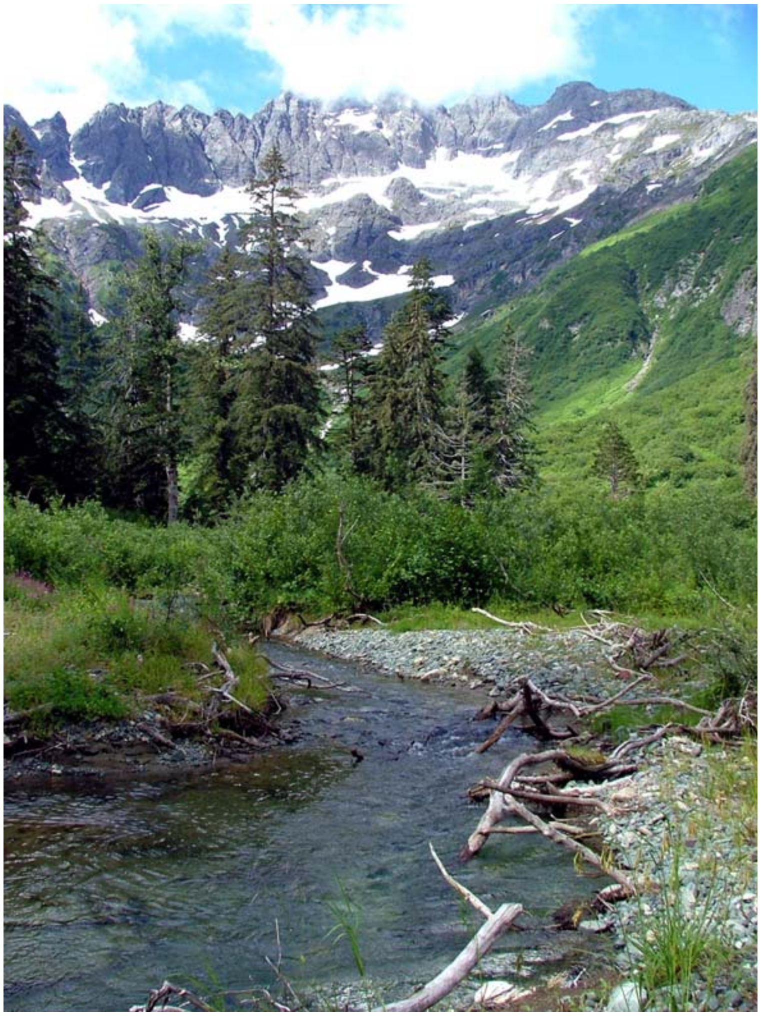
# Kensington Gold Project

# NPDES Permit AK-005057-1

# Annual Water Quality Monitoring Summary
# Volume 1:
# Aquatic Resource Surveys
# 2006



**February 2007**

## 1.0 Introduction

This report describes aquatic resource monitoring conducted in 2006 in compliance with the annual monitoring requirements of the National Pollutant Discharge Elimination System Permit for the Kensington Gold Project, near Juneau, Alaska (Permit No. AK-005057-1). Monitoring was conducted on Sherman, Johnson and Slate Creeks and included analysis of stream sediment, benthic invertebrate surveys, resident fish population estimates, counts of outmigrating salmon fry and returning adult salmon, analysis spawning gravel, 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. The only discharge to Sherman Creek from the Kensington Project is outflow from settling ponds that receive mine drainage (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 prohibit fish passage on both East and West forks approximately 800m from the stream mouth. 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. A tunnel connecting the existing Kensington Mine with Berners Bay is proposed within the Johnson Creek drainage, while the Tailings Storage Facility is proposed to be at Lower Slate Lake with treated tailings water discharging to Slate Creek.

Dolly Varden char (*Salvelinus malma*), pink salmon (*Onchorhynchus gorbuscha*), chum salmon (*O. keta*), cutthroat trout (*O. clarki*), and prickly sculpin (*Cottus asper*) inhabit the reach below the falls barriers on each stream (Konopacky 1992, Biostat 1998). Dolly Varden are the only species occurring upstream of the fish barriers (Biostat 1998).


**Figure 1**: Location of streams near Kensington Mine included in 2006 Aquatic Resource Surveys. Sediment toxicity testing, resident and anadromous fish surveys, analysis of spawning gravel and aquatic vegetations surveys were conducted in Sherman, Johnson and Slate Creeks. Benthic invertebrate monitoring was conducted on these streams as well as Sweeny Creek.

## 3.0 Sediment Monitoring

### 3.1 Introduction

This section summarizes stream sediment toxicity tests, metals analysis of sediments and physical characterization of sediments, as requested by the NPDES permit. Specific tests performed included: (1) 10-day whole sediment toxicity tests on the amphipod *Hyalella azteca,* and the midge *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 the lower reaches of Sherman Creek, Slate Creek and Johnson Creek in early August 2006. Metals tend to adhere to fine clay particles, but there a very few areas of fine sediment deposition in any of the streams. A few areas on the stream margins were found with fine deposits of mud. These areas were targeted for sample collection.

### 3.2 Methods

At each site, a mud sample was collected by personnel using a stainless steel scoop. The mud was shaken through sieves sized at 1.68, 0.42 and 0.15mm to separate coarse and fine sediment. 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 then decanted off the top and the finest sediment left in the bottom of the cone 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 (ENSR, Fort Collins, Colorado). This sample was analyzed for metal concentration and grain size present. 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 ethyl alcohol.

Particle size was determined for each creek by 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: Sediment particle size determination for Sherman, Johnson, and Slate Creek samples.**

| Particle Size % | Sherman | Johnson | Slate |
|---|---|---|---|
| **Sand** | 70 | 18 | 76 |
| **Silt** | 22 | 60 | 16 |
| **Clay** | 8 | 22 | 8 |
| **Texture** | Sandy loam | Silt loam | Sandy loam |

Johnson Creek sediment contained the highest percentage of fine material (silt and clay). The Johnson Creek sample also had higher moisture content and after centrifuging, there was only enough solid material to make 5 replicates instead of the proposed 8. Samples from Sherman and Slate Creek had similar compositions of sand and clay.

Total Solids, Total Volatile Solids, Total Sulfide, and Total Organic Carbon were analyzed by EPA methods 160.3M, 160.4M, and PSEP (Table 2). Concentrations of total organic carbon ranged from 0.3% in Johnson Creek sediment to 2% in Slate Creek sediment. Total volatile solids ranged from 1.4% in Johnson Creek sediment to 4.6% in Slate Creek samples. Sulfide was not detected in any of the samples (0.5 Umoles/kg MRL). The laboratory reports are included as Appendix 1a and b.

**Table 2: Inorganic parameter analysis for Sherman, Johnson, and Slate Creeks.**

| Parameter | Sherman | Johnson | Slate |
|---|---|---|---|
| **Total Solids %** | 69.6 | 58.5 | 69.6 |
| **Total Volatile solids %** | 3.60 | 1.43 | 4.63 |
| **Total Sulfide (umoles/g)** | <0.5 | <0.5 | <0.5 |
| **Total Organic Carbon %** | 1.4 | 0.3 | 2.0 |

### 3.3 Sediment Metal Concentration

Total metals (aluminum, chromium, copper, nickel, silver, zinc) were determined using EPA method 6010B, inductivity-coupled plasma-atomic emission spectrometry (ICP-AES). Solid sample analysis of metals arsenic, cadmium, lead and selenium was carried out using method 6020, inductivity-coupled plasma-mass spectrometry (ICP-MS) and mercury was determined by method 7471A, manual cold-vapor technique. Table 3 summarizes metal concentrations in the sediment collected from each stream.

**Table 3: Concentrations of metals in stream sediment, August 2006 (mg/kg)**

| Analyte | Sherman | Johnson | Slate Creek |
|---|---|---|---|
| Aluminum | 17,200 | 14,900 | 13,200 |
| Arsenic | 27.7 | 18.5 | 5.75 |
| Cadmium | 0.366 | 0.646 | 0.204 |
| Chromium | 55.4 | 27.3 | 42.0 |
| Copper | 113 | 61.9 | 31.4 |
| Lead | 12.0 | 11.6 | 5.47 |
| Mercury | 0.157 | 0.015 | 0.112 |
| Nickel | 37.3 | 41.7 | 36.4 |
| Selenium | 1.26 | 1.50 | 0.47 |
| **Silver** | **<1.0** | **<1.0** | **<1.0** |
| **Zinc** | **121** | **177** | **83.2** |

Six out of the eleven metals appeared to be of highest concentration in Lower Sherman (aluminum, arsenic, chromium, copper, lead and mercury). Eight metals showed lowest concentrations in Slate Creek. All three creeks had high concentrations of aluminum, (17,400 mg/kg in Sherman Creek). The next most abundant metals after aluminum are compared in the pie charts in Figure 2. Zinc, chromium and copper were all well represented at each site.

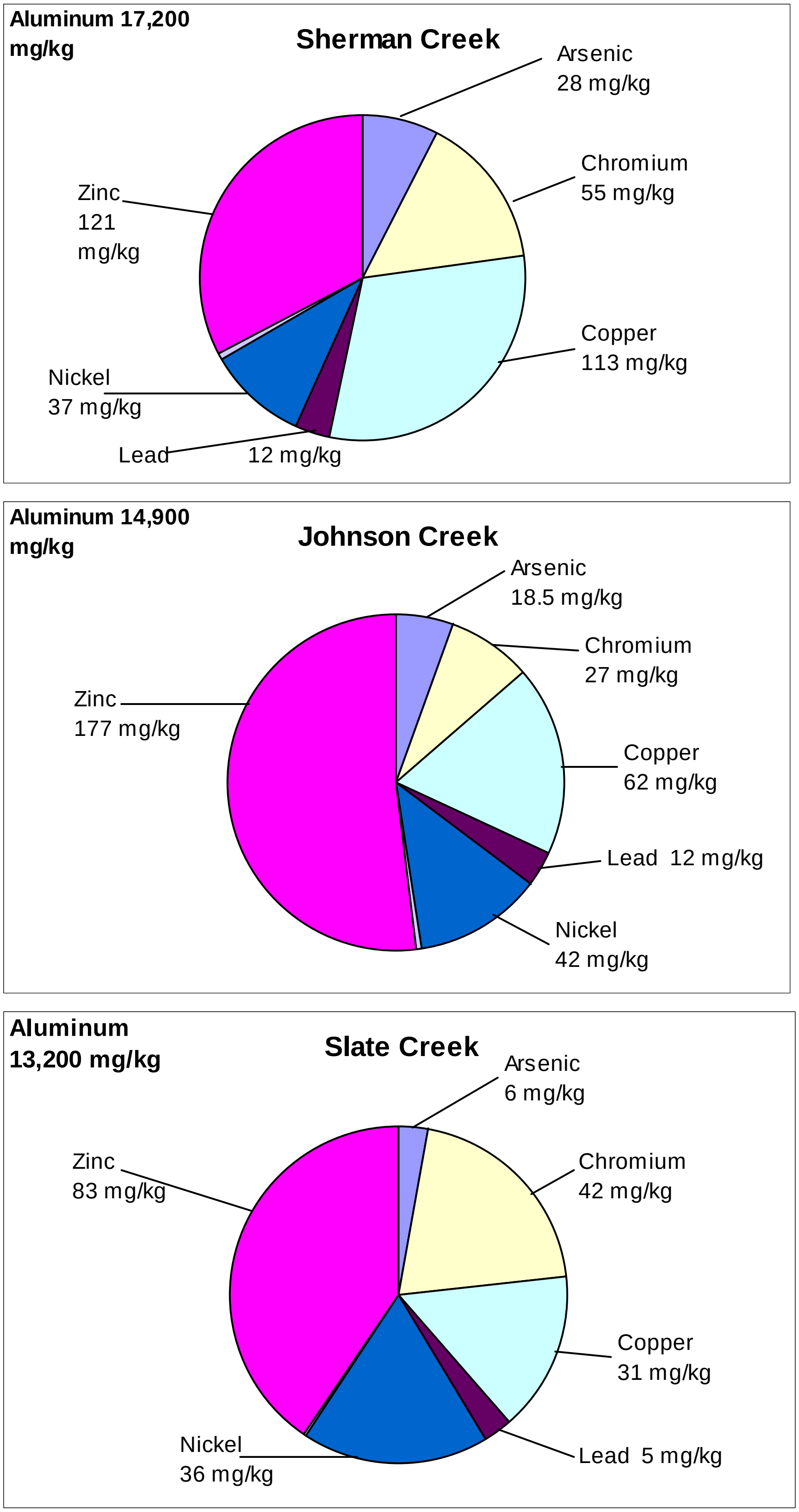



**Figure 2: Metal content of stream sediment.**

### 3.4 Sediment Toxicity Testing

Short-term toxicity testing was conducted using the amphipod *Hyalella azteca* and 3rd instar midge larvae, *Chironomus tentan.* Any endemic organisms in the sediment were removed prior to the testing. Eight replicates of stream sediment were used per treatment with exception of Johnson Creek as this sample yielded only enough material for 5 replicates. The primary control sediment was silica sand and the second control sediment consisted of a smaller grain size and higher organic matter content (Appendix 1a, 1b).

Both organisms underwent 10 day toxicity tests 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, b). There were no significant differences in survival or growth between the test sediments and the laboratory controls. The highest survival for *Hyallela* was shown in Slate Creek and the lowest in Johnson Creek, but the differences were not significant (Table 4). Total organic carbon, which ameliorates the toxicity of several metals, was lower at Johnson Creek, perhaps explaining the difference in survival rates. The relevant QA/QC information can be found in the lab reports (Appendix 1a, 1b).

**Table 4: Survival of organisms after 10-day exposure to sediment.**

| **Biological Data** | | | |
|---|---|---|---|
| **Collection Date and Time** | **Sample ID** | ***Chironomus tentans* Survival (%)** | ***Hyalella azteca* Survival (%)** |
| 8/16/06 11:00 | Sherman Creek | **82.5** | **91.25** |
| 8/17/06 15:00 | Johnson Creek | **86** | **82** |
| 8/17/06 13:00 | Slate Creek | **85** | **95** |
| | Sand - control | **88.75** | **83.75** |
| | Lab Sediment | **87.5** | **88.75** |

## 4.0 Benthic Invertebrates

### 4.1 Aquatic Invertebrate Collection

Benthic invertebrates were collected from established sampling sites on Johnson, Slate, Sherman and Sweeny Creeks in April and May 2006 as required by the NPDES permit. On Johnson Creek samples were collected at the JS-1 flow monitoring site, upstream of the upper bridge crossing on April 19, and on Slate Creek, downstream from SLA on April 23. Samples were collected from Sherman and Sweeny Creeks on May 5 at sites used by Konopacky in 1995 (Konopacky 1996). Reach 1 of Sherman Creek lies from 3 to 29m upstream from the mouth while Reach 2 lies between 288 and 315m. Reach 1 of Sweeny Creek is from 38 to 60m upstream and Reach 2 lies between 236 to 260m. 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, placed in labeled whirlpak bags and preserved with 70% ethyl alcohol.

### 4.2 Invertebrate identification

Sorting and identification of invertebrates was conducted by Elizabeth Flory PhD. in Juneau, Alaska, who 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.

### 4.3 Data Analysis

The area of the Surber sampling device 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.

## 4.4 Taxonomic Classification

Slate Creek samples contained a total of 1255 invertebrates from 29 genera, including 18 EPT taxa (Table 5). The ratio of EPT to non-EPT taxa was the same as 2005 (0.6). Non-EPT taxa included 10 Diptera genera, of which 5 were Chironomidae genera (non-biting midges), and one was the commom pea clam *Psidium*. Johnson Creek samples contained 774 invertebrates from 30 genera composed of 26 EPT taxa, 2 Chironomidae taxa, a Tipulidae (crane flies), and a Simulidae (blackflies), giving a higher ratio of EPT to non-EPT than 2005 (0.9). Sherman Creek samples contained 389 individuals in Reach 1 and 151 individuals in Reach 2. Reach 1 samples contained 22 genera with 19 EPT taxa while Reach 2 samples contained 23 genera including 21 EPT taxa giving a high EPT ratio for both reaches. Non-EPT taxa included 2 Chironomidae and a Tipulidae. Sweeny Creek samples contained only 13 genera (both reaches), with 3 of these non EPT taxa. Each site had roughly equal numbers of Ephemeroptera, Plecoptera and Trichoptera, with the exception of Slate Creek that had fewer Trichoptera then the other two groups. Samples from Johnson and Sherman Creeks contained higher proportions of Ephemeroptera, Plecoptera and Trichoptera than Slate Creek (Figure 3).

