Padden Creek Monitoring Project
Final Report

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1 Executive Summary

This report describes water quality and macroinvertebrate sampling that was done as part of the *Waste Integration Pollution Prevention–Whatcom Watersheds Project* (WIT). Water quality samples were collected at six sites in the Padden Creek watershed from October 2000 through July 2001. One site was located in an unnamed tributary that flows into Lake Padden, four sites were in Padden Creek downstream from the lake, and one site was located in Connelly Creek, a tributary to Padden Creek. Benthic macroinvertebrate samples were collected during September 2000 at each of the six sites.

The water quality in Padden Creek is influenced by the surrounding land use, and, in particular, by the comparatively poorer water quality in Connelly Creek. Connelly Creek adds significant quantities of nitrogen, phosphorus, dissolved solids, and coliforms. The lake acts as a sedimentation basin, which very likely removes some of the nutrients and pollutants that enter from the upper watershed, but it also exports particulate organic matter and algae. The lake warms the water, resulting in elevated temperatures at the outlet, but because the downstream portion of Padden Creek is largely shaded by riparian vegetation, the lake's effect on stream temperatures is minimal.

Upstream from Lake Padden (PD6), and at the lake outlet (PD5) the Padden Creek substrate consisted mostly of course and fine gravel or cobbles. Near the confluence with Connelly Creek (PD4) the substrate shifted toward smaller size classes dominated by sand and fine or coarse gravel. The Fairhaven Park site (PD2) has a very rocky substrate dominated by boulders, cobbles, and coarse gravel. Near the mouth of Padden Creek the substrate was quite diverse, consisting of sand, fine and coarse gravel, and cobbles. The substrate at the Connelly Creek site (PD3) was dominated by sand and fine gravel and had the poorest benthic habitat of all the sites.

The tributary to the lake (PD6) and Padden Creek upstream from the confluence with Connelly Creek (PD4) had the largest number of macroinvertebrate taxa (taxonomic richness), while the lake outlet (PD5), Connelly Creek (PD3), and all Padden Creek sites downstream from Connelly Creek (PD2 and PD1) had fewer taxa. Other measures of macroinvertebrate taxonomic diversity, such as the EPT index (number of Ephemeroptera, Plecoptera, and Trichoptera taxa in the sample) followed similar trends. Large numbers of pollution tolerant macroinvertebrates (Batidae mayflies, chironomids, and oligochaetes) were found in Connelly Creek and the Padden Creek sites downstream from Connelly Creek. The lake outlet (PD5) was unusual in that it had a large percentage of pollution intolerant Plecoptera, as well as large numbers of tolerant chironomids. Many of the taxa found at the outlet were filter-feeders that can take advantage of the fine particulate organic matter that is exported from the lake.

2 Introduction

This project was part of the *Waste Integration Pollution Prevention–Whatcom Watersheds Project* (WIT), funded by the Washington State Department of Ecology and the U. S. Environmental Protection Agency to help reduce or eliminate nonpoint pollution in Whatcom County watersheds. A major component of the WIT project is public eduction designed to reduce nonpoint pollution from households, businesses, and community institutions. The Institute for Watershed Studies (IWS) at Western Washington University has participated in the WIT project by monitoring the water quality and benthic macroinvertebrate community structure in streams within watersheds targeted for public education programs. This report documents the existing conditions in Padden Creek, a small residential creek in south Bellingham, prior to the WIT educational efforts.

2.1 Study Area Description

Padden Creek is located in Bellingham, Washington, population 67,000, in the northwestern corner of Washington State (Figure 1). The region has a temperate climate and receives an average of 91.4 cm (36 in) of precipitation per year. The Padden Creek watershed covers 15.5 km^2. Connelly Creek, a tributary to Padden Creek, drains 3 km^2. The watershed ranges in elevation from sea level to 300 m. Land use in the watershed includes areas of moderate density residential, forested parks, a golf course, a commercial garden and retail areas.

