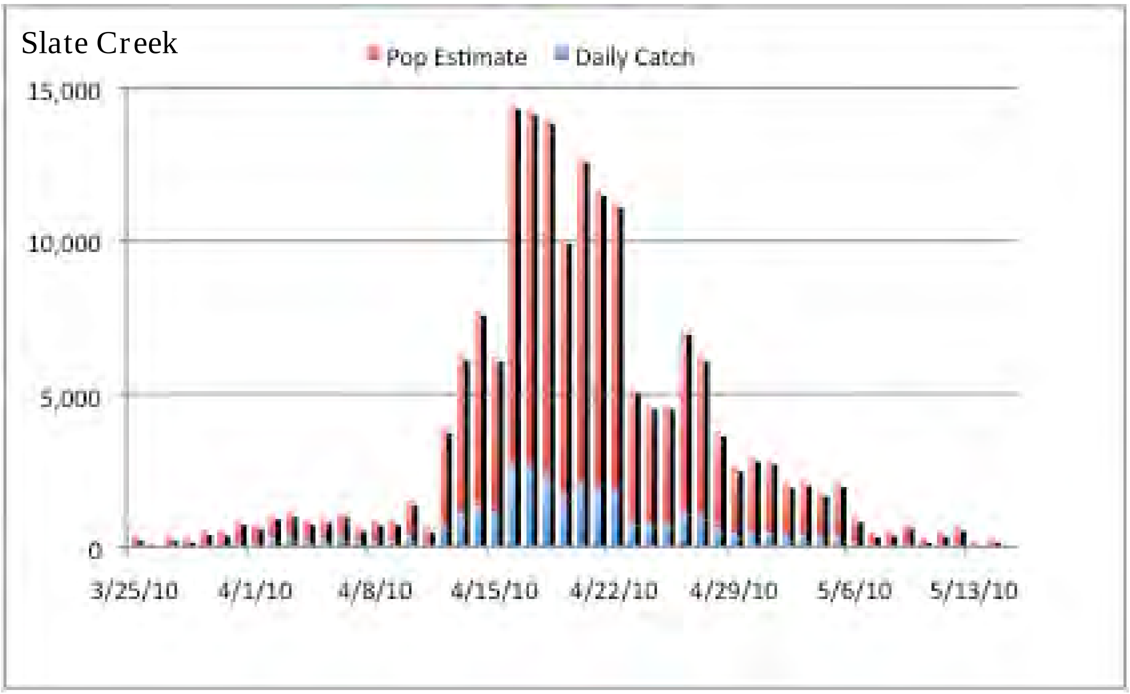


Figure 21: continued.

6.8 Timing of Pink Salmon Outmigration

Numbers of captured fry increased steadily at Johnson Creek from around 1000 fish in late March, rising to around 5,000 by early April, then declining to low numbers by mid-May (Figure 20). Numbers were around 1,500 at Sherman Creek at the beginning of the study and peaked at 3,000 fish in mid-April. Slate Creek numbers began at around 60 fish, peaked around 2,700 fry, in mid-April, and declined in late April. High flows around April 20 and 28 appeared to reduce the number of fry captured at all three streams likely because a smaller proportion of the total flow was sampled (Figure 19). Peaks flows were lower than 2009 when traps had to be removed from the creek to avoid net damage. In addition, the outmigration was more or less over in all streams by the time stream flows really began to increase from snowmelt around May 19. This likely helped keep mortality rates low in 2010. Daily counts of fish at each creek are presented in Appendix 4c.

6.9 Daily Catch and Mark-Recapture Trials

The total catch from Sherman Creek was 53,913 pink salmon fry between April 1 and May 19 with a maximum daily catch of 3,240 fry on April 18. Sherman Creek mark-recapture experiments resulted in 5 to 27% recovery of marked fish with recapture rates varying with stream flow. The lowest recapture rate used for Sherman Creek was 15% to avoid over-estimating the population as some fry may hold close to stream banks for cover rather than migrating in mid-stream where the trap was located. On April 1 there was already a catch of 1,465, therefore the four days prior to this were given estimated catch figures of 200, 400, 600 and 1,000 fish respectively, assuming a bell curve distribution of numbers of fry captured over time. Figure 21 shows the estimated daily total number of pink fry migrating downstream based on mark-recapture trials. The total population estimate for the survey period for Sherman Creek is 301,703 pink fry. Table 18 gives the daily catches of fry and daily population estimates. Highlighted numbers are estimates as no site visit was made on those days.

Johnson Creek was sampled from March 27 to May 19 with a total catch of 162,539 pink fry and maximum daily catch of 8,550 on April 17. Johnson mark-recapture surveys resulted in 8% to 14% recovery. The 14% recapture rate was applied throughout the survey period to avoid overestimating the population. Low recapture rates may result from fry seeking cover from undercut banks when they are released during the daytime. The total population estimate for the Johnson Creek survey based on mark-recapture experiments is 1,160,821 pink fry. Slate Creek was sampled from March 25 to May 15 with a total catch of 31,673 pink fry, and maximum daily catch of 2,704 on April 16. Average recapture rates of typically 20 and 40% resulted in a total population estimate of 147,766 pink fry.

	Sherman		Johnson		Slate	
Date	Pink fry catch	Population Estimate	Pink fry catch	Population Estimate	Pink fry catch	Population Estimate
3/25/10					61	305
3/26/10					14	70
3/27/10			1137	8121	61	305
3/28/10	200	1333	3791	27079	52	260
3/29/10	400	2667	2119	15136	92	460
3/30/10	600	4000	1179	8421	89	445
3/31/10	1000	6667	3680	26286	150	750
4/1/10	1465	9767	4941	35293	126	630
4/2/10	1397	9313	5102	36443	305	763
4/3/10	1652	11013	6351	45364	329	823
4/4/10	1847	12313	7736	55257	254	635
4/5/10	2125	11486	3899	27850	273	683
4/6/10	1211	6546	5438	38843	322	805
4/7/10	2302	12443	5002	35729	196	490
4/8/10	867	3211	2893	20664	205	661
4/9/10	858	3178	4910	35071	209	674
4/10/10	656	2430	4292	30657	358	1155
4/11/10	740	2741	4258	30414	114	543
4/12/10	858	3178	5226	37329	675	3214
4/13/10	1041	3856	5713	40807	1090	5190
4/14/10	1998	7400	5126	36614	1340	6381
4/15/10	2910	10778	7511	53650	1163	5057
4/16/10	1654	6126	3295	23536	2704	11757
4/17/10	2306	8541	8550	61071	2673	11622
4/18/10	3240	12000	7084	50600	2335	11675
4/19/10	2028	7511	3489	24921	1676	8380
4/20/10	2962	16011	1532	10943	2122	10610
4/21/10	965	6307	1223	8736	1939	9695
4/22/10	700	4575	1770	12643	1876	9380
4/23/10	598	3908	5194	37100	862	4310
4/24/10	760	4967	4151	29650	777	3885
4/25/10	946	6183	5218	37271	776	3880
4/26/10	1198	7830	3773	26950	1184	5920
4/27/10	2462	12310	5778	41271	1042	5210
4/28/10	634	4227	1492	10657	632	3160
4/29/10	716	4773	777	5550	441	2205
4/30/10	585	3900	1585	11321	493	2465
5/1/10	738	4920	1546	11043	479	2395
5/2/10	468	3120	2228	15914	351	1755
5/3/10	1072	7147	1936	13829	362	1810
5/4/10	812	5413	1744	12457	303	1515
5/5/10	1317	8780	1570	11214	355	1775
5/6/10	1212	8080	1423	10164	163	815
5/7/10	1111	7407	1590	11357	79	395
5/8/10	785	5233	1274	9100	87	435
5/9/10	623	4153	604	4314	128	640
5/10/10	422	2813	812	5800	49	245
5/11/10	474	3160	591	4221	88	440
5/12/10	385	2567	559	3993	126	630
5/13/10	288	1920	421	3007	30	150
5/14/10	118	787	311	2221	52	260
5/15/10	133	887	262	1871	11	55
5/16/10	147	980	165	1179		
5/17/10	65	433	107	764		
5/18/10	62	413	157	1121		
5/19/10			24	171		
Totals	56,113	301,703	162,539	1,160,993	31,673	147,766

Table 18: Daily Catch and Estimated Daily Population Estimates.