**Table 5: Total number of genera in each taxonomic group**

| | # Ephem. | # Plecop | # Trichop | # EPT | # non-EPT | # Total taxa | EPT ratio |
|---|---|---|---|---|---|---|---|
| **Slate** | 7 | 8 | 3 | 18 | 11 | 29 | 0.62 |
| **Johnson** | 8 | 9 | 9 | 26 | 4 | 30 | 0.87 |
| **Sherman 1** | 7 | 6 | 6 | 19 | 3 | 22 | 0.86 |
| **Sherman 2** | 6 | 8 | 7 | 21 | 2 | 23 | 0.91 |
| **Sweeny 1** | 5 | 4 | 1 | 10 | 3 | 13 | 0.77 |
| **Sweeny 2** | 5 | 3 | 3 | 11 | 2 | 13 | 0.85 |

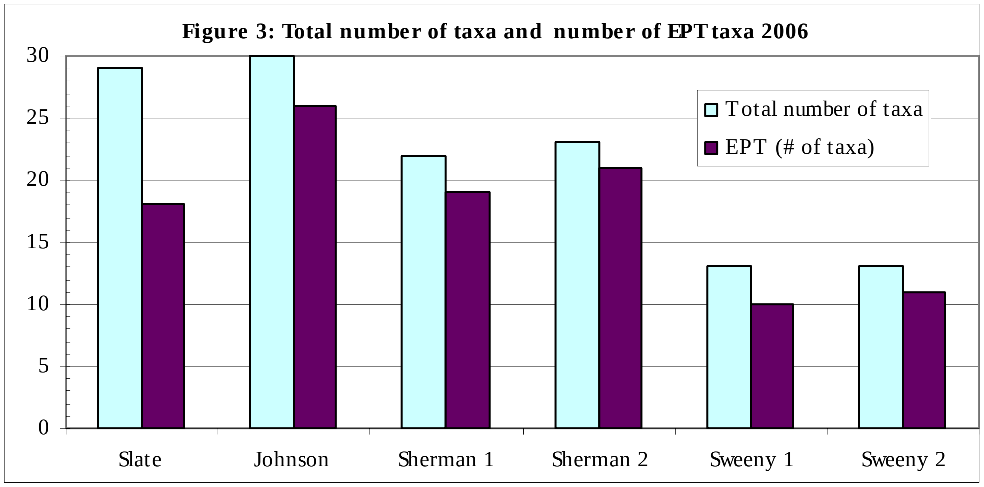


Figure 3: Total number of taxa and number of EPT taxa 2006
30
25
20
15
10
5
0
Total number of taxa
EPT (# of taxa)
Slate
Johnson
Sherman 1
Sherman 2
Sweeny 1
Sweeny 2

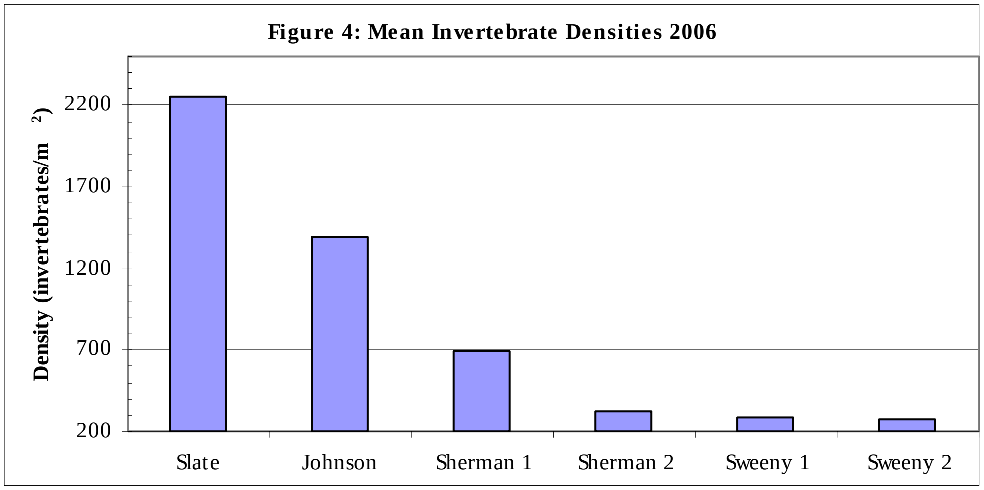


Figure 4: Mean Invertebrate Densities 2006
Density (invertebrates/m 2)
2200
1700
1200
700
200
Slate
Johnson
Sherman 1
Sherman 2
Sweeny 1
Sweeny 2

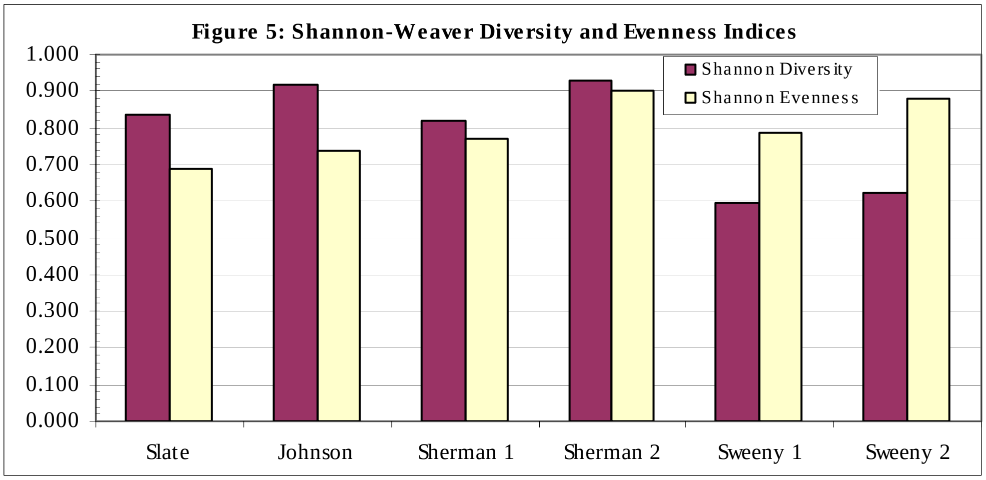


Figure 5: Shannon-Weaver Diversity and Evenness Indices
1.000
0.900
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
Shannon Diversity
Shannon Evenness
Slate
Johnson
Sherman 1
Sherman 2
Sweeny 1
Sweeny 2

Densities of invertebrates in Slate Creek ranged from 903 invertebrates per $m^2$ to $4011/m^2$ with a mean of $2249/m^2$ (Table 7). Johnson Creek densities ranged from 785 to $2172/m^2$ with a mean of $1387/m^2$. Sherman Creek densities ranged from 150 to $1161/m^2$ over both reaches with a mean density of $697/m^2$ in Reach 1 and $326/m^2$ in Reach 2. Sweeny Creek densities ranged from 32 to $409/m^2$ over both reaches with mean density of $290/m^2$ for Reach 1 and $270/m^2$ for Reach 2. Figure 4 compares mean densities between sites. Slate Creek had the highest densities and Sweeny Creek had the lowest.

The most abundant genera in Slate Creek were the mayflies *Baetis*, *Leptophlebia* and *Epeorus*, the blackfly larvae *Prosimulium* and the midges *Eukiefferiella* and *Tanytarsus*. In Johnson Creek, the mayflies *Baetis*, *Cinygmula*, *Epeorus*, *Attenella* and *Drunella*, the stonefly Zapada and the caddis fly *Rhyacophila* were the most numerous. In Sherman Creek the most abundant were the mayflies *Baetis*, *Cinygmula*, *Epeorus*, and *Drunella*, the stoneflies *Plumiperla*, and *Zapada* and caddis flies *Agapetus* and *Rhyacophila*. Sweeny Creek abundant fauna included mayflies *Baetis*, and *Cinygmula* and stoneflies *Plumiperla and Haploperla.*

## 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. Figure 5 compares the diversity and evenness indices between sites.

Sweeny Creek had low diversity but high evenness indicating the few species found were represented by fairly even numbers of species (Table 7). Johnson, Sherman and Slate Creeks all had fairly high diversity and Slate Creek had slightly lower evenness than other sites due to large numbers of mayflies and midge larvae in comparison with other species.

**Table 6: Species Composition of Benthic Invertebrate Samples from Johnson and Slate Creeks, April 2006.**

| Taxonomic Group | | | | Johnson | Slate | Sherman 1 | Sherman 2 | Sweeny 1 | Sweeny 2 |
|---|---|---|---|---|---|---|---|---|---|
| Class | Order | Family | Genus | Mean | Mean | Mean | Mean | Mean | Mean |
| Insecta | Ephemeroptera | Baetidae | Baetis | 40.8 | 37.2 | 28.3 | 2.7 | 9.3 | 8.2 |
| | | | Diphetor | 0.2 | 4.0 | 0.2 | | | |
| | | Heptageniidae | Epeorus | 13.8 | 22.3 | 2.7 | 2 | 1.5 | 1.7 |
| | | | Cinygmula | 16 | 2.8 | 6.8 | 3.3 | 3.7 | 4.2 |
| | | | Rithrogena | 3.7 | 0.3 | 1.7 | 2 | 1.5 | 1.8 |
| | | Ephemerellidae | Attenella | 13.5 | | 0.3 | 0.5 | | |
| | | | Drunella | 6.2 | 1.0 | 4.5 | 3.5 | 0.2 | 0.7 |
| | | Leptophlebiidae | Paraleptophlebia | 0.5 | 25.5 | | | | |
| | | | | | | | | | |
| | Plecoptera | Chloroperlidae | Triznaka | | 0.2 | | | | |
| | | | Haploperla | | | | | 2.0 | |
| | | | Suwallia | | 0.3 | 1.3 | 0.3 | 0.8 | |
| | | | Kathroperla | 1.0 | | | | | |
| | | | Plumiperla | 1.2 | 2.3 | 5 | 7.3 | 6.8 | 6.5 |
| | | | Paraperla | | | | 0.2 | | |
| | | | Utaperla | | | | 0.2 | | |
| | | | Alloperla | | | | | 0.8 | |
| | | Leuctridae | Despaxia | | | | | | 1.2 |
| | | | Zealeuctra | 1.5 | | 1.5 | 1.2 | | |
| | | Perlidae | Hesperoperla | 0.2 | 4.2 | | | | |
| | | | Hansonperla | | 0.3 | | | | |
| | | | Agnetina | | 0.2 | | | | |
| | | | Doroneuria | 0.2 | | | | | |
| | | | Neoperla | | | | 0.2 | | |
| | | | Claassenia | | 0.2 | | | | |
| | | Nemouridae | Zapada | 6.2 | | 2.3 | | | 0.2 |
| | | | Nemoura | 0.3 | 1.0 | 0.2 | 0.7 | 6.8 | |
| | | | Shipsa | 3.2 | | 1.8 | 0.2 | | |
| | | Perlodidae | Megarcys | 0.3 | | | | | |

## Table 6 cont.

| Taxanomic Group | | | | Johnson | Slate | Sherman 1 | Sherman 2 | Sweeny 1 | Sweeny 2 |
|---|---|---|---|---|---|---|---|---|---|
| **Class** | **Order** | **Family** | **Genus** | **Mean** | **Mean** | **Mean** | **Mean** | **Mean** | **Mean** |
| | Trichoptera | Brachycentridae | Micrasema | 0.2 | 0.3 | | | | |
| | | Hydropsychidae | Parapsyche | 1.0 | | | | | 0.2 |
| | | | Arctopsyche | 4 | | 0.3 | 0.2 | | |
| | | Glossosomatidae | Glossoma | 2.3 | | | | | |
| | | | Agapetus | | | 2.2 | 1.8 | | |
| | | Polycentropidae | Neureclipses | 0.3 | | 0.2 | 0.7 | | |
| | | | Paranyctiophylax | | | | 1 | | |
| | | Rhyacophillidae | Rhyacophila | 5.8 | 0.8 | 2.2 | 1.3 | 0.5 | 0.2 |
| | | | Himalopsyche | 1.5 | | 0.8 | 0.7 | | 0.2 |
| | | Psychomiidae | Lype | 0.2 | | | | | |
| | | Phryganeidae | Haganella | 0.2 | 1.0 | | | | |
| | | | Yphria | | | 0.2 | | | |
| | | Lepidostomatidae | Theliopysche | | | | 0.2 | | |
| Non EPT | Diptera | | | | | | | | |
| | Chironomidae | Orthocladiinae | Eukiefferiella | 1.2 | 74.7 | 3.0 | | 0.2 | 0.2 |
| | | | Tvetania | | | | 0.3 | | |
| | | | Corynoneura | | 2.3 | | | | |
| | | | Pagasta | 0.2 | 3.7 | 0.2 | 0.2 | | |
| | | Tanytarsini | Tanytarsus | | 8.7 | | | | |
| | | | Constempellina | | 2.0 | | | | |
| | Nematocera | Tipulidae | Dicranota | | 0.2 | | | | |
| | | | Tipula | 0.7 | 0.2 | 0.2 | | | |
| | | | Antocha | | | | | 0.2 | 0.5 |
| | | Psychodidae | Pericoma | | 0.2 | | | | |
| | Brachycera | Ceratopogonidae | Probezzia | | 2.8 | | | | |
| | | | Limnochares | | | | | 0.2 | |
| | Simuliidae | Simuliidae | Prosimulium | 3 | 8.2 | | | | |
| | | | | | | | | | |
| Bivalva | Sphaeriidae | Psidiinae | Psidium (pea clam) | | 4.0 | | | | |

## Table 7: Diversity and Evenness Indices for Benthic Invertebrates 2006.

| | Density | Shannon | | | Density | Shannon | |
|---|---|---|---|---|---|---|---|
| | (inverts/$m^2$) | Diversity | Evenness | | (inverts/$m^2$) | Diversity | Evenness |
| **Slate** | | | | **Johnson** | | | |
| **1** | 3161.3 | 0.828 | 0.673 | **1** | 1150.5 | 0.939 | 0.734 |
| **2** | 1817.2 | 0.600 | 0.600 | **2** | 1451.6 | 0.829 | 0.674 |
| **3** | 2075.3 | 0.815 | 0.637 | **3** | 1483.9 | 1.036 | 0.796 |
| **4** | 903.2 | 0.906 | 0.715 | **4** | 784.9 | 0.991 | 0.843 |
| **5** | 4010.8 | 0.915 | 0.715 | **5** | 1279.6 | 0.778 | 0.679 |
| **6** | 1526.9 | 0.954 | 0.775 | **6** | 2172.0 | 0.922 | 0.709 |
| **Mean** | **2249.1** | **0.836** | **0.686** | **Mean** | **1387.1** | **0.916** | **0.739** |
| **Sherman 1** | | | | **Sherman 2** | | | |
| **1** | 301.1 | 0.702 | 0.831 | **1** | 440.9 | 1.090 | 0.927 |
| **2** | 1161.3 | 0.859 | 0.713 | **2** | 419.4 | 0.842 | 0.780 |
| **3** | 752.7 | 0.864 | 0.754 | **3** | 311.8 | 1.029 | 0.953 |
| **4** | 215.1 | 0.833 | 0.873 | **4** | 354.8 | 0.920 | 0.920 |
| **5** | 569.9 | 0.798 | 0.739 | **5** | 268.8 | 0.870 | 0.911 |
| **6** | 1182.8 | 0.860 | 0.699 | **6** | 150.5 | 0.829 | 0.918 |
| **Mean** | **697.1** | **0.819** | **0.768** | **Mean** | **324.4** | **0.930** | **0.902** |
| **Sweeny 1** | | | | **Sweeny 2** | | | |
| **1** | 376.3 | 0.706 | 0.782 | **1** | 290.3 | 0.579 | 0.829 |
| **2** | 397.8 | 0.793 | 0.831 | **2** | 204.3 | 0.647 | 0.926 |
| **3** | 161.3 | 0.374 | 0.784 | **3** | 344.1 | 0.885 | 0.850 |
| **4** | 354.8 | 0.494 | 0.707 | **4** | 344.1 | 0.694 | 0.822 |
| **5** | 279.6 | 0.575 | 0.739 | **5** | 32.3 | 0.276 | 0.918 |
| **6** | 172.0 | 0.617 | 0.882 | **6** | 408.6 | 0.646 | 0.925 |
| **Mean** | **290.3** | **0.593** | **0.788** | **Mean** | **270.6** | **0.621** | **0.878** |

## 5.0 Resident Fish Population

### 5.1 Delineation of Strata

Population surveys of resident fish were conducted in 2006 in the Lower, Middle and Upper strata of Sherman, Johnson and Slate Creeks (Figures 6, 7). Each strata is 360m in length. Sherman Creek strata were designated during aquatic resource surveys in 1998 (Aquatic Science Inc. 1998). Lower Sherman extends from the stream mouth to the barrier falls 360m upstream. All middle and upper strata are located above barrier falls and are thereby inaccessible to sea-run fish. 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.

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 8.