The headwaters for Padden Creek flow into Lake Padden, which is located in a forested city park with trails, a golf course and open grassy areas. The outfall from Lake Padden flows 4.72 km through residential and urban areas before flowing into Bellingham Bay. The golf course in the upper watershed drains into small, unnamed tributaries that flow into Lake Padden along with other small tributaries that collect drainage from the park and residential areas. Most of the upper watershed is forested except for cleared, grassy recreational areas around the lake, and a fairly extensive network of gravel and dirt trails. The outflow is located at the west end of the the lake and is controlled by an overflow weir that only allows discharge from the lake when the lake level is high. A storm drain from the neighborhood north of the lake outlet ties into the Padden Creek channel near the overflow weir. A second pipe, which seems to flow all year, discharges into Padden Creek approximately 100 m downstream from the lake outlet. The pipe was originally part of the historic water supply distribution system that once served the City of Bellingham, and drains water from the bottom of Lake Padden (City of Bellingham Public Works Department, personal communications, 2002). Water from this pipe has a ”rotten egg” (H_2S) smell during summer and supports a thriving growth of iron-oxidizing bacteria where it flows into the creek. The flow from the pipe is a major water source for Padden Creek during dry periods when the lake level is too low to overtop the outlet weir.

The stream channel from the lake outlet to Interstate 5 is forested and has a steep gradient. Downstream from Interstate 5 the gradient is more gradual and the stream flows through residential areas. Much of the drainage to Padden Creek downstream from Lake Padden occurs via storm drains. Connelly Creek drains into Padden Creek near 22nd Street and Old Fairhaven Parkway. Shortly after Connelly Creek flows into Padden Creek, Padden is diverted for about 650 m through an underground culvert along Fairhaven Parkway. The creek resurfaces in Fairhaven Park, a partially forested park in the lower reaches of Padden Creek. There are patches of forest throughout the lower watershed, but the dominant land use is residential. Storm water from the south end of Western Washington University flows into Padden Creek via storm drains on Taylor Avenue and storm water runoff from the Sehome Village mall drains into Connelly Creek. The mouth of Padden Creek, located near Harris Avenue, flows into the Padden Lagoon, a recently revegetated estuary, then into Bellingham Bay.

Most of the soils in the drainage channel and in the lower reaches of Padden Creek are described as Whatcom-Labounty complex. These areas are on glaciomarine drift plains (Easterbrook, 1976). These soils are formed by a mixture of loess, volcanic ash, and glaciomarine deposits, and are very deep, ranging from moderately well-drained (Whatcom soil) to poorly drained (Labounty soil). In the upper reaches of Padden Creek in gently sloping to very steep locations the soils are a combination of Squalicum, Chuckanut, and Nati, which are deep to very deep, and moderately well-drained to well-drained (SCS, 1992).

2.2 Previous Padden Creek Macroinvertebrate Studies

Hachmöller (1989) characterized the aquatic macroinvertebrate communities and collected physical and chemical data at four sites in Padden Creek downstream from the lake outlet. Hachmöller et al. (1991) and Matthews et al. (1991) found that there was a distinct water quality and substrate gradient in the creek that correlated to changes in the macroinvertebrate community structure. Uhlig (1991) further characterized the macroinvertebrate community structure as part of her study regarding predator-prey relationships between stoneflies and mayflies in Padden Creek. Two factors were found to correlate with stonefly taxonomic richness and numerical abundance: water quality and the availability of suitable substrate. Padden Creek stonefly abundances dropped sharply downstream from Connelly Creek, but were also low in clean water areas upstream from Connelly Creek that had fine grained sediments. Downstream from Connelly Creek, other pollution intolerant taxa were less abundant, while the numbers of tolerant taxa (e.g., chironomids and oligochaetes) increased. Since 1989–1990, when these studies were completed, Padden and Connelly Creek have been part of numerous stream restoration efforts. Most of Padden Creek now has a forested buffer, and shading in the lower reaches of Connelly Creek has increased due to the restoration efforts. Chum salmon use Padden Creek for spawning habitat.