6.10 Total Population Estimates

Numbers of pink fry migrating downstream in the spring of 2010 were estimated from mark-recapture experiments as 301,703, 1,160,821 and 147,766 in Sherman, Johnson and Slate respectively. These estimates only include fry that hatched upstream of the traps. These estimates only include fry that hatched upstream of the traps. Sherman Creek has approximately 12% of total spawning habitat located downstream of the trap. If an equivalent number of fry emerged downstream of the trap, then the total out-migrating fry count would include an additional 12% or 36,204 fry bringing the total to 337,907. Johnson Creek has approximately 10% of the total spawning habitat downstream of the trap giving a final total estimate of 1,276,904. Slate Creek had an additional 12% of potential spawning habitat downstream of the trap giving a total estimate of 165,498 pink fry. Based on these estimates, total mortality caused by monitoring was 0.24% (1091 fry), 0.04% (527 fry) and 0.45% (744 fry) of the total estimated outmigration in Sherman, Johnson and Slate Creeks, respectively.

Estimates of pink salmon out-migrants varied widely between years (Table 19). At Sherman Creek, there were four times as many fry captured in 2010 than 2009, but this was partly due to the use of wings trapping a greater proportion of fry. The number of fry emigrating should be related to the number of adult salmon present the previous fall. The number of spawning pink salmon adults estimated in 2009 was 2,060 in Sherman Creek, 5,968 in Johnson Creek and 837 in Slate Creek. Assuming a 1:1 sex ratio, the numbers of adult female salmon present would have been 1,030 at Sherman, 2,984 at Johnson and 418 at Slate Creek. The estimated number of fry produced per adult female is therefore 328 at Sherman Creek, 423 at Johnson Creek and 396 at Slate Creek. Previous estimates for Sherman Creek vary widely from only 7 fry per female in 2006 to 782 in 2008. The low estimate for Sherman Creek in 2006 came after a large flood event in December 2005, which may have scoured out many redds in the short, 350m spawning reach available in this stream. Slate Creek also showed a relatively lower ratio of fry per female (134) for that same year. The high estimate was thought to be in error and adjusted accordingly. Average pink salmon fry production over 15 brood years in Auke Creek, SE Alaska, was 25 fry per female (Fukushima 1996). In other streams fry production varied between 50 and 200 (Chebanov 1989) and between 103 and 562 (Shershnev and Zhul'kov 1980).

Sherman Creek					Total eggs laid		Egg to fry survival	
	Fry	PY Adults	PY Females	Ratio	1500 eggs	2000 eggs	1500 eggs	2000 eggs
2006	10,254	2,973	1487	6.9	2,229,750	2,973,000	0.5%	0.3%
2007	184,149	1,000	500	368.3	750,000	1,000,000	24.6%	18.4%
2008	152,532	390	195	782.2	292,500	390,000	52.1%	39.1%
2009	123,152	784	392	314.2	588,000	784,000	20.9%	15.7%
2010	337,907	2,060	1030	328.1	1,545,000	2,060,000	21.9%	16.4%
Johnson Creek					Total eggs laid		Egg to fry survival	
	Fry	PY Adults	PY Females	Ratio	1500 eggs	2000 eggs	1500 eggs	2000 eggs
2006	539,705	2,782	1391	388.0	2,086,500	2,782,000	25.9%	19.4%
2007	1,221,691	6,534	3267	373.9	4,900,500	6,534,000	24.9%	18.7%
2008	785,793	3,158	1579	497.7	2,368,500	3,158,000	33.2%	24.9%
2009	874,855	7,954	3977	220.0	5,965,500	7,954,000	14.7%	11.0%
2010	1,276,904	5,968	2984	427.9	4,476,000	5,968,000	28.5%	21.4%
Slate Creek					Total eggs laid		Egg to fry survival	
	Fry	PY Adults	PY Females	Ratio	1500 eggs	2000 eggs	1500 eggs	2000 eggs
2006	38,722	576	288	134.5	432,000	576,000	9.0%	6.7%
2007	1,032,843	2,428	1214	850.8	1,821,000	2,428,000	56.7%	42.5%
2008	20,721	88	44	470.9	66,000	88,000	31.4%	23.5%
2009	349,766	1,878	939	372.5	1,408,500	1,878,000	24.8%	18.6%
2010	165,498	837	419	395.5	627,750	837,000	26.4%	19.8%
	PY = previous year spawners							

Table 19: Number of pink fry and previous year spawner estimates used to calculate numbers of fry produced per female salmon.

There is evidently large variability in fry production from year to year and from stream to stream. Examination of previous year spawning numbers can still help explain variation in numbers of fry. In 2009 there was an estimated 2,060 adults at Sherman Creek compared to 784 in 2008 (Table 19). In 2010 there was almost 338,000 fry compared to 110,000 in 2009. This indicated that around 2.6 times as many adults produced about 3 times as many fry. At Johnson Creek, there was 1.6 times as many fry in 2010 compared to the previous year, but they were produced by one third fewer adult salmon. This suggests either conditions in the stream resulted in higher survival of embryos or it could be related to the odd-year salmon population laying more eggs. 2006, 2008 and 2010 all show higher ratios of fry to adult females. It is possible that competition for redd sites in years when more adult salmon are present, results in overall loss of salmon embryos. Fukushima et al. (1998) found that use of limited spawning areas led to the loss of eggs by displacement by late spawners and was roughly proportional to spawner abundance.

Slate Creek had about half as many adult salmon in 2009 compared to 2008, and the pink fry population was estimated at around half that of the previous year. In summary, the population estimates were within the range expected from the number of adults observed spawning the previous year.

The survival rate from egg to emergent fry can be estimated by assuming each female lays between 1500 and 2000 eggs (Heard 1991). For Sherman Creek, total egg production would lie between 1,545,000 eggs (1030 females x 1500 eggs) and 2,060,000 eggs (1030 females x 2000 eggs). If 337,907 fry emerged in April and May then between 16.4 and 21.9% survived from the egg stage (Table 18B). For Johnson Creek, an estimated 4,476,000 to 5,968,000 eggs produced 1,276,904 fry or between 21 and 28.5% survived. At Slate Creek, an estimated 627,750 to 837,000 eggs produced 165,498 fry so the survival rate was between 20 and 26%. Overall freshwater survival of pink salmon from egg to alevin, even in highly productive streams, commonly reaches only 10-20%, and at times is as low as 1% (Heard, 1991). In Sashin Creek, SE Alaska, egg to fry survival varied from 0.1 to 22 % (Heard, 1978) over a 28 year period. Quinn (2005) gives a rate of 11.5% as being typical.

6.11 Other Species Collected

In addition to pink salmon, six other species were caught in the fyke nets (Table 20). 6,587 chum salmon fry (*Oncorhynchus keta*) were captured in Johnson Creek during the study, but only 126 were caught at Slate Creek and 6 in Sherman Creek. Most of the chum salmon at Johnson Creek were captured throughout April, tailing off in May while at Slate Creek were caught chum were mostly caught during the last two weeks of April. Other species caught in Sherman Creek included two Dolly Varden, caught May 3 and 14 and a coast-range sculpin (*Cottus aleuticus*) captured April 27. A total of 387 coast-range sculpins were caught in Slate Creek and 39 were caught in Johnson Creek. 115 juvenile coho salmon were caught in Johnson Creek and 43 caught in Slate Creek. Over 40 Dolly Varden fry (*Salvelinus malma*) were captured in Johnson and Slate Creeks. 53 eulachon (*Thaleichtys pacificus*) were captured in Slate Creek between mid-April and mid-May as they entered the stream to spawn. Some spawned-out eulachon were found in the Slate Creek trap.