**Table 8**: GPS Coordinates of Sherman, Johnson and Slate Creek Strata

| Strata | GPS Coordinates | Elevation |
|---|---|---|
| Lower Sherman | N 58º52.121  W 135º08.506’ | 12 ft |
| Middle Sherman | N 58º52.041’ W 135º06.961’ | 420 ft |
| Upper Sherman | N 58º51.785’ W 135º06.118 | 720 ft |
| Lower Johnson | N 58º49.437’ W 135º59.966 | 12 ft |
| Middle Johnson | N 58º49.845’ W 135º02.325 | 550 ft |
| Upper Johnson | N 58º51.088’ W 135º02.935 | 800 ft |
| Lower Slate | N 58º47.754’ W 135º02.332 | 15 ft |
| Middle Slate | N 58º48.201’ W 135º02.322 | 350 ft |
| Upper Slate | N 58º48.847’ W 135º02.418 | 800 ft |

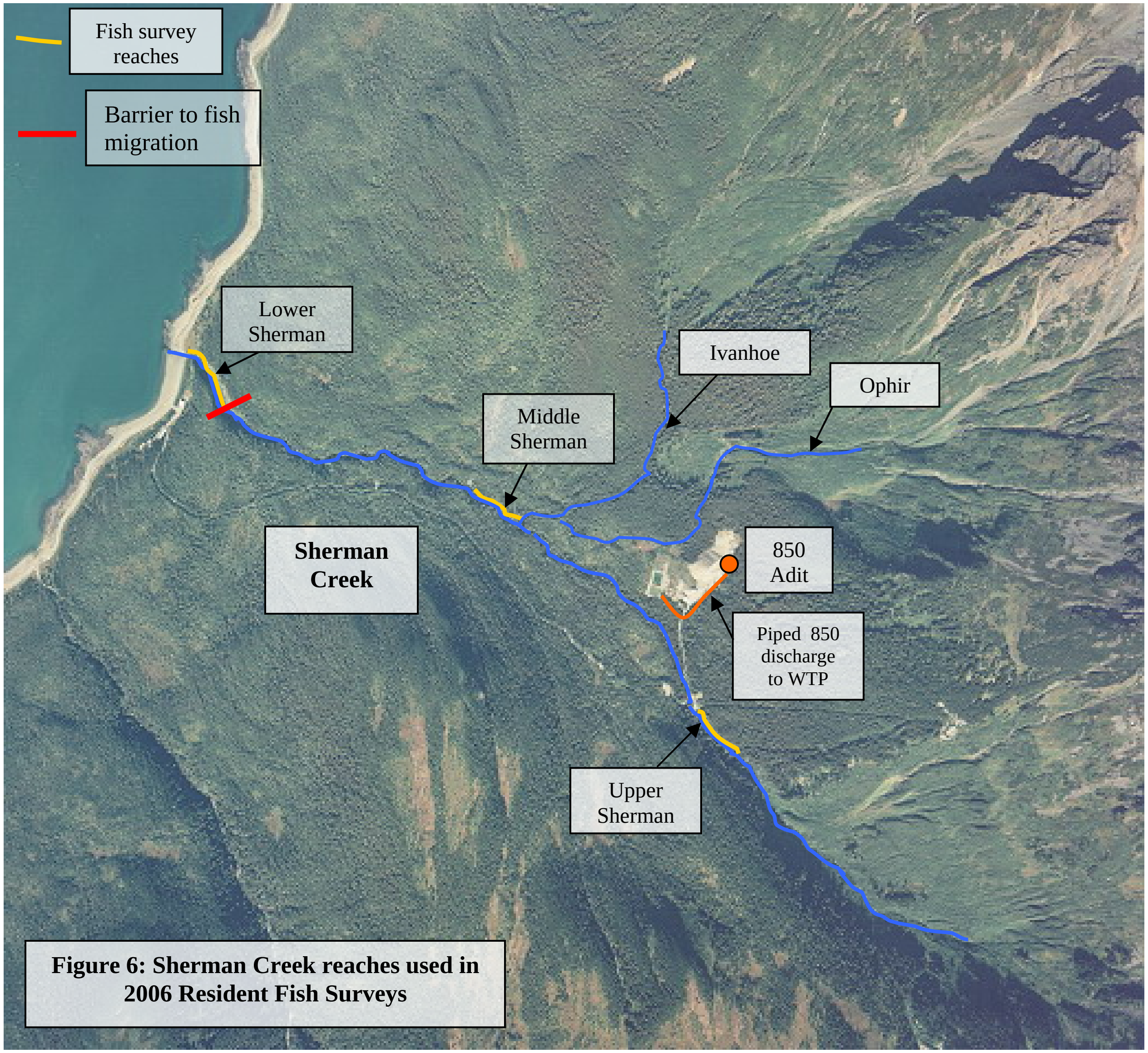



**Figure 6: Sherman Creek reaches used in 2006 Resident Fish Surveys**

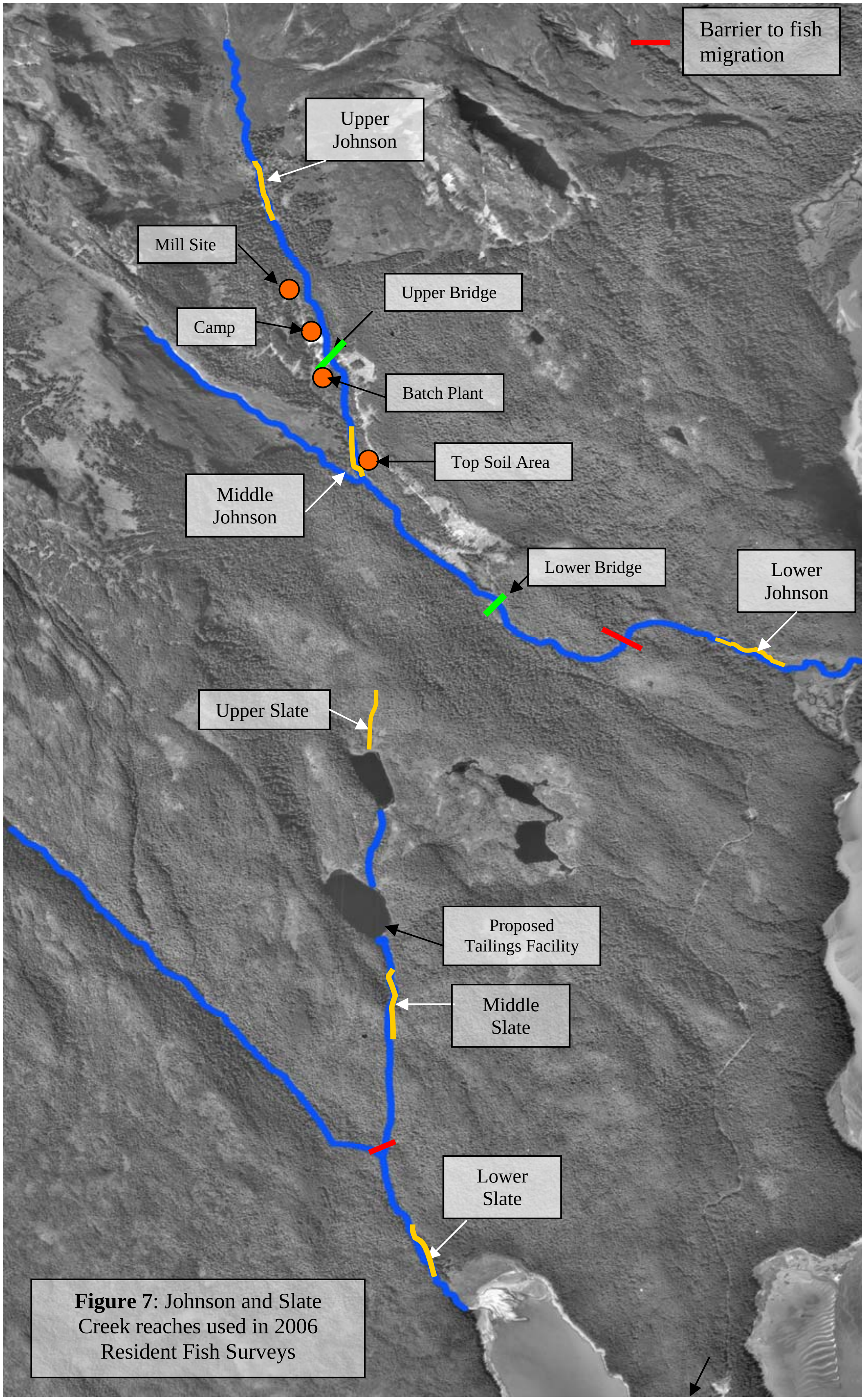



**Figure 7**: Johnson and Slate Creek reaches used in 2006 Resident Fish Surveys

## 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 Konopacky (1995). The 2006 resident fish surveys were conducted between July 25 and August 9. Lower reaches were surveyed first prior to adult pink salmon entering streams to spawn. Minnow traps instead of electrofishing gear were employed in these anadromous reaches, 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. One team member, equipped with dry suit and snorkel, quietly entered the water at the downstream end of a selected unit and proceeded upstream observing fish underwater. A second team member, 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 tape measure.

In non-anadromous reaches, 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 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 the diver. 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 to recover before being returned to the habitat unit from which they were captured.

### 5.3 Data analysis methods

The number of each fish species within a stratum was estimated by first applying a correction factor to the visual counts based on electro-shocking counts. These corrected counts were then extrapolated over the total number of units of each habitat type within a stratum. Standard deviations and 95% confidence intervals for the population estimates were determined for each stratum using equations (5) through (11) in Hankin & Reeves (1988). Minimum detectable differences between population estimates were calculated by performing analysis of variance on fish counts for each habitat unit. The dimensions of each habitat unit in each stratum are given in Appendix 3b. The total area of each habitat type was calculated and used in the computation of fish densities.

### 5.4 Population estimates

Counts of fish made by visual observation and numbers of fish captured by electro-fishing and trapping are summarized in Table 8. Population estimates by habitat type and by stratum are presented in Table 9 and illustrated in Figure 8. The precision of population estimates was calculated by expressing 95% confidence intervals as a percentage of the estimated population size. Dolly Varden were found in all strata, while cutthroat trout were only present in the lower reaches of each creek, below the barrier falls. Dolly Varden numbers were highest in pools, particularly in Lower Johnson Creek, and Upper Slate Creek. Cutthroat numbers were highest in Lower Slate and lowest in Lower Johnson, perhaps due to the dominance of Dolly Varden in this reach.

The 49 Dolly Varden captured by electro-fishing and minnow trapping in the three strata of Sherman Creek represented 29% of the estimated Dolly Varden population of Sherman Creek. The 14 cutthroat trout captured in Lower Sherman represented 32.5% of the estimated Sherman Creek cutthroat population. The 94 Dolly Varden captured in Johnson Creek represented 54.6% of the estimated population of Johnson Creek strata. The 50 Dolly Varden captured in Slate Creek composed 24.4% of the Slate Creek population. Actual counts of fish obtained by snorkeling and electro-fishing in each habitat unit are presented in Appendix 3c.

**Table 8: 2006 Resident Fish Counts by Habitat Type in Sherman, Johnson and Slate Creeks.**

| Stream Reach | Habitat Type | Total Units (N) in stratum | Snorkeling: Numbers Observed – Units (n) snorkled | Snorkeling: Dolly | Snorkeling: Cutthroat | Electrofishing/Trapping: Numbers Captured – Units (n') fished | Electrofishing/Trapping: Dolly | Electrofishing/Trapping: Cutthroat |
|---|---|---|---|---|---|---|---|---|
| Lower Sherman | Riffle | 16 | 13 | 4 | 11 | 4 | 2 | 5 |
| | Pool | 22 | 16 | 35 | 21 | 4 | 9 | 5 |
| | Glide | 4 | 4 | 4 | 7 | 2 | 4 | 4 |
| | All Units | 42 | 33 | 43 | 39 | 10 | 15 | 14 |
| Middle Sherman | Riffle | 19 | 11 | 1 | 0 | 5 | 2 | 0 |
| | Pool | 48 | 38 | 35 | 0 | 8 | 12 | 0 |
| | Glide | 2 | 2 | 2 | 0 | 1 | 1 | 0 |
| | All Units | 69 | 51 | 38 | 0 | 14 | 15 | 0 |
| Upper Sherman | Riffle | 15 | 11 | 2 | 0 | 6 | 2 | 0 |
| | Pool | 36 | 28 | 24 | 0 | 9 | 14 | 0 |
| | Glide | 2 | 2 | 4 | 0 | 1 | 3 | 0 |
| | All Units | 53 | 41 | 30 | 0 | 16 | 19 | 0 |
| Lower Johnson | Riffle | 10 | 6 | 2 | 0 | 3 | 0 | 0 |
| | Pool | 16 | 10 | 26 | 0 | 5 | 44 | 0 |
| | Glide | 4 | 2 | 0 | 1 | 2 | 0 | 0 |
| | All Units | 30 | 18 | 28 | 1 | 10 | 44 | 0 |
| Middle Johnson | Riffle | 15 | 8 | 1 | 0 | 5 | 1 | 0 |
| | Pool | 65 | 46 | 38 | 0 | 11 | 21 | 0 |
| | Glide | 3 | 3 | 1 | 0 | 2 | 3 | 0 |
| | All Units | 83 | 57 | 40 | 0 | 18 | 25 | 0 |
| Upper Johnson | Riffle | 19 | 10 | 4 | 0 | 3 | 3 | 0 |
| | Pool | 37 | 27 | 22 | 0 | 12 | 20 | 0 |
| | Glide | 10 | 7 | 2 | 0 | 4 | 2 | 0 |
| | All Units | 66 | 44 | 28 | 0 | 19 | 25 | 0 |
| Lower Slate | Riffle | 16 | 11 | 1 | 9 | 6 | 1 | 7 |
| | Pool | 24 | 19 | 22 | 30 | 8 | 10 | 14 |
| | Glide | 10 | 9 | 12 | 19 | 3 | 5 | 7 |
| | All Units | 50 | 39 | 35 | 58 | 17 | 16 | 28 |
| Middle Slate | Riffle | 17 | 9 | 1 | 0 | 6 | 1 | 0 |
| | Pool | 43 | 11 | 3 | 0 | 7 | 3 | 0 |
| | Glide | 11 | 4 | 0 | 0 | 2 | 0 | 0 |
| | All Units | 71 | 24 | 4 | 0 | 15 | 4 | 0 |
| Upper Slate | Riffle | 33 | 18 | 23 | 0 | 3 | 4 | 0 |
| | Pool | 43 | 20 | 34 | 0 | 9 | 17 | 0 |
| | Glide | 14 | 8 | 19 | 0 | 5 | 9 | 0 |
| | All Units | 90 | 46 | 76 | 0 | 17 | 30 | 0 |

**Table 9: Population estimates by species, habitat type and stratum, 2006.**

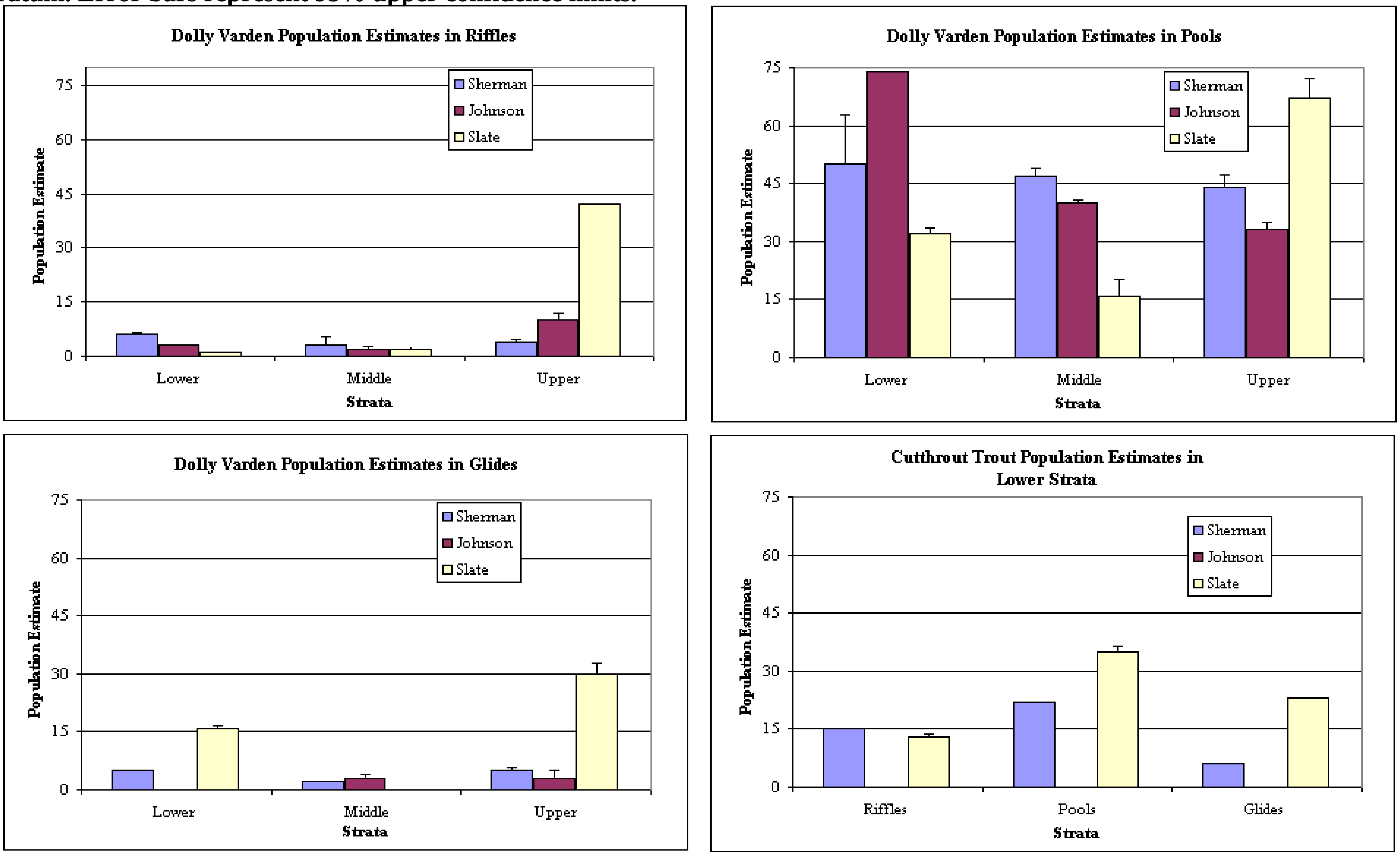
| Sherman Creek Dolly Varden | | | | | |
|---|---|---|---|---|---|
| **Reach** | Habitat Unit | Estimate | C.I. | Precision (%) | Std. Dev |
| **Lower** | Riffles | 6 | 0.52 | 8.7 | 0.96 |
| | Pools | 50 | 2.43 | 4.9 | 4.96 |
| | Glides | 5 | 0.46 | 9.2 | 0.47 |
| | **All Units** | **59** | **1.51** | **2.6** | **4.42** |
| | | | | | |
| **Middle** | Riffles | 3 | 2.44 | 81.3 | 4.13 |
| | Pools | 47 | 0.44 | 0.9 | 1.38 |
| | Glides | 2 | - | - | - |
| | **All Units** | **55** | **0.59** | **1.1** | **2.16** |
| | | | | | |
| **Upper** | Riffles | 15 | 0.79 | 5.3 | 1.35 |
| | Pools | 22 | 0.62 | 2.8 | 1.68 |
| | Glides | 6 | - | - | - |
| | **All Units** | **43** | **0.83** | **1.9** | **2.70** |

| Johnson Creek Dolly Varden | | | | | |
|---|---|---|---|---|---|
| **Reach** | Habitat Unit | Estimate | C.I. | Precision (%) | Std. Dev |
| **Lower** | Riffles | 3 | - | - | - |
| | Pools | 74 | 12.6 | 17.0 | 20.33 |
| | Glides | 0 | - | - | - |
| | **All Units** | **78** | **12.06** | **15.5** | **26.11** |
| | | | | | |
| **Middle** | Riffles | 2 | 0.85 | 42.5 | 1.22 |
| | Pools | 40 | 2.03 | 5.1 | 7.04 |
| | Glides | 3 | - | - | - |
| | **All Units** | **47** | **2.12** | **4.5** | **8.16** |
| | | | | | |
| **Upper** | Riffles | 10 | 1.92 | 19.2 | 3.10 |
| | Pools | 33 | 3.08 | 9.33 | 8.17 |
| | Glides | 3 | 0.63 | 21.00 | 0.85 |
| | **All Units** | **47** | **3** | **6.38** | **10.15** |

| Slate Creek Dolly Varden | | | | | |
|---|---|---|---|---|---|
| **Reach** | Habitat Unit | Estimate | C.I. | Precision (%) | Std. Dev |
| **Lower** | Riffles | 1 | 0.46 | 46.0 | 0.78 |
| | Pools | 32 | 1.45 | 4.5 | 3.23 |
| | Glides | 16 | 0.58 | 3.6 | 0.90 |
| | **All Units** | **51** | **1.19** | **2.3** | **3.81** |
| | | | | | |
| **Middle** | Riffles | 2 | 0.82 | 41.0 | 1.25 |
| | Pools | 16 | 4.05 | 25.3 | 6.85 |
| | Glides | 0 | - | - | - |
| | **All Units** | **15** | **2.19** | **14.6** | **5.48** |
| | | | | | |
| **Upper** | Riffles | 42 | 0.48 | 1.2 | 1.04 |
| | Pools | 67 | 4.95 | 7.4 | 11.29 |
| | Glides | 30 | 2.79 | 9.3 | 4.03 |
| | **All Units** | **139** | **3.12** | **2.2** | **10.81** |

| Cutthroat Trout | | | | | |
|---|---|---|---|---|---|
| Creek | Habitat Unit | Estimate | C.I. | Precision (%) | Std. Dev |
| **Sherman** | Riffles | 15 | 0.54 | 3.6 | 0.98 |
| Lower | Pools | 22 | 0.38 | 1.7 | 0.78 |
| | Glides | 6 | 0.16 | 2.7 | 0.16 |
| | **All Units** | **43** | **0.44** | **1.0** | **1.30** |
| | | | | | |
| **Johnson** | Riffles | - | - | - | - |
| Lower | Pools | - | - | - | - |
| | Glides | 1 | - | - | - |
| | **All Units** | **1** | **-** | **-** | **-** |
| | | | | | |
| **Slate** | Riffles | 13 | 0.85 | 6.5 | 1.44 |
| Lower | Pools | 35 | 1.29 | 3.7 | 2.88 |
| | Glides | 23 | 0.23 | 1.0 | 0.35 |
| | **All Units** | **74** | **1.04** | **1.4** | **3.33** |

**Figure 8: 2006 Population Estimates of Resident Fish in Sherman, Johnson and Slate Creeks by species, habitat type and stratum. Error bars represent 95% upper confidence limits.**



### 5.5 Minimum detectable differences among population estimates.

By specifying the significance level and samples size for an analysis of variance, it is possible to determine what the smallest detectable difference between population means will be. Minimum detectable differences in mean numbers of fish counted in each stratum and in each habitat type were calculated using the following equation:

$$\delta = \sqrt{\frac{2\,k\,s^2\,\phi^2}{n}}$$

where $\delta$ is the minimum detectable difference between means, k is the number of groups being compared, $s^2$ is the mean square error derived from analysis of variance, n is the sample size (number of habitat units), and $\phi$ is a quantity read from tables, incorporating k, n, and the probabilities of committing a Type I and Type II error (Zar 1999). A significance level ($\alpha$) of 0.05, and a statistical power ($1 - \beta$) of 0.8 were specified for the analysis, determining that differences between means at a 95% significance level could be detected 80% of the time.

Mean number of fish in each habitat type were used to compute minimum detectable differences between strata. Table 10 gives the mean number of fish in each habitat type and the MDD resulting from comparing habitat types in each strata. A difference in means of 1 to 2 fish per habitat unit was detectable among riffles in Sherman and Johnson Creeks, and around 4 fish for Upper Slate Creek. Minimum detectable differences were greater for pool and glides, reflecting the higher variation in numbers of fish in these habitats. Some pools in Johnson Creek held large numbers of fish, while no fish were observed in other pools. Glide habitat was also limited, restricting the number of units that can be surveyed. The ability to detect small differences in numbers of fish is important in detecting changes in the population from year to year.

**Table 10:** Mean number of Dolly Varden per habitat type and minimum detectable differences (MDD) between means for different strata.

| Dolly Varden 2006 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sherman Creek | | | Johnson Creek | | | Slate Creek | | |
| **Strata** | Riffle | Pool | Glide | Riffle | Pool | Glide | Riffle | Pool | Glide |
| **Lower** | 0.385 | 2.250 | 1.250 | 0.333 | 4.600 | 0.000 | 0.091 | 1.316 | 1.222 |
| **Middle** | 0.182 | 0.974 | 1.000 | 0.125 | 0.609 | 1.000 | 0.111 | 0.364 | 0.000 |
| **Upper** | 0.273 | 1.214 | 2.500 | 0.500 | 0.889 | 0.286 | 1.278 | 1.550 | 2.125 |
| **MDD** | **0.494** | **3.510** | **5.585** | **1.107** | **12.249** | **4.109** | **4.029** | **3.200** | **6.589** |

| Dolly Varden 2006 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Lower Strata | | | Middle Strata | | | Upper Strata | | |
| **Strata** | Riffle | Pool | Glide | Riffle | Pool | Glide | Riffle | Pool | Glide |
| **Sherman** | 0.385 | 2.250 | 1.250 | 0.182 | 0.974 | 1.000 | 0.273 | 1.214 | 2.500 |
| **Johnson** | 0.333 | 4.600 | 0.000 | 0.125 | 0.609 | 1.000 | 0.500 | 0.889 | 0.286 |
| **Slate** | 0.091 | 1.316 | 1.222 | 0.091 | 0.364 | 0.000 | 1.278 | 1.550 | 2.125 |
| **MDD** | **1.036** | **8.912** | **5.460** | **0.257** | **2.083** | **3.641** | **3.002** | **1.568** | **13.180** |

| Cutthroat Trout 2006 | | | |
|---|---|---|---|
| | Lower Strata | | |
| **Strata** | Riffle | Pool | Glide |
| **Sherman** | 0.923 | 1.000 | 1.000 |
| **Johnson** | 0.000 | 0.000 | 0.000 |
| **Slate** | 0.818 | 1.474 | 1.778 |
| **MDD** | **2.708** | **3.989** | **6.341** |

**Figure 9**: Dolly Varden in Upper Slate Lake.

## 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 easier comparisons between strata and habitat types. Densities of both fish species tended to be highest in pool habitat and lowest in riffle habitat in each stream (Table 11).

**Table 11: Densities of fish by species, stratum and habitat type.**

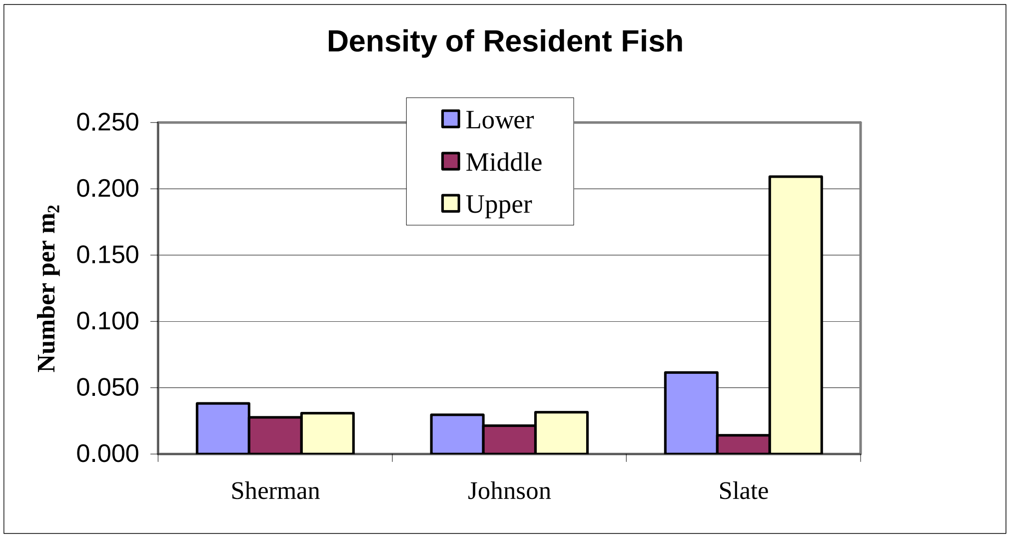
| Fish Density (number of fish/m$^2$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Dolly Varden | | | | Cutthroat Trout | | | |
| **Creek** | **Strata** | **Riffles** | **Pools** | **Glides** | **All** | **Riffles** | **Pools** | **Glides** | **All** |
| **Sherman** | Lower | 0.003 | 0.142 | 0.014 | 0.022 | 0.008 | 0.062 | 0.017 | 0.016 |
| | Middle | 0.003 | 0.061 | 0.043 | 0.028 | | | | |
| | Upper | 0.031 | 0.025 | 0.164 | 0.031 | | | | |
| **Johnson** | Lower | | 0.035 | 0.000 | 0.029 | 0.000 | 0.000 | 0.010 | 0.000 |
| | Middle | 0.002 | 0.040 | 0.020 | 0.021 | | | | |
| | Upper | 0.011 | 0.164 | 0.009 | 0.031 | | | | |
| **Slate** | Lower | 0.001 | 0.153 | 0.019 | 0.025 | 0.016 | 0.211 | 0.032 | 0.036 |
| | Middle | 0.006 | 0.058 | 0.000 | 0.014 | | | | |
| | Upper | 0.161 | 0.235 | 0.252 | 0.209 | | | | |

Dolly Varden density was highest in Upper Slate, which appears to be a spawning and nursery area for Upper Slate Lake (Figure 10). Lower Slate had a high total density of fish due to a mixture of Dolly Varden and cutthroat trout there. The steep, middle reaches of each creek had the lowest fish densities perhaps due to lower abundance of pool and glide habitat here.

**Table 12: Densities of Resident Fish 2006.**

| Fish Density (# of fish/m$^2$) | | | | | |
|---|---|---|---|---|---|
| | | **Dolly Varden and Cutthroat** | | | |
| **Creek** | **Strata** | **Riffles** | **Pools** | **Glides** | **All Units** |
| **Sherman** | Lower | 0.011 | 0.199 | 0.054 | 0.038 |
| | Middle | 0.003 | 0.061 | 0.065 | 0.028 |
| | Upper | 0.008 | 0.045 | 0.192 | 0.031 |
| **Johnson** | Lower | | 0.033 | | 0.029 |
| | Middle | 0.002 | 0.040 | 0.020 | 0.021 |
| | Upper | 0.011 | 0.164 | 0.009 | 0.031 |
| **Slate** | Lower | 0.014 | 0.321 | 0.047 | 0.061 |
| | Middle | 0.006 | 0.058 | 0.000 | 0.014 |
| | Upper | 0.161 | 0.235 | 0.252 | 0.209 |

**Figure 10: Densities of Resident Fish in Sherman, Johnson and Slate Creeks, 2006**




## 5.7 Fish condition

Fish condition was determined from lengths and weights of fish measured in the field. The histograms in Figure 13 show the range in size of fish captured in the two creeks. Slate Creek had a high number of small Dolly Varden captured in Upper Slate, which provides a nursery and spawning area for the upper lake. Lengths and weights of fish were used to calculate Fulton's condition factor (K) using the equation given in Anderson & Gutreuter (1983):

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

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 stratum are presented in Table 13 and Figure 13. Condition of Dolly Varden appeared slightly lower in Lower Strata perhaps due to competition with cutthroat trout.