Species	Sherman	Johnson	Slate	Total
Pinks	56,113	162,515	31,673	250,301
Chum	6	6,587	126	6,719
Coho	0	115	43	158
Dolly Varden	2	45	2	49
Cutthroat	0	0	0	0
CR Sculpin	1	39	387	427
Eulachon	0	0	53	53

Table 20: Other species captured in fyke nets at each creek.

6.12 Discussion and Recommendations

Fry estimates produced by mark-recapture can be over-estimated if fry are able to avoid capture either by deliberate movement around the trap or by being eaten by predators. Flow at Sherman Creek is typically swift enough to prevent fry from deliberately avoiding trap, but release site for marked fish is upstream of a deep pool that may shelter predators such as Dolly Varden. Predation could result in fewer marked fish being recaptured and inflated population estimates, although the lowest recapture rates were excluded from estimates. There could also be error in counts of adult salmon that would affect estimates of numbers of fry per adult female. Since the 2010 fry estimates seem to have reasonable egg-to-fry survival rates, no further adjustment of figures was made.

In 2010, Johnson Creek had almost 8 times the population of Slate Creek and almost 4 times that of Sherman Creek. This is a similar pattern to that found in previous years. Johnson Creek has more spawning habitat than the other creeks, with barrier falls located approximately 1.5km upstream from Berners Bay. Sherman Creek has barrier falls only 360m upstream from the ocean and Slate Creek has barrier falls approximately 900m from the ocean. Additionally, pink salmon at Slate Creek rarely ascend beyond 600m upstream. The total anadromous area in Sherman Creek was measured as 1,944m^2 in July 2005 (Resident Fish Surveys, Coeur Annual Report 2005). The anadromous area of Johnson Creek has not been measured, but can be estimated from the distance from stream mouth to falls (1.5km) multiplied by average stream width of 8m giving an area of roughly 12,000m^2. Slate Creek can be estimated by multiplying 900m by 9m giving 8100m^2, with the area in the first 600m approximating 5,400m^2. The difference in numbers of fry between Johnson Creek and Sherman Creek is roughly in proportion to the difference in habitat area present.

Fukushima et al. (1998) found that use of limited spawning areas led to the loss of eggs by displacement by late spawners and was roughly proportional to spawner abundance. Smirnov (1975) suggested that 1.5 - 2.0 m^2 of spawning area per female was necessary for effective use of spawning grounds. A total of 1,030 female spawners at Sherman Creek during the previous fall, would allow 1.8m^2 per female and 2,984 females at Johnson Creek would allow 4m^2 per female. At Slate Creek, the majority of adults were observed in the first 600m of the creek, but even with 5,400m^2, the 419 females at Slate Creek would have had 12.9m^2 per female. Even though the spawning substrate available would be much less than the total stream area available, it appears that spawning area limitation was not a factor affecting fry survival.

Mortality due to sampling in 2010 was less than 0.5% of the total estimated population for Sherman and Slate Creek and less than 0.1% for Johnson Creek. Mortality can occur when high flow causes fry to become impinged against the net wall or large amounts of debris trap fry against the walls of the holding box. The height-adjustable legs of the holding boxes made it easy to accommodate a wide range of stream flows from day to day, helping reduce mortality rates. In 2010, debris traps set upstream of the fyke nets, greatly reduced the amount of debris in the traps and the amount of mortality. Low flows also helped keep mortality rates down.

Outmigration began around 2 weeks earlier in 2010 in a pattern following other streams near Juneau (Kate Kanouse, ADFG). This is likely a function of water temperature. All three streams peaked close to the same time between April 16 and 18. This was only one day earlier than 2009 for Sherman Creek, but 10-12 days earlier for Johnson and Slate Creeks respectively.

7.0 Adult Salmon Counts

7.1 Surveys and Analysis

Counts of migrating adult pink salmon were made once a week in the anadromous reaches of Sherman, Johnson and Slate creeks from July 22 to September 15, 2010. Prior to the first survey, markers were placed along one bank of each creek at 50m intervals (Sherman and Sweeny Creeks) or 100m intervals (Slate Creek). Each survey on Sherman and Slate Creeks was conducted by biologists on foot, who began at the intertidal zone and proceeded upstream along the bank, recording live and dead salmon present in each reach. Johnson Creek was surveyed using a combination of foot surveys and aerial surveys from a helicopter. Reach numbers painted on sheet metal are located on various log jams and can be read from the air to locate reaches. Approximate stream flow (low, average, high) and water clarity (visibility of fish) were noted at the beginning of each survey.

Data gathered during weekly surveys was used to determine the abundance and distribution of returning adult salmon in each stream, as well as the timing of the spawning run. Total escapement (the number of salmon that return to their natal stream to spawn) for pink salmon was estimated using the methods of Neilson and Geen (1981), where the sum of all weekly counts is divided by the average residence time of adult spawners in the stream. Since each weekly count includes some fish counted in the previous survey, an adjustment was made to avoid overestimation of escapement. The number of times an individual fish may have been counted during consecutive surveys is assumed to equal the average residence time. A residence time of two weeks was used to compute escapement, as this has been used in previous studies in the area (Biotec 1998, USDA 1997). In a tagging study conducted by Pentec (1990), the residence time of pink salmon spawners in Sherman Creek ranged from one to three weeks. Chum and coho were only observed for one week so the total number observed was used as the escapement for these salmon.