**Table 13:** Mean condition factor of Dolly Varden and cutthroats by stratum.

| | | Sherman | | Johnson | | Slate | |
|---|---|---|---|---|---|---|---|
| | **Strata** | Mean K | 95% C.I. | Mean K | 95% C.I. | Mean K | 95% C.I. |
| Dolly Varden | **Lower** | 0.814 | 0.061 | 0.785 | 0.021 | 0.795 | 0.074 |
| | **Middle** | 0.863 | 0.056 | 0.843 | 0.026 | 0.912 | 0.041 |
| | **Upper** | 0.885 | 0.053 | 0.871 | 0.027 | 0.896 | 0.039 |
| Cutthroat | **Lower** | 0.95 | 0.081 | 0.747 | 0.024 | 0.898 | na |

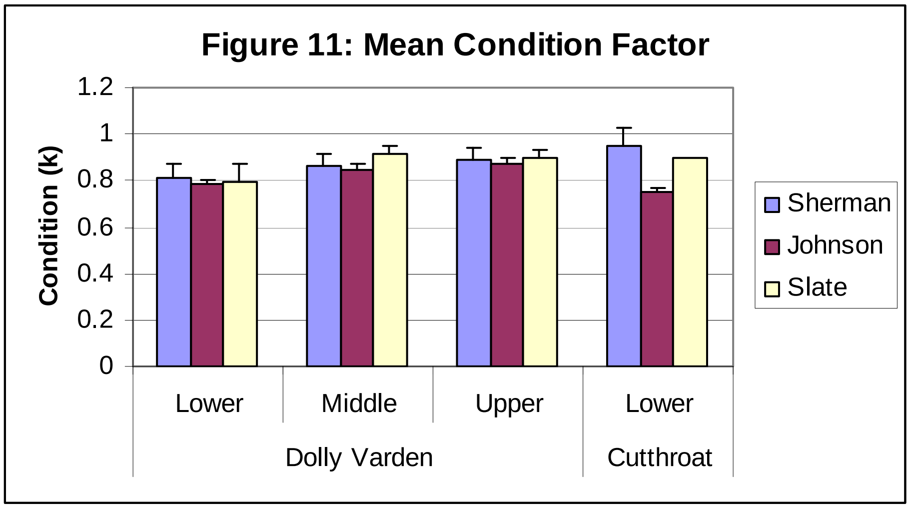
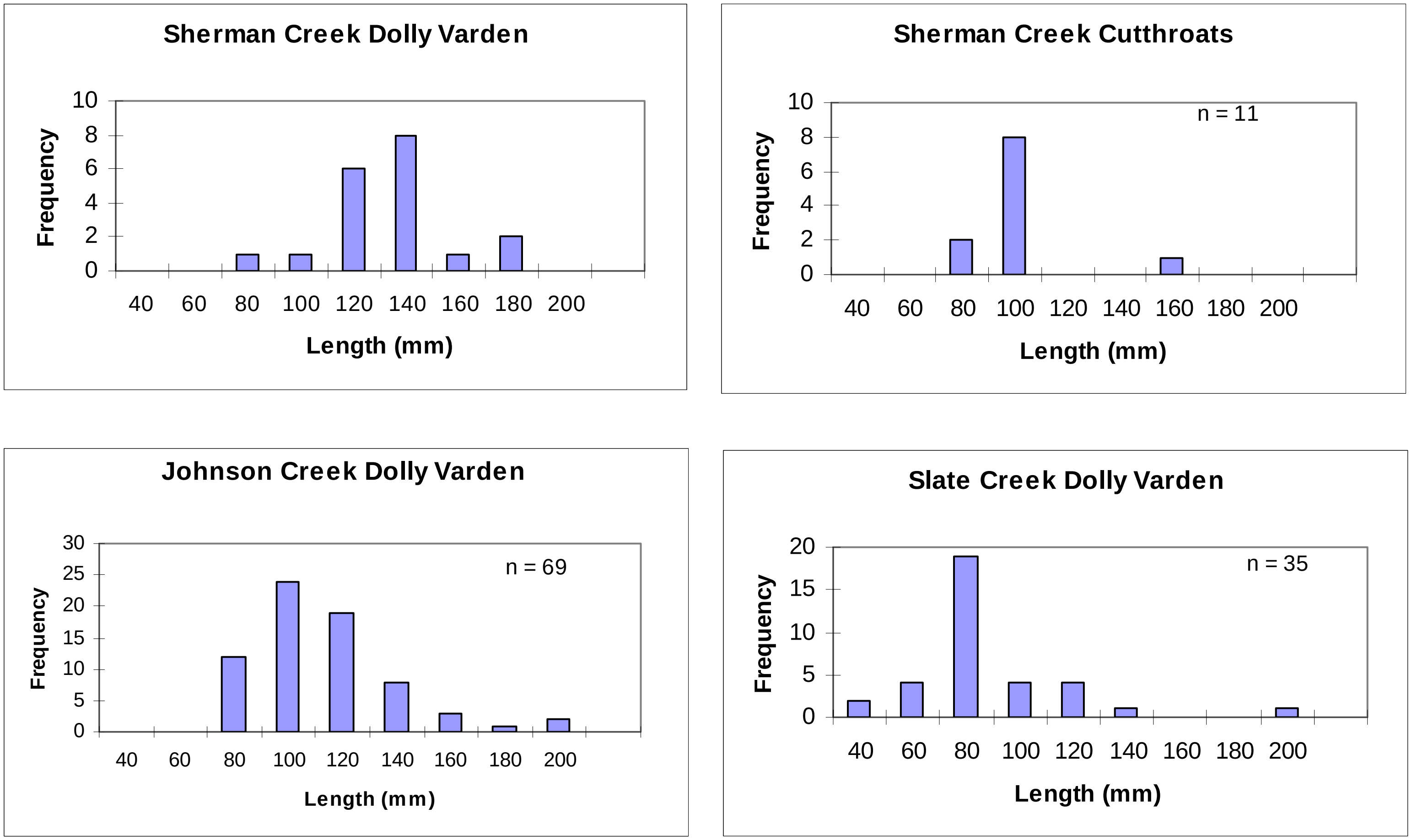



**Figure 12:** The largest Dolly captured in Upper Sherman Creek, July 2006.

**Figure 13**: Length-frequency histograms for Dolly Varden and cutthroat trout captured in Sherman, Johnson and Slate Creeks in 2006.



## 6.0 Anadromous Fish Monitoring

### 6.1 Pink Salmon Ecology

Pink salmon, also known as humpbacks or humpies for the exaggerated dorsal hump that develops in mature males, are the most abundant salmon species and also the smallest (about 2kg) at maturity. All pink salmon migrate to sea, are 2 years old at maturity and all die after spawning. This results in odd-year and even-year populations that do not interbreed (Quinn 2005). Around Southeast Alaska, even-year populations are generally larger than odd years.

Pre-spawning adult pink salmon migrate into coastal streams between July and 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). 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 were 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 reduced. Due to the distance between streams and the necessity of checking traps daily, two teams of field personnel were required to conduct the study. Sherman Creek was accessed by one team from Comet Beach camp, while a second team accessed Johnson Creek via a trail from the Jualin road at mile 3, and Slate Creek via sea kayak from the Slate Cove dock (Figure 1).

In 2006, fyke nets with adjustable wings constructed from 1/8 inch mesh were used to trap outmigrating salmon fry on Sherman, Johnson and Slate Creeks (Figure 1). The opening of the nets was adjusted depending on stream flow, from 4 feet across with no wings used to 11 feet wide with wings deployed. 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. Ice cover was present on streams at the beginning of April presenting some difficulty with the installation of traps. One net was set in Sherman Creek on April 11 approximately 50m upstream of the creek mouth at mean high water. A net was set in Johnson Creek on April 12 approximately 100m from the confluence with the Lace River (Figure 14). The Slate Creek net was also set on April 11 approximately 25m above mean high water. Each net was attached to a live holding box that contained a partition to deflect the flow, but allowed fry to pass underneath to a compartment of low flow (Figure 15). An experimental inclined-plane trap (IPT) was built out of welded aluminum following the specifications of Todd (1994), and installed in Sherman Creek on April 28 in addition to the fyke net to compare trapping efficiency and performance (Figure 16).

## 6.3 Physical Data Collection

Water temperature and stream discharge were monitored throughout the sampling period on each stream by datalogging units that recorded measurements every 15 minutes. On Sherman Creek the datalogger was adjacent to the net; on Johnson and Slate Creeks the dataloggers were over 1km upstream, but still gave an indication of changes in flow when combined with measurements near the nets. Stream discharge was measured in each creek 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 frequently 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. In addition to total stream discharge, the discharge flowing through the nets was measured.

**Figure 14:** Fyke nets in Johnson Creek (top) and Slate Creek (bottom).

**Figure 15:** Scooping salmon fry out of a holding box.

**Figure 16**: Inclined-plane trap at Sherman Creek

## 6.4 Fish Data Collection

Prior to the beginning of field operations, Coeur Alaska obtained a Fish Resource Permit from the Alaska Department of Fish and Game (Appendix 4a) which authorized sampling fish in each creek with fyke nets or inclined-plane traps. In addition, a Fish Habitat Permit from the Alaska Department of Natural Resources was obtained prior to commencing the study (Appendix 4b).

The outmigration count began on April 12 in Sherman Creek, on April 13 in Johnson and Slate Creeks and continued until negligible numbers of fish remained. Sampling was halted on May 9 in Sherman Creek, on May 17 in Slate Creek and on May 19 in Johnson Creek. Fish in each trap were counted each morning, since the majority of pink salmon juvenile migrate at night just after dusk (EVS, 2000). Before conducting the counts, a general assessment of the flow, debris accumulation, and number of dead fish in the traps was conducted. If mortality proved to be unreasonably high, actions were taken to modify the system to reduce mortality. Fish were scooped out of the holding box using small hand nets, identified with the help of a field guide (Pollard et al 1997) and released into the stream. A total count of each species was kept each day.

A random sample of 10 juvenile pink salmon were measured for standard length (from tip of snout to end of notochord, to the nearest mm) and weighed (to nearest 0.1 g) on at least three occasions at each creek. All other fish caught in the trap were identified to species and returned to the stream.

## 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 what fraction of the total number caught are marked. This allowed calculation of the sampling efficiency of the nets ie. 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 fry outmigrating based on the ratio between marked and unmarked individuals. 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 (Figure 18). Fish were immersed for 10-15 minutes in 1.5 gallons of water that contained 0.3 g of dye. A battery operated aerator was place in the container of water with the fry to increase oxygen. After immersion, fish were transferred to clean water and released approximately 30 to 50 m upstream of the nets. The location where fish were released was narrow to allow fish to mix randomly across the whole stream width. The following day marked fish were identified among all fish retained in the live boxes. 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.

The number of fish marked depended on numbers initially captured each day. Five marking events were conducted in Sherman Creek with between 46 and 146 fish marked on each occasion. On Johnson Creek 10 mark-recapture trials were conducted with between 50 and 500 fish marked at each event. At Slate Creek 8 trials were conducted with 31 to 185 fish marked, although high flow forced the net out of place during one trial and a high number of potential predators in the holding box may have affected a second trial. The trials were separated by at least three days to avoid capturing marked fish from an earlier marking episode.

## 6.6 Population Estimates

The total number of outmigrating pink fry from each stream was estimated using the average ratio of marked (i.e., dyed) and unmarked fish re-captured by the nets during successive marking events. The relationship between the percentage of stream flow sampled and percentage of fish recaptured was examined for a correlation. In theory, a larger number of fish should be recaptured when a greater proportion of stream flow is sampled. Marked fish were recaptured over a period of 2-3 days after release, during which time stream flow could fluctuate widely.

**Figure 18:** unmarked salmon fry (top); fry marked with Bismark Brown dye (bottom)

The total daily number of outmigrating pink salmon fry was calculated using the average ratio of marked to unmarked fish. For example, at Sherman Creek on April 16, 49 marked fish were released and 22 were recaptured (45% of total released) while 17 fish of the 80 released on April 19 were captured (22%). The average of these two catch rates is 33%. A daily catch of 109 unmarked fish divided by 0.33 gives a total estimate of 330 fish. The estimated total catch was calculated in this way for each day and then a final total summed for the period of the project. The actual recapture rates for the first and last trials were used to estimate fish numbers at the beginning and end of the study respectively.

## 6.7 Physical Data

Water temperature of Sherman Creek increased slightly between early April and early May, from 2.0 to 3.0$^{o}$C (Figure 19). Water temperature of Johnson Creek was slightly warmer increasing from 3.0$^{o}$C to 4.0°C, perhaps due to the influence of groundwater flow. Johnson Creek appeared to be cooled slightly by high rainfall events around April 24 and May 4 (Figure 20). Slate Creek remained fairly cold (1.5 to 2°C) until early May when temperature increased rapidly to 7°C. This distinct temperature regime is associated with the lakes which feed into the stream having ice cover in April then being free from ice in May.

Stage-discharge relationships were developed for each stream based on manual discharge measurements, staff gage readings and pressure data from the dataloggers. These relationships were then used to calculate discharge for logged pressure readings for each morning and afternoon of the fry study (Figure 20). All three streams had peak flows around the same times (eg, April 23-24 and May 3-4). Sherman Creek had the highest peak flow at 132 cubic feet per second (cfs) and also the greatest difference between high and low flows, being influenced by rainfall events in nearby coastal mountains. The highest flow in Slate Creek was 104 cfs and in Johnson Creek was 89 cfs. Johnson Creek had the most stable flow regime with more moderate high and low flows, again suggesting groundwater influence. Slate Creek showed a large peak at the time ice was melting on the lake and then flows appeared to stabilize. Average flows in Sherman and Johnson were similar at around 40 cfs while Slate Creek had around half the mean flow at 22 cfs. The proportion of the flow sampled by the nets varied with discharge from around 15% sampled at high flow to 70% at low flow on each creek.

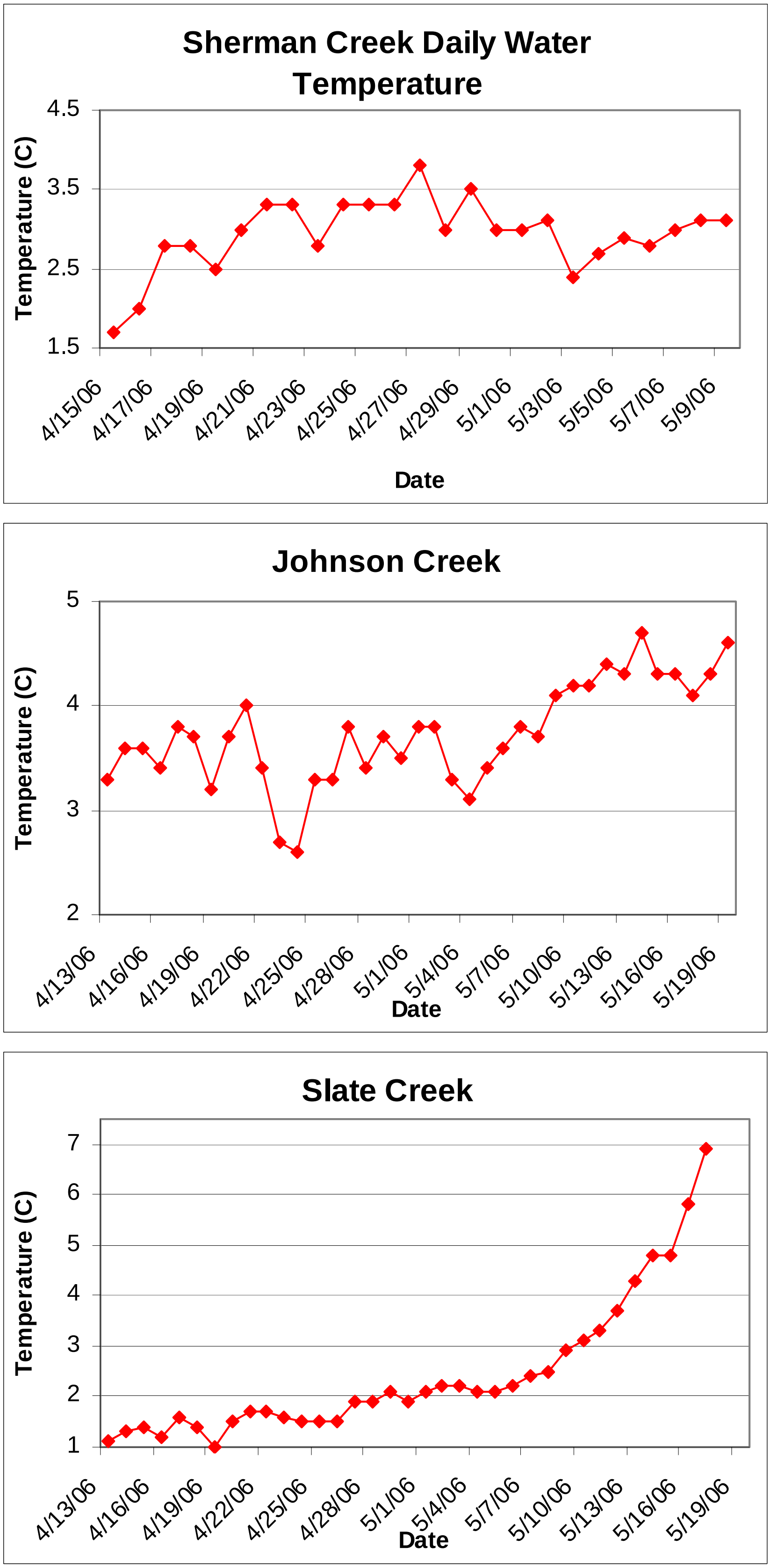



**Figure 19: Water temperature measured at 0900 hrs in each creek.**

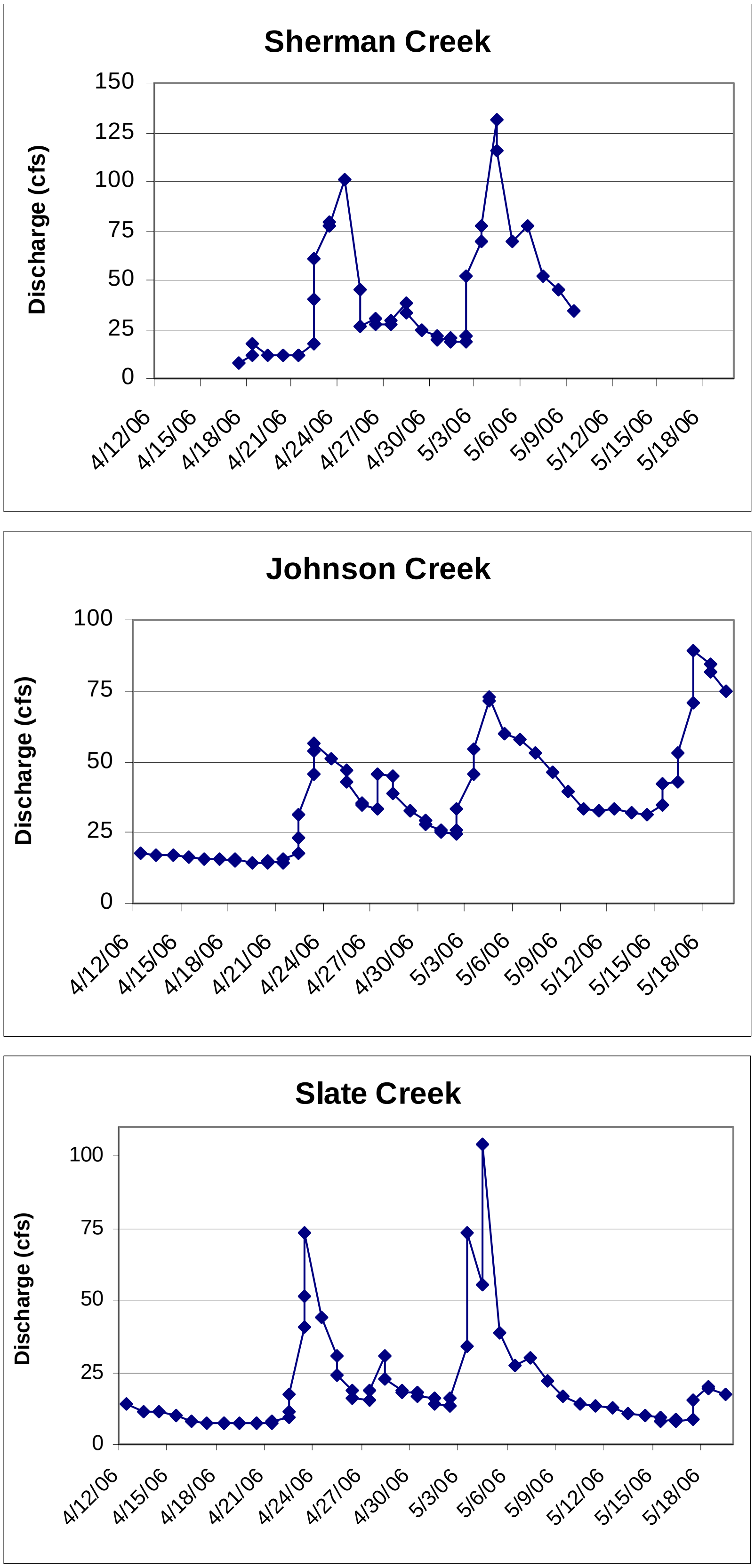
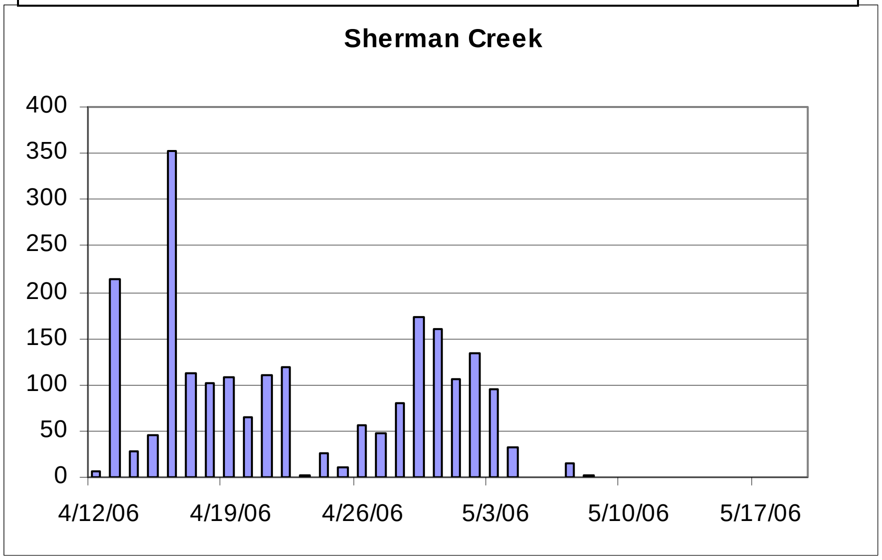
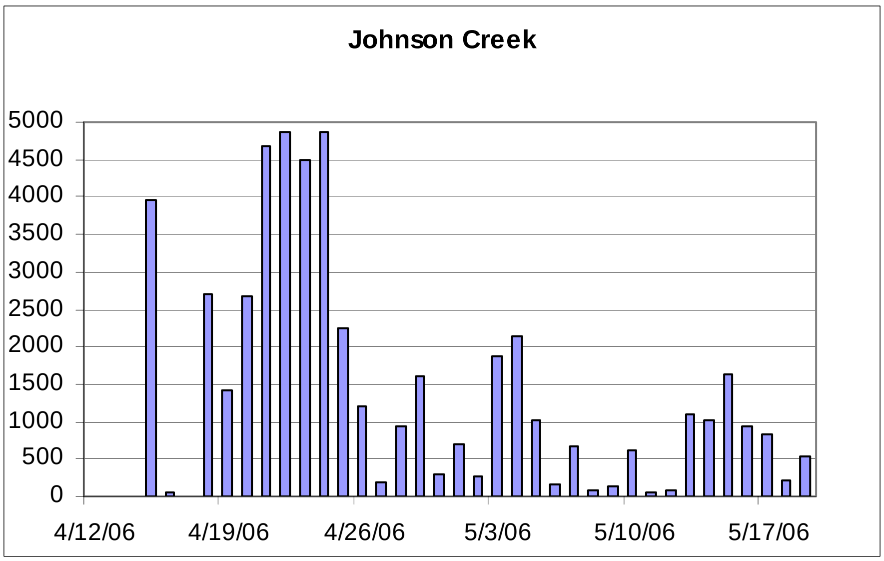



**Figure 20: Discharge flow recorded at 9am and 9pm in each creek.**

**Figure 21: Daily Catch of Pink Salmon Fry at each creek.**



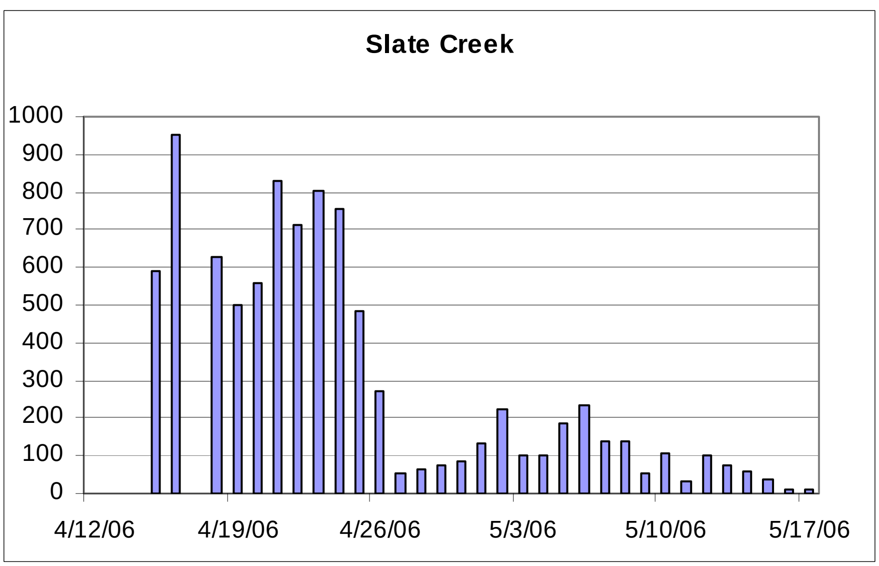
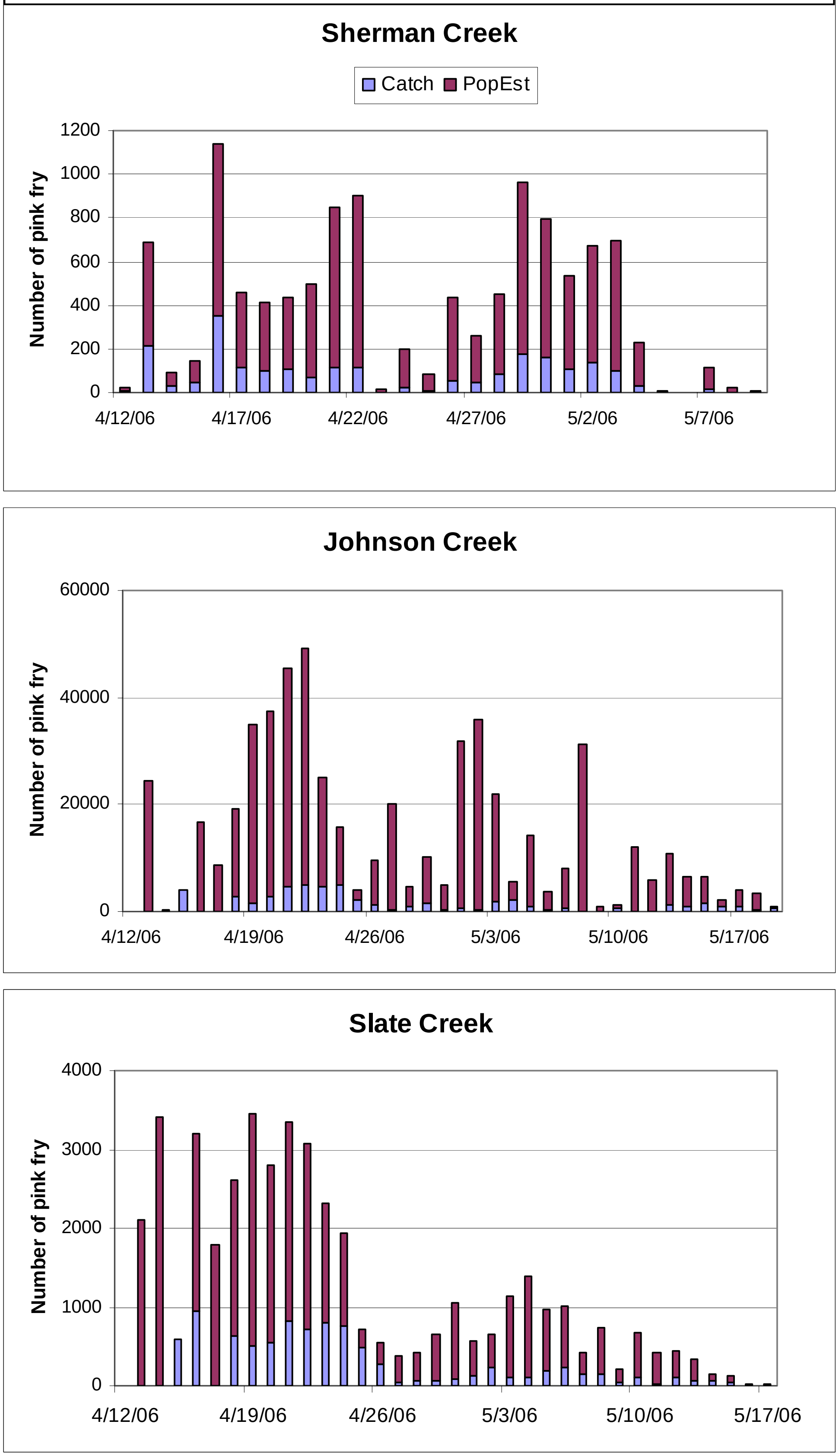



**Figure 22: Estimated daily total pink fry migrating downstream.**



## 6.8 Timing of Pink Salmon Outmigration

Numbers of captured fry were already relatively high at the beginning of the study. Traps should really have been in place by April 1, however, ice cover on the creeks presented some difficulties here. Slate Creek showed the earliest peak in daily catch rate (April 14), closely followed by Sherman Creek (April 16) then Johnson Creek (April 22). Numbers remained high at Slate Creek until April 24 after which, fewer fry were collected, but outmigration continued until mid-May. Daily catch at Sherman Creek was fairly consistent except for a single peak day (April 16) and for a few days from April 23 to 27 when catch was low. This period coincided with high flow that may have affected trap efficiency. Less of the total stream flow was sampled when discharge was high so some fry likely passed around the net.

Outmigration at Sherman Creek ceased much earlier (few fry after May 5) than at Slate or Johnson Creeks (May 17-19). The daily catch at Johnson Creek was often ten times the magnitude at either Slate or Sherman Creeks and also continued the longest. Johnson Creek had lower catches on April 25, 28-30, and May 4-10. High flow around April 24 and May 4 may have affected the catch as the wings of the net could not be deployed. Temperature did not seem to affect the magnitude of the daily catch.

## 6.9 Daily Catch and Mark-Recapture Trials

The total catch of pink salmon fry from Sherman Creek was 2210 fry between April 12 and May 9 with a maximum daily catch of 353 fry on April 16 (Figure 21). Sherman mark-recapture experiments resulted in 45% recovery of marked fish at the beginning of the survey to 34% at the end of April and 16% in early May (Table 1). Figure 22 shows the estimated daily catch of pink fry based on mark-recapture trials. The total population estimate for the survey period for Sherman Creek based on mark-recapture trials was 8917 pink fry. No chum fry were observed in Sherman Creek. Table 2 gives the daily catches of fry and population estimates.

Johnson Creek was sampled from April 13 to May 19 with a total catch of 50,779 pink fry and maximum daily catch of 4862 on April 22. 1557 chum salmon fry, 64 juvenile cohos and 10 coast-range sculpin were also captured over the survey. Johnson mark-recapture surveys resulted in 16% recovery at the beginning of the survey to less than 2% in early May then 17%

recovery toward the end of the survey. Fewer fish were captured in early May partly because the wings of the fyke net were not deployed due to high flows. Predation of marked fry released upstream of the net may have contributed to low recovery rates at times. The total population estimate for the Johnson Creek survey based on mark-recapture experiments is 490,641 pink fry.

Slate Creek was sampled from April 13 to May 17 with a total catch of 8180 pink fry and maximum daily catch of 954 on April 14. There were 4 days on Slate Creek when no fish were captured due to the net being washed out of place by high flows. Catch numbers for these days were estimated from the average of the catch on the day before and day after net failure. The total catch including these estimates was 9099 fry. 230 coast-range sculpin, 11 juvenile coho and 39 eulachon were also captured in the fyke net at Slate Creek. Between 11 and 35% of fish were recovered during mark-recapture experiments giving a total population estimate of 34,573 pink fry.

### 6.10 Total Population Estimates

Numbers of pink fry migrating downstream in the spring of 2006 were estimated as 8917, 490,641, and 34,573 in Sherman, Johnson and Slate respectively. These estimates only include fry that hatched upstream of the traps. Sherman Creek has approximately 15% of total spawning habitat located downstream of the trap. If an equal number of fry is assumed to have emerged downstream of the trap, then the total outmigrating fry count would include an additional 15% or 1337 fry bringing the total to 10,254. Johnson Creek has approximately 10% of the total spawning habitat downstream of the trap giving a final total estimate of 539,705. Slate Creek had an additional 12% of potential spawning habitat downstream of the trap giving a total estimate of 38,722 pink fry. Based on these numbers, total mortality caused by monitoring was 3.4%, 0.24% and 0.82% in Sherman, Johnson and Slate Creeks, respectively.

The number of spawning pink salmon adults counted in the fall of 2005 was 2,973 in Sherman Creek, 2782 in Johnson Creek and 574 in Slate Creek. Numbers of fry produced per adult female was 7 in Sherman Creek (total number of adults divided by 2 gives number of females, then divide fry estimate by this number). The total number of adults counted at Johnson Creek may have been less than the actual escapement since high turbidity may have prevented salmon from being counted. The graphical presentation of numbers of fish over time should have a bell-shaped curve, but no salmon were counted the week after numbers peaked (Coeur Alaska 2005). Actual numbers may have been closer to 5,500 or higher, to produce the expected bell-shaped distribution. Given an estimated 2750 females (half the total adults), the number of fry produced per female could have been close to 196 at Johnson Creek. The number of fry per female at Slate Creek is estimated at 135.

The survival rate from egg to emergent fry can be estimated by assuming each female is lays between 1500 and 2000 eggs (Heard 1991). For Sherman Creek it is estimated that between 2,229,000 eggs (1486 females x 1500) and 2,972,000 eggs (1486 females x 2000) were deposited, 10,254 fry emerged or between 0.34 and 0.46% survived. For Johnson Creek, an estimated 4,125,000 to 5,500,000 eggs produced 539,705 fry or between 9.8 and 13% survived. At Slate Creek, an estimated 430,500 to 574,000 eggs produced 38,722 fry so the survival rate was between 6.7 ands 9%.

### 6.11 Pink Fry Lengths and Weights

Over the course of the study, the lengths and weights for juvenile pink salmon remained relatively constant at each creek. Juvenile pink salmon captured in Sherman Creek between April 13 and May 7 ranged in length from 31 to 39mm, with a mean of 34.5mm. Mean weight was 0.197g (Table 14). In Johnson Creek, fish captured between April 13 and May 14 were of similar size to fish from Sherman Creek ranging from 32 to 36mm, with a mean length of 34.3mm and mean weight was 0.17g. Slate Creek fry ranged from 30 to 38mm with a mean length of 35.4 and mean weight of 0.27g. Differences in length and weight between creeks were not significant.