7.2 Adult Salmon Counts

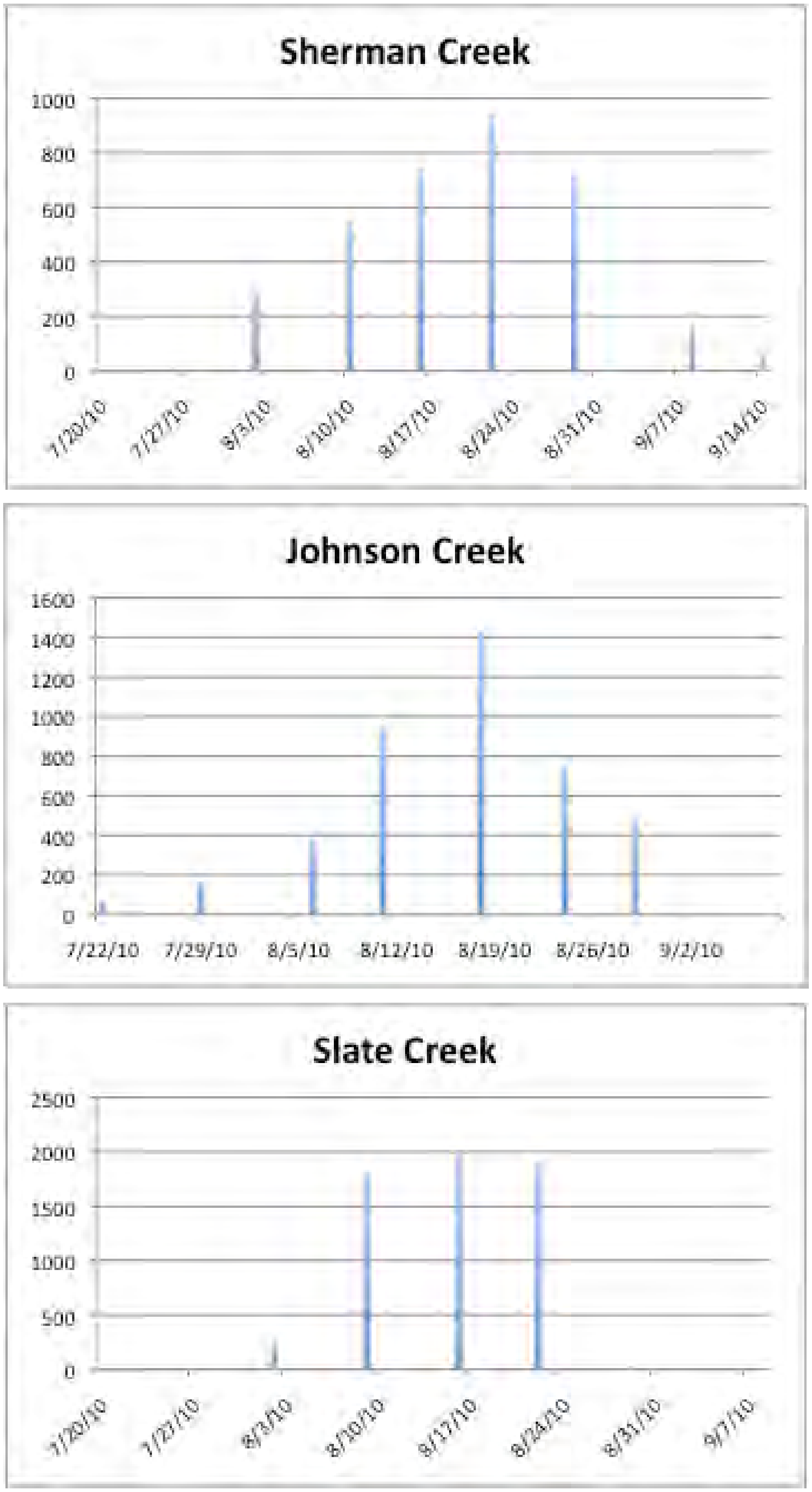
Weekly counts of adult salmon migrating into streams to spawn in 2010 are presented in Appendix 5. Figure 22A shows the magnitude and timing of the pink salmon spawning runs in Sherman, Johnson and Slate Creeks. Pink salmon were observed in Sherman Creek from July 22 to September 14 with a maximum of 945 live individuals observed on August 22. No chum or coho salmon were observed in Sherman Creek. At Johnson Creek, pink salmon were observed from July 22 to August 29, with numbers peaking at around 1,440 fish on August 18. Around 20 chum salmon were observed in Johnson Creek on July 22, around 80 on July 29, around 180 on August 6, and 80 on August 11.

At Slate Creek, pinks were observed from July 26 to August 29 with numbers peaking at 2,015 on August 16. No chum salmon were observed in Slate Creek in 2010. Numbers of pink salmon reached a peak around mid-August in each stream. The magnitude of the pink salmon escapement in Johnson Creek is normally much greater than Sherman and Slate Creek, but low flows in August 2010 may have affected salmon migration into Johnson Creek. Slate Creek actually had the highest number of salmon of the three streams in 2010 (Table 21).

Table 21: Salmon Escapement by stream for 2010.

	Salmon Escapement		
	Sherman Creek	**Johnson Creek**	**Slate Creek**
Pink	**1,750**	**2,114**	**3000**
Chum	**0**	**180**	**0**

Figure 22A: Weekly Counts of Adult Pink Salmon.



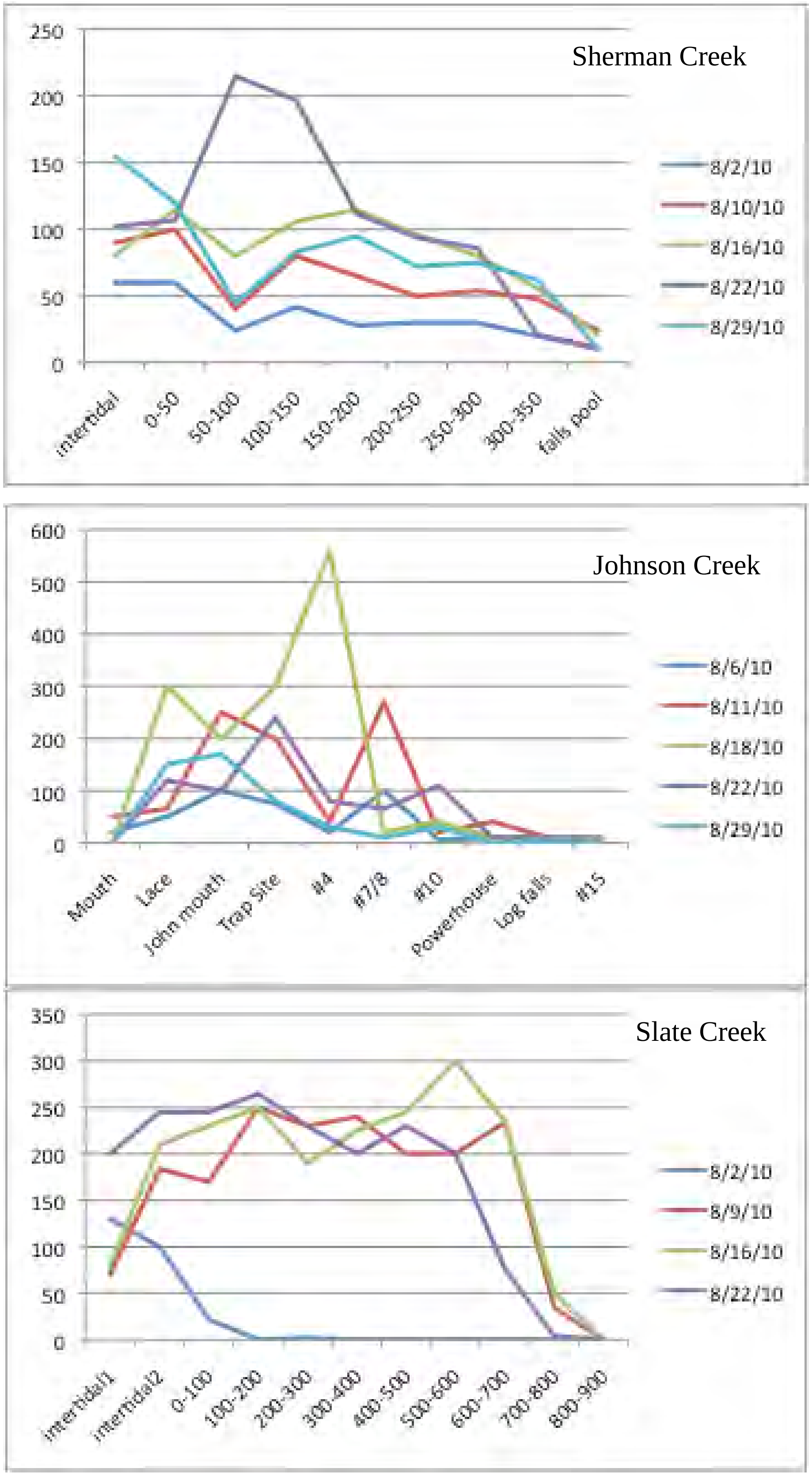


Figure 22B: Distribution of pink salmon at Sherman, Johnson and Slate Creeks.

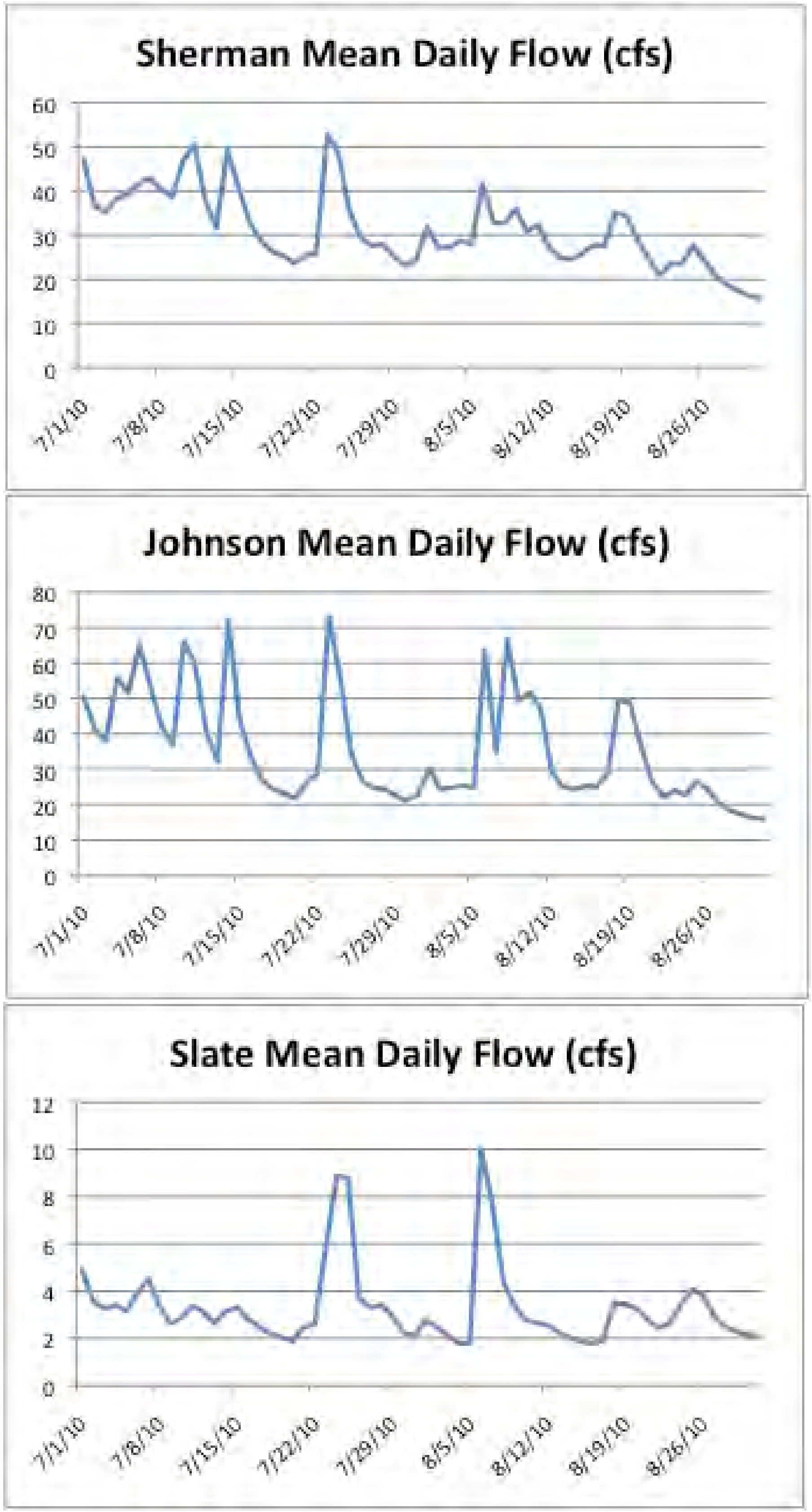


Figure 23: Mean daily flow in cubic feet per second

The distribution of salmon in each stream throughout the surveys is shown in Figure 22B. Salmon were fairly evenly distributed throughout Sherman Creek on all survey dates except for lower numbers between 50 and 100m, which is dominated by fast riffle. There was an exception to this on August 22 when flows were lower and more salmon concentrated here to spawn. In Johnson Creek, there was a peak in numbers of pink salmon around #4 marker (approx 400m upstream) on August 18, with lower numbers all the way up to the old powerhouse site about 1km upstream from the mouth. The stream changes here from gentle riffle and deep pools to faster, steeper riffle with less spawning habitat available. Similarly the majority of salmon at Slate Creek were observed below 700m, prior to the creek changing from gravel to bedrock substrate. A small log jam was also observed at around 720m to act as a barrier to further upstream migration.

7.3 Pink Salmon Escapement Comparison

A comparison of pink salmon escapement between 2005 and 2010 is shown in Figure 25. In South-East Alaska, the size of the adult pink salmon return is generally higher in even-years than odd-years due to their 2 year life cycle and lack of interbreeding between two distinct populations (Quinn 2005). It is thought that the even-year salmon populations are better adapted to cooler water. The last ice age may have divided one population into a warm-water adapted southern (odd-year) population and a cooler water northern (even-year) population.

This pattern can be seen in the lower numbers returning to Johnson and Slate Creeks in 2005 and 2007 and higher returns 2006 and 2008. The pattern does not hold well in drier summers, particularly at Sherman and Slate Creeks where low flow inhibits upstream migration. Escapement at Sherman and Slate Creeks in 2007 appeared to be affected by low flows due to dry weather in August coinciding with the peak of the salmon run. Schools of pink salmon were observed in the intertidal zones of these streams, apparently unable to ascend upstream due to lack of water. Low flow in 2010 also appeared to inhibit salmon migration to Johnson Creek, but did not affect Sherman or Slate Creek. Slate Creek had the highest run recorded since 2005. It is possible that some salmon unable to ascend Johnson Creek, instead entered Slate Creek. Johnson Creek was previously thought to be somewhat protected from low flow due to groundwater flows, but this did not hold for 2010. A peak flow of 50cfs on August 18 may have allowed fish upstream before declining to 15cfs at the end of August (Figure 23).

Sherman Creek may have the opposite pattern of higher odd year returns, based on numbers in 2005 and 2009 being higher than other years, but 2010 also showed a relatively high return, being the third highest since 2005. If odd years are higher at Sherman, then 2007 should also have been a high year, but very low flows inhibited access to the stream as salmon could not negotiate the falls near the mouth of the creek. The right combination of stream flows and tide may partly determine the number of salmon that ascend Sherman Creek. Hide tides over 18ft were observed from August 9-15 in 2010, which coincided with peak salmon numbers (Figure 23). One or two brown bears are also often observed feeding on salmon for long periods at the mouth of Sherman. One brown bear was observed removing 20 salmon from the intertidal zone in less than one hour in 2009. There were very few bear sightings at the streams in 2010, which may also have contributed to higher numbers Sherman and Slate.

The salmon run at Slate Creek was likely also aided by high tides in mid-August since numbers increased rapidly between August 3 and 10. There was a sharp decline in Slate salmon numbers between August 22 and 29 when flows and tides remained low. Given the large number of healthy salmon (almost 2,000) observed on August 22 and large number of dead salmon present a week later, it is possible that some salmon died before spawning, perhaps due using up all the oxygen at low flow. If this was the case it will affect numbers of fry out-migrating in 2011.

Johnson Creek experienced a peak in flow around August 18-19 of 50cfs, which just preceded peak salmon numbers. Salmon numbers then declined as flow dropped towards 15cfs by the end of August (Figure 23). The 2009 return still stands as an unusually high odd-year return at Johnson and Slate Creeks. In general, 2010 appears to have had a strong return, inhibited by low flow at Johnson Creek.

Figure 24: Pink salmon observed in Sherman Creek.