**Table 14:** Mean Lengths and Weights of Pink Salmon Fry at each creek.

| | Min Length | Max Length | Mean Length | SD | Mean Weight | SD |
|---|---|---|---|---|---|---|
| **Sherman** | 31 | 39 | 34.5 | 1.627 | 0.197 | 0.062 |
| **Johnson** | 32 | 36 | 34.3 | 1.22 | 0.17 | 0.047 |
| **Slate** | 30 | 38 | 35.4 | 1.53 | 0.268 | 0.131 |

## 6.12 Other Species Collected

In addition to pink salmon, six other species were caught in the fyke nets (Table 15). 1557 chum salmon fry (*Oncorhynchus keta*) were captured in Johnson Creek during the study, but only one was caught in Slate Creek and none were captured in Sherman Creek. The only other species caught in Sherman Creek was Dolly Varden with 4 juveniles caught between April 13 and 24. 230 Coast-range sculpins (*Cottus aleuticus*) were caught in Slate Creek and 10 were caught in Johnson Creek. 64 juvenile coho salmon were caught in Johnson Creek and 11 were caught in Slate Creek. One juvenile cutthroat trout was captured in each of Johnson and Slate Creeks. 39 eulachon (*Thaleichtys pacificus*) were captured in Slate Creek during the last week of April as spawners returned to the ocean.

**Table 15:** Other species captured in fyke nets at each creek.

| | Sherman | Johnson | Slate |
|---|---|---|---|
| **Chum** | 0 | 1557 | 1 |
| **Coho** | 0 | 64 | 11 |
| **Dolly V.** | 4 | 1 | 15 |
| **Cutthroat** | 0 | 1 | 230 |
| **Sculpin** | 0 | 10 | 39 |
| **Eulachon** | 0 | 0 | 1 |

## 6.13 Inclined-Plane Trap Trials

An inclined-plane trap was constructed from welded aluminum following the specifications of Todd (1994). A trial was carried out with this trap at Sherman Creek on April 28. It was evident that modifications would be required to make the trap suitable for use in the shallow, fast waters of Sherman Creek. The entrance to the holding box had to be lowered to allow water to enter at low flow. 54 live pink fry were released at the mouth of the IPT ramp to test trap efficiency. As the fish approached the ramp, low velocities and reduced flow allowed some fish to turn around and attempt to swim back down the ramp. 27 of the 54 fish released, entered the live box with some swimming underneath the ramp. A second trial was conducted on May 2 with 25 pink fry released upstream of the ramp and 13 recovered in the live box. Some fish entered the perforations in the aluminum ramp instead of entering the holding box. It may be difficult to obtain sufficient flow through the trap at low stream flows. High flow could also be problematic unless some form of flotation and suspension in the current is used. The trap was very difficult to move at higher flows with water flowing over the top and high turbulence in the live box. The ramp height should be more adjustable to allow control over the amount of water flowing through the trap. The vexar mesh on the sides of the trap was broken against the force of water at high flow. The vexar should be replaced with rigid perforated aluminum or stronger netting attached with cable ties.

### 6.14 Discussion and Recommendations

The population estimate for Sherman Creek may be rather low since the trap was installed when the number of daily migrants was already fairly high. If the trap had been installed earlier, it is likely that a larger total number would have been captured and the total estimate would have been higher. If number of daily migrants plotted on a graph assumed a bell-shaped distribution then the estimate might be closer to 12,000. The estimate for Johnson Creek might be high since it is based on mark-recapture trials and recapture rates were low on this stream. Kingfishers, dippers, mergansers as well as juvenile Dolly Varden and coho salmon have all been observed in lower Johnson Creek. The fry largely emerge from the gravel and migrate downstream at night as an adaptation against predation, however, mark-recapture trials were conducted during the day. Dyed fish may also be more visible to predators. It is possible that some predation of marked and released fry occurred before they could reach the trap, however, the release site is only 50m upstream and it seems unlikely that predators could remove large numbers of fry when 500 were all released at once near overhanging vegetation.

It is suspected that there were a number of adults that were not detected in the 2005 adult salmon survey in Johnson Creek due to high turbidity reducing visibility. The adult fish counts were conducted from helicopter and some reaches were also difficult to see due to vegetation. No salmon were observed during the week after peak numbers, but a bell-shaped distribution is expected, therefore, it is likely that total escapement of adult pink salmon in Johnson Creek was underestimated. An adjustment in adult numbers was made to account for this from an actual count of 2782 to 5500, but this may still be an underestimate. If more adults were counted, fry production per female would be reduced.

Total estimates of outmigration may be transformed to number of fry produced per female salmon in order to compare data between years. In 1998, the estimated number of fry produced per female in Sherman Creek was 194 (assuming a 1:1 sex ratio, EVS 1999). In 2000, the numbers were approximately 10-fold lower with 15 fry per female in Sherman Creek (EVS 2000) and in 2006, numbers were lower again at only 7 fry per female. Johnson Creek produced fry at a rate similar to that for Sherman Creek in 1998 (196). Average pink salmon fry production over 15 brood years in Auke Creek, SE Alaska, was 12.3 fry per spawner (Fukushima, 1996) or approximately 25 fry per female. In other streams fry production varied between 50 and 200 (Chebanov, 1989) and between 103 and 562 (Shershnev and Zhul'kov, 1980). There is evidently large variability in fry production from year to year and stream to stream. Sherman Creek appeared rather low in fry production in 2006.

Assuming that each female produces between 1500 and 2,000 eggs (Heard, 1991), the egg to fry survival in Sherman Creek was less than 0.5%. In 2000, the rate was estimated as 0.6%. The survival rate in Johnson Creek was between 9.8 and 13% and in Slate Creek was between 6.7 and 9%. These estimates should be considered with caution since they are based on estimated fecundities. 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. Therefore, the survival rate estimated for Sherman Creek could be considered in the low range for pink salmon streams, while Johnson and Slate are average.

The Johnson Creek population estimate was around 50 times that of Sherman Creek and almost 14 times that of Slate Creek. The actual catch of fish in Johnson Creek was 23 times that of Sherman Creek and 6 times that of Slate Creek. Even if total population estimates are high, there were still far more fish counted in Johnson Creek. Johnson Creek does have more spawning habitat than the other creeks, with barrier falls located approximately 1.2km 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. The limited spawning area in Sherman Creek may result in late spawners superimposing their redds on previously constructed redds and displacing eggs of previous spawners (McNeil, 1964), and may be one of the causes for differences between the streams.

Fukushima et al. (1998) found that use of limited spawning areas led to the loss of eggs 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. The total stream area in Sherman Creek was measured as 1,944 $m^2$ in July 2005 (Aquatic Science 2005). Using a total of 2973 spawners, this leaves only 1.3 $m^2$ per female. However, the spawning substrate available would be much less than the total stream area available, suggesting that superimposition of redds may have occurred in Sherman Creek and resulted in lower fry production than in Johnson or Slate Creeks. In Slate Creek particularly, spawning area limitation may not have been as large a factor due to the lower number of adults and the larger area of spawning habitat.

A large freshet occurred in November 2005 in Sherman Creek, with around 17 inches of rain falling near the site within a week. Given the typical peaks in flow that tend to occur in Sherman Creek with rainfall, it is likely that a high level of scouring occurred in the stream, which may have destroyed some redds and the embryos within, resulting in lower numbers of fry observed in 2006. Fluctuations in stream flow between the time of spawning and fry migration is one of the most significant non-biological factor influencing pink salmon survival in freshwater (Wickett, 1958). Involuntary emergence may occur when floods scour the streambed. In addition, the severity of winter conditions can influence successful pink salmon embryo development (McNeil, 1966). Sherman Creek did experience more icing and cooler temperatures than Johnson or Slate Creeks, perhaps contributing to low survival of eggs there.

After experimenting with an inclined-plane trap and making comparisons with fyke nets, it would seem that improvements can be made to the sampling equipment to reduce mortality. The flow regime of Sherman and Slate Creeks seems to involve large peaks in flow with rainfall, which may make it impossible to sample juvenile salmon without causing some mortality. Sherman Creek had the highest mortality rate at 3.4%, which should be reduced if possible. Mortality due to sampling in Slate and Johnson Creeks was less than 1%.

For subsequent years, it is recommended that fyke nets be used in Johnson and Slate Creeks, but the following adjustments should be made to the inclined-plane trap for use in Sherman Creek:

1- Replace 1/8" mesh Vexar (black plastic) on sides of trap with either rigid perforated aluminum or stronger netting attached with cable ties.

2- Reduce perforation size of aluminum on ramp: no larger than 5/16 inch diameter holes.

3- Make an adjustable front panel in the live box where the ramp enters to allow operation in shallower depths.

4- ½ inch metal mesh should be placed in front of the box within the first section, to prevent predators (larger fish) from entering the holding chamber (this should be added to the holding boxes at all streams).

## 7.0 Weekly Adult Salmon Counts

### 7.1 Surveys and Analysis

Counts of migrating adult salmon were made once a week in the anadromous reaches of Sherman, Johnson and Slate creeks from July 25 to October 26, 2006. Prior to the first survey, flagging was placed along one bank of at 50m intervals (Sherman Creek) 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.

The data gathered from the 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 method 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. Where chum or coho were only observed for one week, the total number observed was counted as the escapement.

### 7.2 Adult Salmon Counts

Weekly counts of adult salmon for 2006 are presented in Appendix 5. Figure 23 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 27 to September 28 with a maximum of 481 individuals observed on August 10. One chum salmon was observed in Sherman Creek on August 3, and two chums on August 10. No coho salmon were observed in Sherman Creek during the survey period. In Johnson Creek, pink salmon were observed from July 25 to September 21, with numbers peaking at around 4,800 fish on August 10. Around 250 chum salmon were observed in Johnson Creek on August 3 and around 50 on August 10. Approximately 50 coho salmon were observed in Johnson Creek on October 12. In Slate Creek, pinks were observed from July 29 to September 13 with numbers peaking at 1,949 on August 17. No chum or coho salmon were observed in Slate Creek in 2006. Numbers of pink salmon reached a peak around mid-August in each stream. The magnitude of the pink salmon escapement in Johnson Creek was around 6.5 times that of Sherman Creek and 2.5 times that of Sweeny Creek (Table 16).

**Table 16: Salmon Escapement in Sherman, Johnson and Slate Creeks in 2006.**

| | Salmon Escapement | | |
|---|---|---|---|
| | **Sherman Creek** | **Johnson Creek** | **Slate Creek** |
| **Pink** | **1000** | **6534** | **2428** |
| **Chum** | **2** | **250** | **0** |
| **Coho** | **0** | **50** | **0** |

**Figure 23: Weekly Counts of Pink Salmon in Sherman, Johnson and Slate Creeks.**

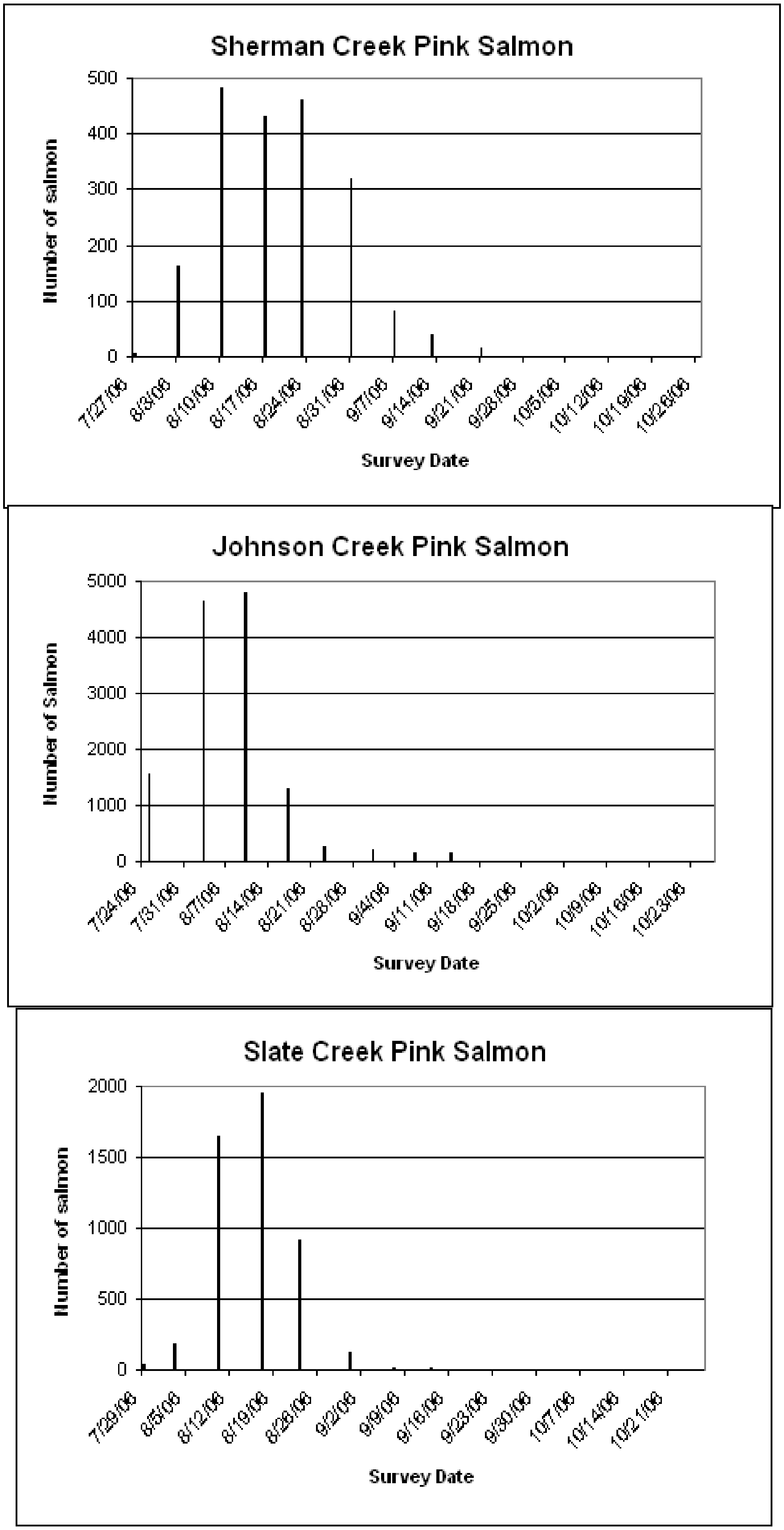
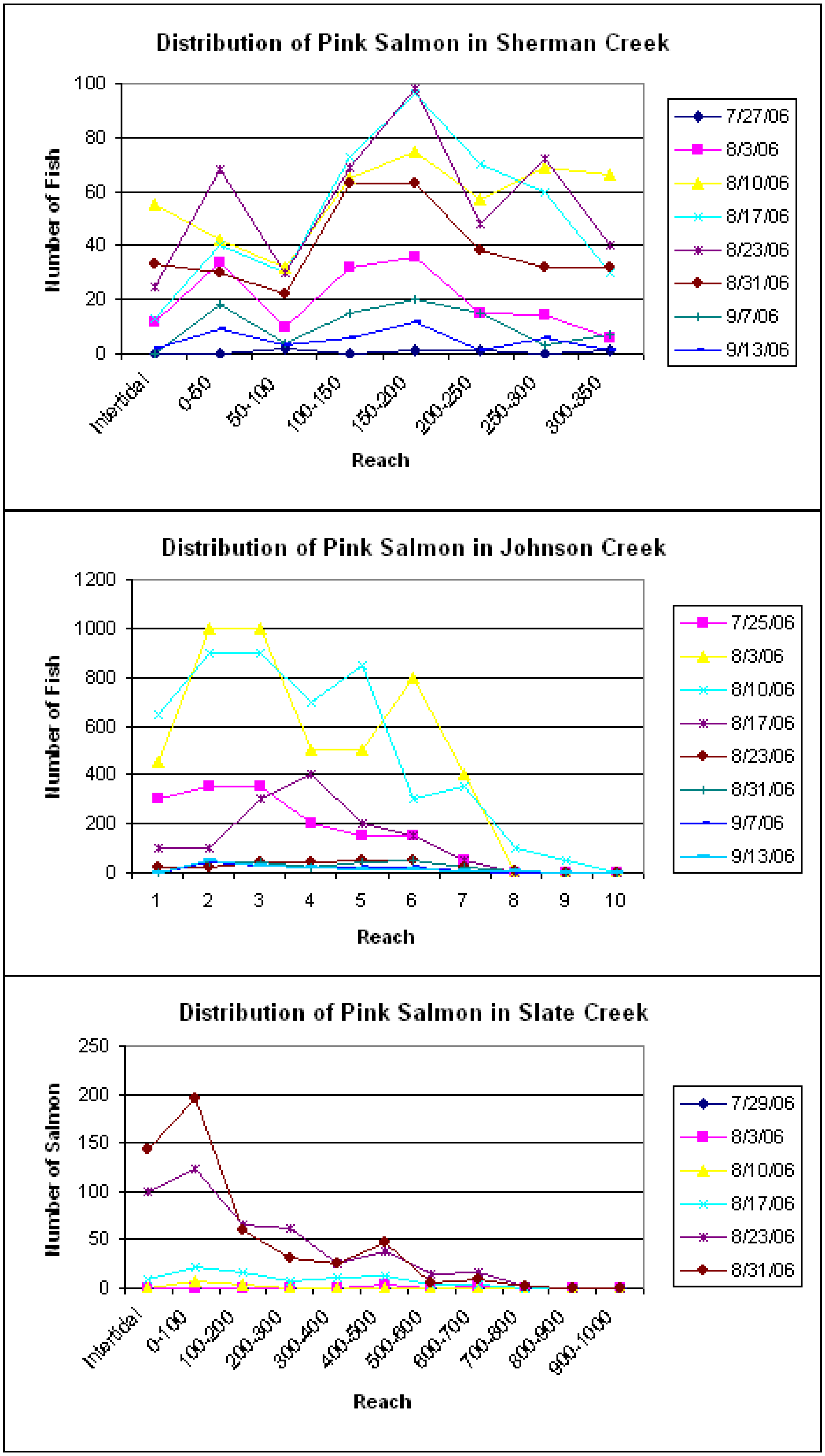


**Figure 23: Distribution of Salmon in each creek in 2006.**



The distribution of salmon in each stream throughout the surveys is shown in Figure 42. In Sherman Creek, pink salmon seemed fairly well distributed throughout the stream from the intertidal reach to the falls barrier. In Johnson Creek pink salmon were mostly observed in reaches 1 to 7. In Sweeny Creek, pink salmon were mostly observed in the first 500m of the stream.