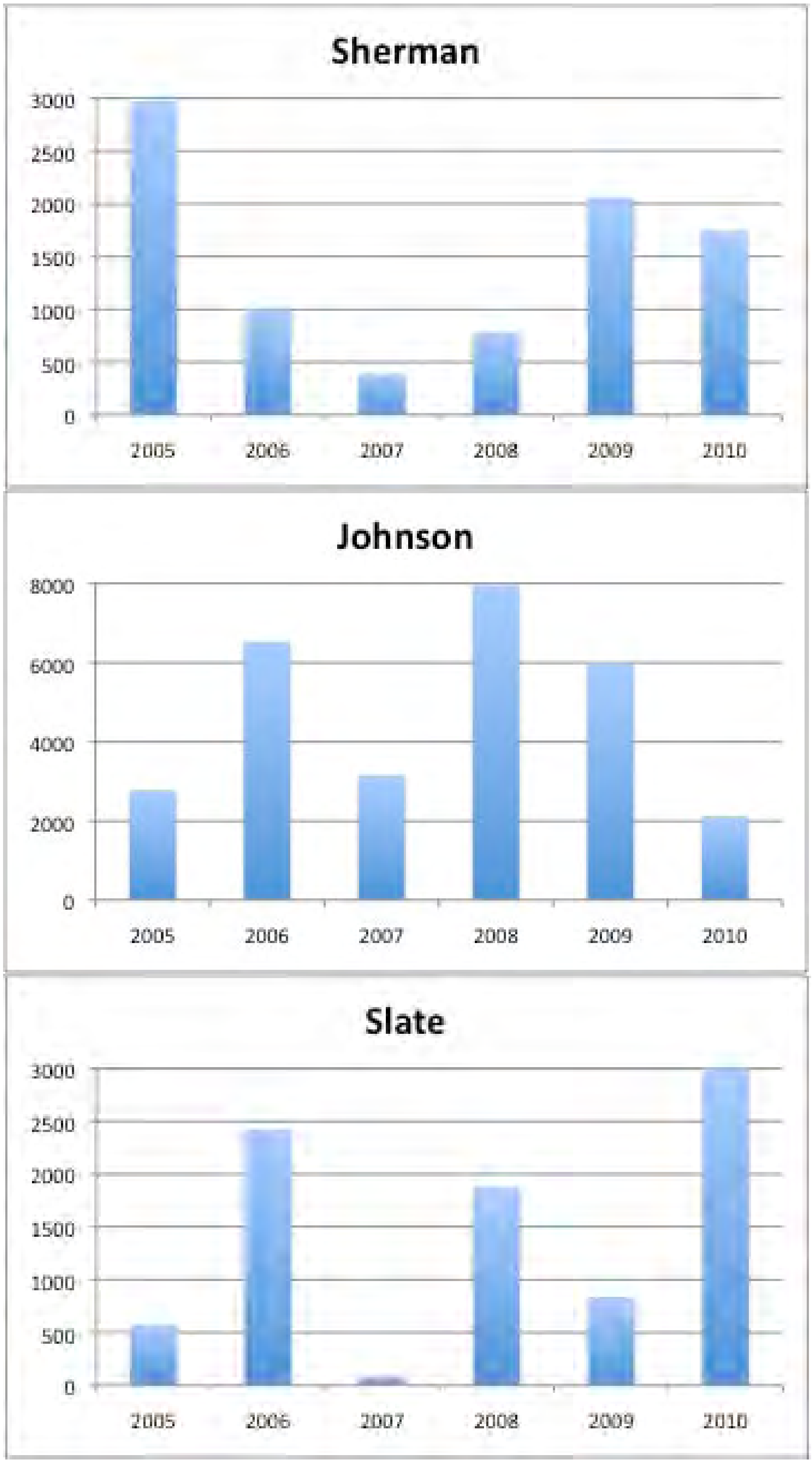


Figure 25: Estimated pink salmon escapement from 2005 to 2010.

8.0 Quality of Spawning Substrate

8.1 Sample Collection and Analysis

Core samples of spawning gravel were collected from each of two reaches in Sherman Creek on July 21, Slate Creek on August 2 and Johnson Creek on July 20, 2010, prior to salmon spawning activity. At Sherman Creek, Reach 1 lies between 3 and 29m, and Reach 2 lies between 288 and 315m from the stream mouth, as defined by Konopacky (1992). The two sampling reaches at Slate Creek are located between 125 and 150m, and between 175 and 200m from the stream mouth. At Johnson Creek the sampling reaches are located between 320 and 340m, and between McNeil-type sampler with a basal coring diameter of 15cm and a coring depth of 25cm (Figure 26). Individual sample sites were randomly chosen from all potential spawning areas that were suitable for sampling, namely, substrate size less than 15cm and water depth less than 30cm as described by Valentine (1995).

Figure 26: McNeil sampler in place at Reach 2 of Johnson Creek.

Collected substrate was wet-sieved on site through the following sieve sizes in mm: 101.6, 50.8, 25.4, 12.7, 6.35, 1.68, 0.42, and 0.15, which were used by Konopacky (1992) for baseline sampling. The contents of each sieve were allowed to drain and then measured by volume of water displaced to the nearest 5ml for the 101.6 to 0.42mm sieve sizes and to the nearest 1ml for the 0.15mm sieve. Fine material that passed through the smallest sieve was poured into Imhoff cones to settle out; and this volume read directly from each cone.

Figure 27: Displacement of water is used to measure volumes of gravel.

Due to the presence of interstitial and surface water in each sample, the volumetric measurements were converted to dry weights using correction factors determined by Shirazi et al (1981) assuming a gravel density of 2.6g/cm^3. The geometric mean particle size and sorting coefficient (the distribution of grain sizes present) were calculated for each sample using methods from Lotspeich & Everest (1981). The geometric mean particle size (d_g) is an index of the textural composition. The grain size at the midpoint of each size class is raised to a power equal to the decimal fraction of its volume. In other words, the volumes of sediment in each size class are converted to percentages of the whole sample then the midpoint of each size class is raised to this power.

The products of each size class are then multiplied together to obtain the geometric mean, d_g:

$$d_g = (d_1^{v1} \, x \, d_2^{v2} \ldots\ldots\ldots\ldots x \, d_n^{v_n})$$

where: dg = geometric mean particle size

d = midpoint diameter of particles retained by a given sieve

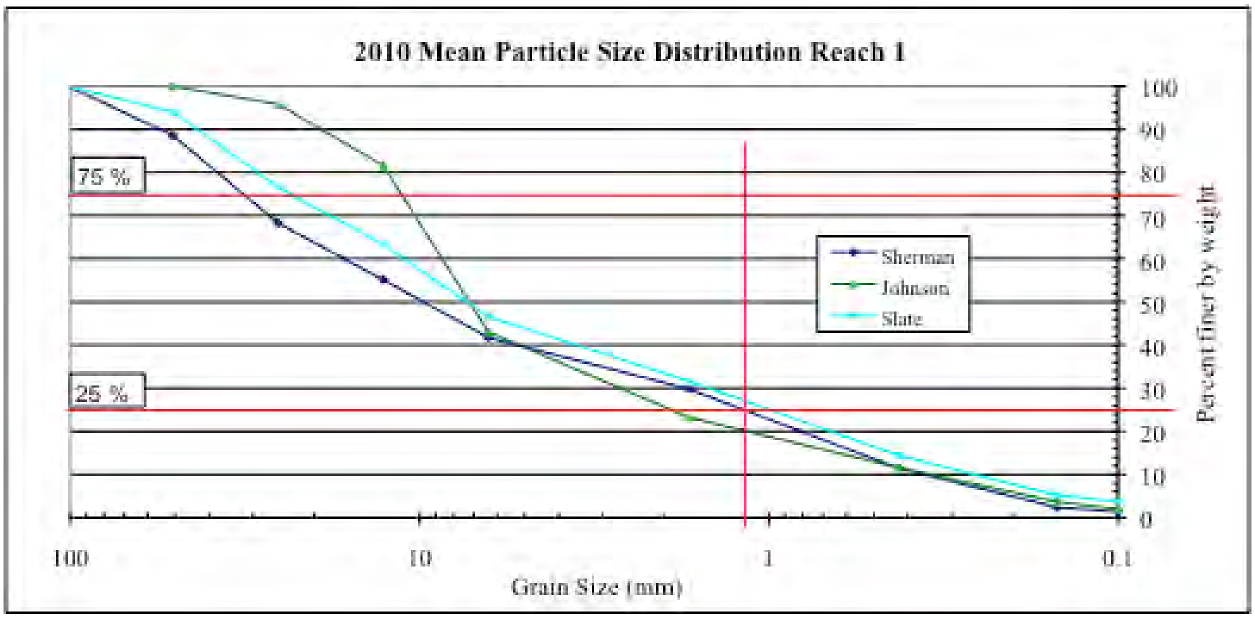
v = decimal fraction by volume of particles retained by a given sieve

Sediment texture does not control survival to emergence of embryos directly, but the influence of texture on pore size and permeability affects embryo survival (Lotspeich & Everest 1981). The sorting coefficient (S_o) is an index of the size distribution of sediment particles in a sample and provides a useful indicator of the permeability of gravel for salmonid spawning. The grain size at the 75th percentile of total sample volume is divided by that at the 25th percentile. The square root of the result provides the sorting coefficient. A gravel consisting of only one grain size has a S_o of 1. A S_o greater than 1 represents gravel made up of several grain sizes with the smaller grains filling up pores between larger ones. S_o is therefore inversely proportional to permeability (Lotspeich & Everest 1981). The Fredle index (F_i), or stream quality index, is a ratio of geometric mean particle size and sorting coefficient and provides a measure of the quality of spawning gravel for salmonid reproduction (Lotspeich and Everest, 1981). As the magnitude of the Fredle index increases, both pore size and permeability increase.

$$F_i = d_g/S_o$$

8.2 Spawning Gravel Composition

The volumetric measurements of gravel sizes retained by sieves are presented in Appendix 4. The geometric mean particle size (d_g), grain size percentiles (75th and 25th), sorting coefficient (S_o), Fredle index (F_i), and Embryo Survival Prediction (%) are presented in Table 22. Embryo survival predictions and grain size percentiles are obtained graphically from Lotspeich & Everest (1981). The average geometric mean particles size at Sherman Creek was 12.72mm at Reach 1 and 15.6 at Reach 2. At Johnson Creek, Average d_g ranged from 11.4 to 11.7 mm and Slate Creek from 11.9 to 12.8mm. Sherman and Slate Creeks had similar gravel composition, but Johnson Creek generally had smaller gravel (Figure 29).



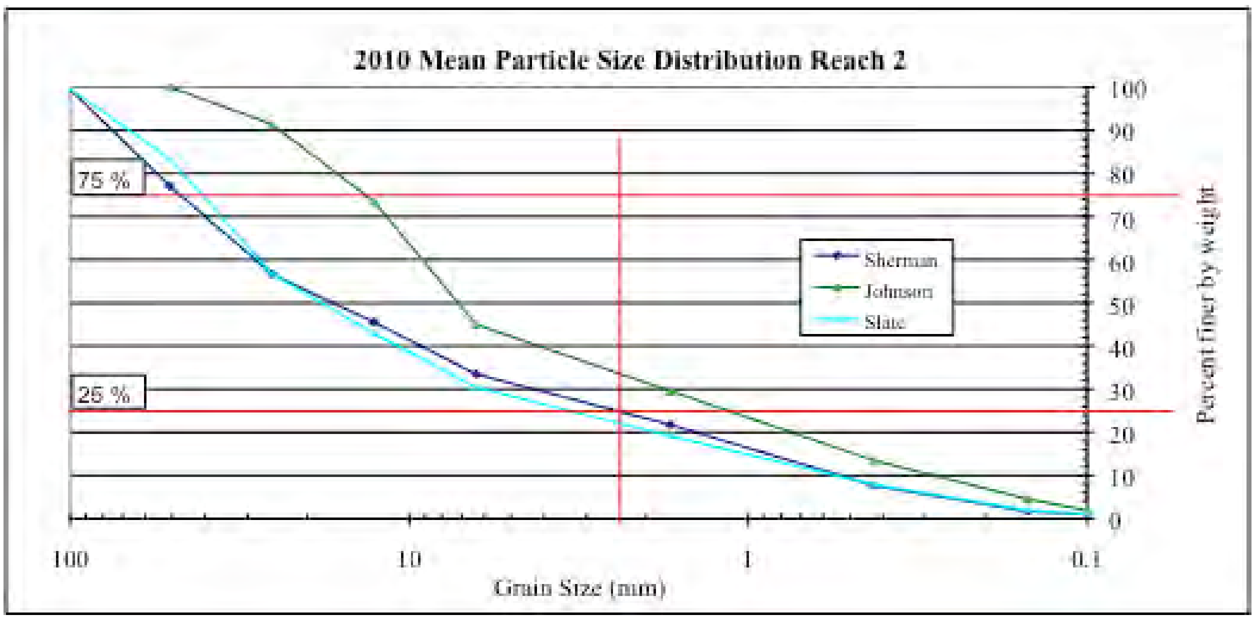


Figure 29: Cumulative size distribution curves for gravel samples collected in 2010. The vertical red line is used to identify data meeting the 25% and 75% percentiles.

	Sample	Geometric Mean (mm) dg	Grain size percentile (75th and 25th) d75	d25	Sorting Coefficient So	Fredle Index (f = dg/So)	Survival-to-Emergence Prediction (%)
Sherman Creek							
Reach 1	1	11.24	13	0.95	13.68	0.82	1.0
	2	13.35	23	1.2	19.17	0.70	1.0
	3	11.39	19	0.99	19.19	0.59	0.8
	4	14.82	27	1.1	24.55	0.60	0.8
	Mean	**12.70**	**20.50**	**1.06**	**19.15**	**0.68**	**0.9**
	Standard Deviation	1.71	5.97	0.11	4.43	0.11	0.1
	95% Confidence Interval	1.67	5.85	0.11	4.35	0.10	0.1
Reach 2	1	16.26	61	10	6.10	2.67	35.0
	2	13.00	30	1.3	23.08	0.56	0.5
	3	11.26	15	1.3	11.54	0.98	1.0
	4	22.12	72	12	6.00	3.69	50.0
	Mean	**15.66**	**44.50**	**6.15**	**11.68**	**1.97**	**21.6**
	Standard Deviation	4.78	26.51	5.66	8.03	1.46	24.9
	95% Confidence Interval	4.68	25.98	5.55	7.87	1.43	24.4
Johnson Creek							
Reach 1	1	11.64	11	1.8	6.11	1.90	25.0
	2	11.79	12	1.8	6.67	1.77	20.0
	3	11.84	12	2.5	4.80	2.47	35.0
	4	11.69	11	1.8	6.11	1.91	25.0
	Mean	**11.74**	**11.50**	**1.98**	**5.92**	**2.01**	**26.3**
	Standard Deviation	0.09	0.58	0.35	0.79	0.31	6.3
	95% Confidence Interval	0.09	0.57	0.34	0.78	0.30	6.2
Reach 2	1	10.85	11	0.62	17.74	0.61	0.8
	2	12.17	18	3.4	5.29	2.30	34.0
	3	11.83	14	2.3	6.09	1.94	23.0
	4	10.83	11	0.62	17.74	0.61	0.8
	Mean	**11.42**	**13.50**	**1.74**	**11.72**	**1.37**	**14.7**
	Standard Deviation	0.68	3.32	1.36	6.97	0.88	16.6
	95% Confidence Interval	0.67	3.25	1.34	6.83	0.87	16.3
Slate Creek							
Reach 1	1	11.20	18	0.8	22.50	0.50	0.5
	2	12.41	28	1	28.00	0.44	0.5
	3	12.87	28	1.8	15.56	0.83	1.0
	4	11.03	14	0.8	17.50	0.63	0.6
	Mean	**11.88**	**22.00**	**1.10**	**20.89**	**0.60**	**0.7**
	Standard Deviation	0.90	7.12	0.48	5.57	0.17	0.2
	95% Confidence Interval	0.89	6.98	0.47	5.46	0.17	0.2
Reach 2	1	13.91	40	3.8	10.53	1.32	9.0
	2	9.67	70	11	6.36	1.52	15.0
	3	13.93	31	1.9	16.32	0.85	1.0
	4	13.84	27	2.6	10.38	1.33	9.0
	Mean	**12.84**	**42.00**	**4.83**	**10.90**	**1.26**	**8.5**
	Standard Deviation	2.11	19.44	4.19	4.10	0.28	5.7
	95% Confidence Interval	2.07	19.05	4.11	4.01	0.28	5.6

Table 22: Calculated indices for gravel samples collected from Sherman, Johnson and Slate Creeks in 2010. Geometric mean particle sizes are expressed in mm.