### 7.3 Pink Salmon Escapement Comparison

A comparison of pink salmon escapement between 2005 and 2006 is shown in Figure 25. More than twice as many pink salmon were estimated to have returned to Johnson Creek in 2006 than the previous year, while four times as many returned to Slate Creek. Sherman Creek, however, had only around one third of the escapement as the previous year. Sherman Creek is more subject to flashy flood events than either groundwater based Johnson Creek or lake-buffered Slate Creek. Returns may also have been affected by the size of the stock in 2004, which was low in some streams due to low flows caused by low rainfall.

**Figure 25:** Estimated pink salmon escapement for 2005 and 2006.

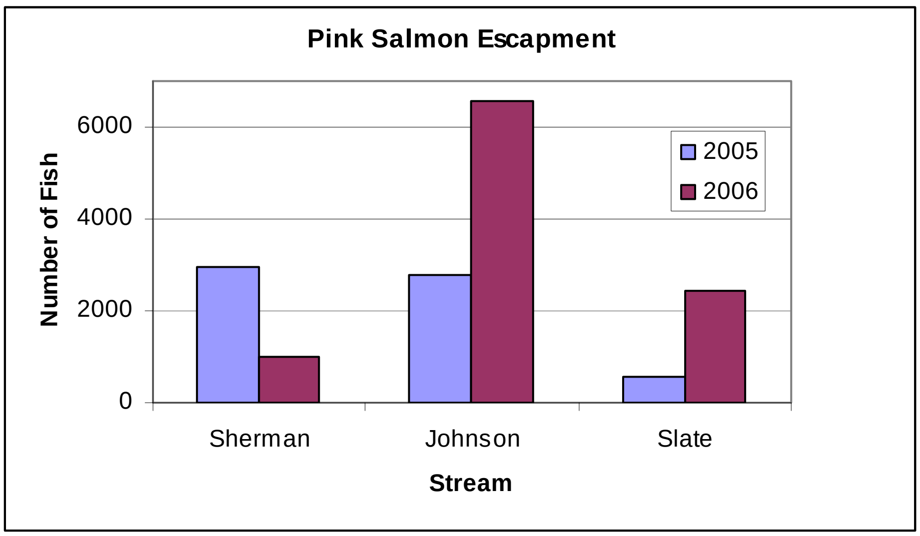


**Figure 26:** Pink salmon observed in Johnson Creel from helicopter.

**Figure 27:** Pink salmon observed in Slate Creek from bank.

## 8.0 Quality of Spawning Substrate

### 8.1 Sample Collection and Analysis

Samples of spawning gravel were collected from each of two reaches in Sherman Creek on July 26, in Johnson Creek on July 25, and in Slate Creek on July 29, 2006. The two reaches in Sherman Creek lie between 3 and 29m, and between 288 and 315m from the stream mouth as defined by Konopacky (1992). The two reaches in Johnson Creek are located between 320 and 340m, and between 425 and 450m from the stream mouth. The two reaches in Slate Creek are located between 125 and 150m, and between 175 and 200m from the stream mouth. Four samples were collected from each reach using a McNeil-type sampler with a coring diameter of 15cm and a coring depth of 25cm. 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.

Collected substrate was wet-sieved on site through the following sieve sizes given 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). The contents of each sieve were allowed to drain, then were measured by volume displacement 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 placed in an Imhoff cone to settle out; this volume was read directly from the cone.

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.

The products of each size class are then multiplied together to obtain $d_g$:

$$d_g = (d_1^{v_1} \times d_2^{v_2} \ldots\ldots\ldots\ldots\ldots \times d_n^{v_n})$$

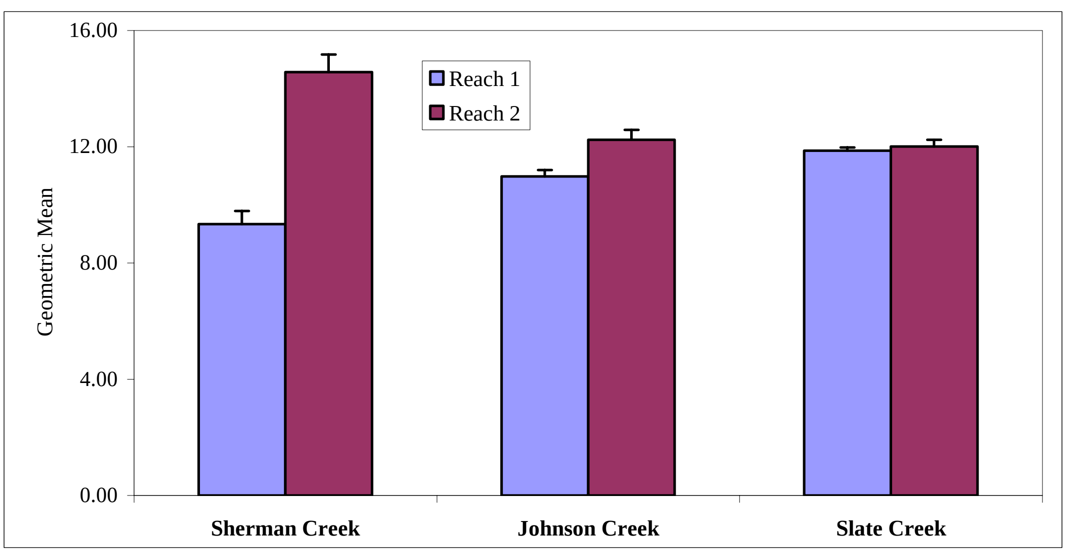
where dg = geometric mean particle size
d = midpoint diameter of particles retained by a given sieve
v = decimal fraction by volume of particles retained by a given sieve

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 75$^{th}$ percentile of total sample volume is divided by that at the 25$^{th}$ 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, 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.

$$F_i = d_g/S_o$$

**Figure 28.** A comparison of spawning gravel geometric mean particle sizes.



## 8.2 Spawning Gravel Composition

The volumetric measurements of gravel sizes retained by sieves are presented in Appendix 4. The geometric mean particle sizes ($d_g$), grain size percentiles (75$^{th}$ and 25$^{th}$), sorting coefficients ($S_o$), Fredle Indexes ($F_i$), and Embryo Survival Prediction (%) are presented in Table 17. Embryo survival predictions and grain size percentiles are obtained graphically from Lotspeich & Everest (1981).

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), geometric mean particle size and Fredle indexes for 2006 gravel samples, predict embryo survival to range from 37 to 49% for both reaches of Johnson and Slate Creek. Sherman Creek embryo survival prediction ranges from 68% in the lower reach to 77% in the upper reach.

**Table 17.** Calculated Indices for Spawning Gravel samples collected from Sherman, Johnson, and Slate Creeks in July 2006.

| | | Geometric Mean | Grain size percentile (75th and 25th) | | Sorting Coefficient | Fredle Index | Embryo Survival-to-Emergence Prediction |
|---|---|---|---|---|---|---|---|
| **Sample** | | **dg** | **d75** | **d25** | **So** | **(f = dg/So)** | **(%)** |
| **Sherman Creek** | | | | | | | |
| **Reach 1** | 1 | 8.83 | 11.9 | 3.85 | 1.76 | 5.02 | 62.0 |
| | 2 | 8.84 | 12.2 | 2.9 | 2.05 | 4.31 | 59.0 |
| | 3 | 8.96 | 12.1 | 2.9 | 2.04 | 4.39 | 59.5 |
| | 4 | 10.73 | 12.2 | 9.6 | 1.13 | 9.52 | 93.0 |
| **Mean** | | 9.34 | **12.10** | **4.81** | **1.74** | | **68.4** |
| Standard Deviation | | 0.93 | 0.14 | 3.22 | 0.43 | | 16.5 |
| 95% Confidence Interval | | 0.45 | 0.14 | 3.16 | 0.42 | | 16.1 |
| **Reach 2** | 1 | 13.74 | 25.4 | 8.8 | 1.70 | 8.09 | 86.0 |
| | 2 | 13.27 | 27.5 | 5.5 | 2.24 | 5.94 | 71.0 |
| | 3 | 15.79 | 66.5 | 10.8 | 2.48 | 6.36 | 75.0 |
| | 4 | 15.47 | 58 | 11.5 | 2.25 | 6.89 | 78.0 |
| **Mean** | | **14.57** | **44.35** | **9.15** | **2.17** | | **77.5** |
| Standard Deviation | | 1.25 | 20.98 | 2.69 | 0.33 | | 6.4 |
| 95% Confidence Interval | | 0.61 | 20.56 | 2.64 | 0.32 | | 6.2 |
| **Johnson Creek** | | | | | | | |
| **Reach 1** | 1 | 10.91 | 11.20 | 0.75 | 3.86 | 2.82 | 39.0 |
| | 2 | 10.41 | 9.20 | 0.52 | 4.21 | 2.47 | 35.0 |
| | 3 | 11.17 | 14.20 | 0.93 | 3.91 | 2.86 | 40.0 |
| | 4 | 11.44 | 15.00 | 0.61 | 4.96 | 2.31 | 34.0 |
| **Mean** | | **10.98** | **12.40** | **0.70** | **4.23** | | **37.0** |
| Standard Deviation | | 0.44 | 0.00 | 0.18 | 0.51 | | 2.9 |
| 95% Confidence Interval | | 0.22 | 2.63 | 0.18 | 0.50 | | 2.9 |
| **Reach 2** | 1 | 12.08 | 21.50 | 1.40 | 3.92 | 3.08 | 43.0 |
| | 2 | 11.68 | 19.50 | 1.25 | 3.95 | 2.96 | 42.5 |
| | 3 | 13.25 | 29.90 | 3.50 | 2.92 | 4.53 | 62.0 |
| | 4 | 11.95 | 23.00 | 1.80 | 3.57 | 3.34 | 50.0 |
| **Mean** | | **12.24** | **23.48** | **1.99** | **3.59** | | **49.4** |
| Standard Deviation | | 0.69 | 4.52 | 1.03 | 0.48 | | 9.1 |
| 95% Confidence Interval | | 0.34 | 4.43 | 1.01 | 0.47 | | 8.9 |
| **Slate Creek** | | | | | | | |
| **Reach 1** | 1 | 11.99 | 21.50 | 2.70 | 2.82 | 4.25 | 59.0 |
| | 2 | 11.74 | 25.00 | 3.10 | 2.84 | 4.14 | 58.0 |
| | 3 | 12.12 | 20.50 | 1.25 | 4.05 | 2.99 | 42.5 |
| | 4 | 11.62 | 18.50 | 0.91 | 4.51 | 2.58 | 36.0 |
| **Mean** | | **11.87** | **21.38** | **1.99** | **3.56** | | **48.9** |
| Standard Deviation | | 0.23 | 2.72 | 1.07 | 0.86 | | 11.4 |
| 95% Confidence Interval | | 0.11 | 2.67 | 1.05 | 0.84 | | 11.2 |
| **Reach 2** | 1 | 12.18 | 23.00 | 1.40 | 4.05 | 3.00 | 42.0 |
| | 2 | 12.59 | 16.50 | 0.98 | 4.10 | 3.07 | 43.0 |
| | 3 | 11.81 | 20.50 | 1.70 | 3.47 | 3.40 | 48.0 |
| | 4 | 11.47 | 18.00 | 1.10 | 4.05 | 2.83 | 39.0 |
| **Mean** | | **12.01** | **19.50** | **1.30** | **3.92** | | **43.0** |
| Standard Deviation | | 0.48 | 2.86 | 0.32 | 0.30 | | 3.7 |
| 95% Confidence Interval | | 0.24 | 2.80 | 0.32 | 0.29 | | 3.7 |

## 8.3 Comparison with Geometric Mean Particle Size in 2005.

The geometric mean particle size of samples from each site was compared with samples collected in 2005 by applying a single factor ANOVA to the data. Table 18 shows geometric means for 2005 and 2006, while Table 19 summarizes p values from ANOVA. The only significant difference at the 95% level between years was for Sherman Creek Reach 2, which revealed the geometric mean was greater in 2006, indicating less fine material. This may have been due to fine material being washed out of the stream during flood events in late 2005. It also illustrates the wide range in results possible at the same site.

**Table 18: Comparison of Dg for 2005 and 2006.**

| Geometric Mean Particle size (dg) of Spawning Gravel | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Sherman | | Johnson | | Slate | |
| | | 2005 | 2006 | 2005 | 2006 | 2005 | 2006 |
| Reach 1 | 1 | 9.94 | 8.83 | 10.76 | 10.91 | 11.60 | 11.99 |
| | 2 | 9.57 | 8.84 | 11.04 | 10.41 | 11.63 | 11.74 |
| | 3 | 9.47 | 8.96 | 11.03 | 11.17 | 13.60 | 12.12 |
| | 4 | 9.30 | 10.73 | 10.38 | 11.44 | 12.42 | 11.62 |
| **Geometric Mean (X)** | | **9.57** | **9.34** | **10.80** | **10.98** | **12.31** | **11.87** |
| Standard deviation | | 0.27 | 0.93 | 0.31 | 0.44 | 0.94 | 0.23 |
| 95% Confidence level | | 0.27 | 0.45 | 0.31 | 0.22 | 0.92 | 0.11 |
| Reach 2 | 1 | 1.80 | 13.74 | 11.80 | 12.08 | 13.12 | 12.18 |
| | 2 | 2.79 | 13.27 | 13.64 | 11.68 | 13.14 | 12.59 |
| | 3 | 3.63 | 15.79 | 12.51 | 13.25 | 13.20 | 11.81 |
| | 4 | 3.37 | 15.47 | 10.85 | 11.95 | 17.47 | 11.47 |
| **Geometric Mean (X)** | | **2.90** | **14.57** | **12.20** | **12.24** | **14.23** | **12.01** |
| Standard deviation | | 0.81 | 1.25 | 1.17 | 0.69 | 2.16 | 0.48 |
| 95% Confidence level | | 0.79 | 0.61 | 1.15 | 0.34 | 2.12 | 0.24 |

**Table 19: Significance results from ANOVA**

**Single Factor Anova**

| 2005 vs 2006 | p value |
|---|---|
| **Sherman Reach 1** | 0.6494 |
| **Sherman Reach 2** | 0.0002 |
| **Johnson Reach 1** | 0.5275 |
| **Johnson Reach 2** | 0.9700 |
| **Slate Reach 1** | 0.3936 |
| **Slate Reach 2** | 0.1461 |

## 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 2006. These reaches are downstream of outfall 001 (Sherman Creek), the proposed outfall 002 (Slate Creek) and the mill process site (Johnson Creek). In Sherman Creek, aquatic vegetation was negligible with only larger, more stable substrate exhibiting a thin algal covering (Figure 29).

**Figure 29: Lower Sherman Creek; some algae on larger boulders.**

Johnson and Slate Creeks showed very little aquatic vegetation on the substrate (Figures 30 and 31). Periodic high flows in these steep, coastal streams are likely to disturb the substrate and restrict aquatic plant growth. Some mosses and ferns are present in the splash zone, particularly near waterfalls.

**Figure 30:** Lower Slate Creek; negligible aquatic vegetation.

**Figure 31**: Middle Johnson Creek; very little aquatic vegetation.

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