Sediment texture affects salmonid embryo survival by influencing the pore size and permeability of the gravel. These properties regulate oxygen transport to incubating embryos and control the movement of alevins within the gravel. An excess of fine sediments in spawning gravel is a direct cause of embryo and alevin mortality (Shirazi et al, 1981). The higher the numerical value of the geometric mean the higher is the survival percentage of salmonid embryos.

Based on published relationships between these indices and salmon embryo survival rates (Chapman 1988; Lotspeich and Everest 1981), the calculated indices for 2010 gravel samples, predict average embryo survival to range from 15 to 26% for Johnson Creek, and nearly 22% at Reach 1 of Sherman Creek. The predicted emergence for Slate Creek and Reach 2 of Sherman was rather lower, however, at less than 1% to 10%. The Fredle index is lower in some samples than previous years due to a greater amount of fine material present in those samples, giving a wide range in predicted embryo survival rates.

8.3 Comparison with Geometric Mean for previous years.

The geometric mean particle size of samples from each site was compared with samples collected in 2005 through 2010 by applying a single factor ANOVA to the data. Table 23 shows geometric means for 2005 to 2010 and p values from ANOVA. Only Reach 1 of Sherman Creek showed a significant difference in geometric mean particle size over time with *dg* at Reach 1 being higher from 2007 to 2010 than previous years. A larger geometric mean particle size indicates samples contain less fine material and are more suitable for salmon spawning. There were no significant differences in *dg* at other sites over time. The amount of fine sediment in the gravel depends on how much sediment is deposited and also how frequently high flows flush fine sediment from the gravel so there could be substantial variation over time.

Kondolf (2000) pointed out some limitations of geometric mean diameter, and likewise Fredle index, as a measure of complete size distribution since similar means can be derived from very different gravel mixtures. He suggested instead examining the percentage of fine material present since this is more closely related to salmon embryo survival. The measurement of fine material present is limited to the sieve sizes used with 0.83mm to 1mm often used to define “fine” sediment in gravel.

Sieve sizes used in baseline data in Kensington streams would allow a 1.7mm or 0.425mm cut-off for the amount of fine material measured. The amount of gravel passing through the 0.425mm and 0.150mm sieves was summed and expressed as a percentage of the total and compared to previous years to examine any changes in the amount of fine sediment accumulating (Table 23b). At Reach 1 of Sherman Creek, 2010 had more fine sediment than 2006 and 2008, but was similar to 2005. At Johnson Creek, 2010 also had more fine sediment than 2006 and at Slate Creek there was more fine sediment in 2010 compared to 2009 and more in 2009 than 2008. These changes could be in line with the scouring flood of November 2005 that likely removed fine gravel from the streams. Flows have been more tempered since then allowing more fine sediment to accumulate. There were no significant differences at Reach 2 of Sherman Creek, Reach 1 of Johnson Creek and Reach 2 of Slate Creek due to a large variation among samples collected within the same year.

	Geometric Mean (*dg*) mm					
Site	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**p value**
Sherman Reach 1	9.57	9.34	12.64	12.72	13.29	12.7	*0.00013
Sherman Reach 2	10.74	14.57	12.54	12.96	12.95	15.66	0.0810
Johnson Reach 1	10.8	10.98	11.11	11.22	11.79	11.74	0.1240
Johnson Reach 2	12.2	12.24	11.28	11.02	11.95	11.42	0.1210
Slate Reach 1	12.3	11.87	11.55	11.64	12.33	11.88	0.4690
Slate Reach 2	14.23	12.01	12.29	12.1	12.06	12.84	0.2420
			*significant at 95% level				

Table 23a: Comparison of *dg* for 2005 -2010.

Percentage Fines <0.425mm							
Site	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**p value**
Sherman Reach 1	2.33	1.13	1.88	1.34	2.05	2.36	*0.0181
Sherman Reach 2	2.09	0.75	1.66	1.05	1.20	1.67	0.4580
Johnson Reach 1	2.36	1.57	4.09	3.47	2.38	3.67	0.1795
Johnson Reach 2	1.98	1.43	2.92	4.42	3.04	4.51	*0.04235
Slate Reach 1	1.02	1.48	1.82	3.49	2.08	5.17	*0.00064
Slate Reach 2	1.44	1.20	1.96	3.15	2.36	1.93	0.1596

Table 23b: Comparison of the percentage of material less than 0.425 diameter.

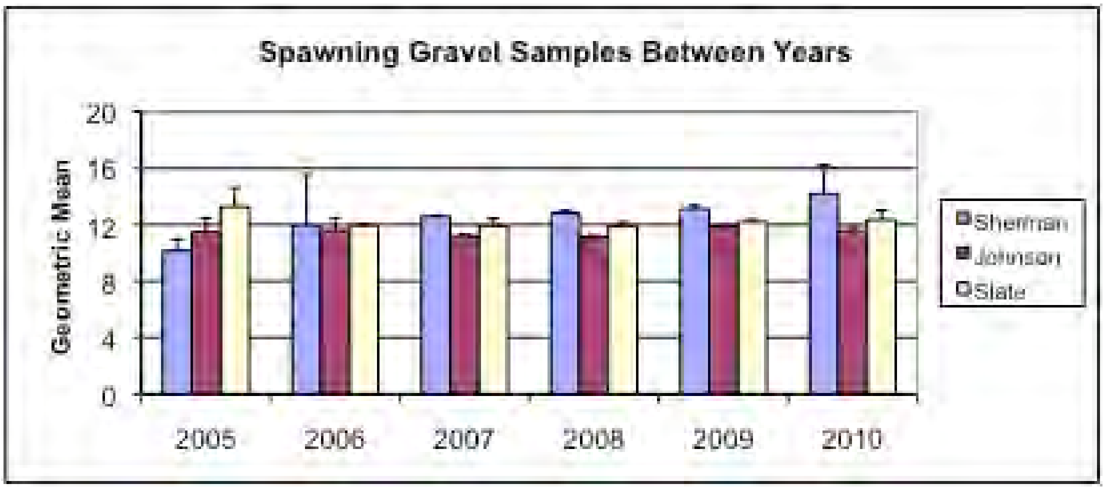


Figure 30: A comparison of geometric mean from 2005 to 2010.

9.0 Aquatic Vegetation

A visual survey of instream vegetation was carried out in the lower and middle reaches of Sherman, Johnson, and Slate Creeks in July and August 2010 during resident fish surveys. These reaches are downstream of outfall 001 (Sherman Creek), downstream from the proposed outfall 002 (Slate Creek) and downstream from the mill process site (Johnson Creek).

Green and or brown algae were observed growing on larger rocks in Lower and Middle Sherman Creek during resident fish surveys in August 2010 (Figure 31). Johnson showed barely any aquatic vegetation on the substrate (Figure 32). Middle Slate substrate had a thick growth of brown filamentous algae growing on newly deposited fine sediment, but none was present in Lower Slate Creek. This had not been observed before. Periodic high flows in these steep, coastal streams frequently disturb the substrate and may remove both sediment and algae during the next high flow event.

Figure 31: Middle Sherman Creek has some algal growth on larger rocks.

Figure 32: Typical underwater view of Lower Johnson Creek with little to no vegetation present on the substrate.

Figure 33: Middle Slate Creek had some thick growth of filamentous brown algae, not previously observed there.

Figure 34: No instream vegetation in Lower Slate Creek.

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