3 Methods

3.1 Site Descriptions

Six sites were selected in the Padden Creek watershed for water quality monitoring and macroinvertebrate sampling. The sites were selected using the following criteria:

- the locations were representative of all portions of the watershed;
- past study sites were included to allow comparisons with historic data;
- sites were located upstream and downstream from the confluence of Connelly and Padden Creeks; and
- the water quality sampling sites overlapped with the sites selected by the Department of Ecology for pesticides monitoring.

Using these criteria, one site was located in a stream flowing into Lake Padden, four of the sites were in Padden Creek downstream from the lake, and one site was in Connelly Creek just upstream from the point at which it flows into Padden Creek (Table 1 and Figure 1). Water quality samples were collected monthly at each site from October 2000 through July 2001. Benthic macroinvertebrate samples were collected during September 2000 at four riffles at each of the six sites.

3.2 Water Quality Sampling and Analysis

All water quality samples were analyzed at the IWS laboratory[1] except fecal coliforms, which were analyzed at the City of Bellingham Public Works Department. Standard operating procedures adapted from APHA (1998) were used for all analytical work (Table 2). Temperature was measured in the field using a calibrated mercury or alcohol thermometer. Dissolved oxygen samples were collected using 300 mL BOD bottles; Winkler reagents were added in the field. Sterile Nalgene bottles provided by the City of Bellingham were used to collect fecal coliform samples. A combined water sample for conductivity, pH, turbidity, total phosphorus, total nitrogen, soluble reactive phosphate, ammonia, and nitrate+nitrite was collected in an acid-washed 1-L Nalgene bottle. Because pH was measured in the lab, the water samples were collected with a minimal head space to reduce effects of gas exchange. All samples were transported back to the laboratory on ice. The monthly water quality data are included in electronic format on the CD that accompanies this report and in Excel and ASCII files linked to the web version of this report (Appendix A).

[1]The Institute for Watershed Studies is accredited by the Washington State Department of Ecology (Accreditation #A006).

3.3 Macroinvertebrate Sampling and Analysis

Benthic macroinvertebrates samples were collected in September 2000 following Washington State Department of Ecology protocols (Plotnikoff and Wiseman, 2001). Each site was designated as a 150 meter reach, and four benthic macroinvertebrate samples were collected in each reach. Each benthic macroinvertebrate sample was collected using a 500 μm mesh D-frame net that had an attached 1×2 ft metal frame (0.186 m^2). One sample was collected from each of four riffles within the 150 m reach. In order to improve the macroinvertebrate diversity in the sample, one sampling goal was to select riffles within each reach that were expected to have different taxa. A second goal was to space the riffles approximately equally throughout the reach. All rocks that were at least 60% within the 1×2 ft sampling area were scrubbed with a brush, and the sediment inside the sampling area was disturbed by kicking for 3 minutes. Each sample was placed in a wide mouth Nalgene container with enough 95% ethanol to produce 70% ethanol in the final mixture.

The macroinvertebrate samples were processed following Washington State Department of Ecology protocols (Plotnikoff and White, 1996). Macroinvertebrate specimens were sorted from the substrate in the laboratory using a 10× tabletop magnifying lens. Organisms were transferred to a screw top 50 mL vial containing 70% ethanol+glycerin. All macroinvertebrates were counted identified to the taxonomic resolution specified in Plotnikoff and White (1996). The identified and enumerated organisms were returned to the 50 mL vial and one voucher specimen for each taxon was retained for the IWS reference collection. The macroinvertebrate data are included in electronic format on the CD that accompanies this report and in Excel and ASCII files linked to the web version of this report (Appendix B).

At the time that the macroinvertebrate samples were collected the following habitat parameters were assessed for each reach: canopy cover, substrate structure, wetted width, bankfull width, stream gradient, stream velocity at 0.9 and 0.6 depths, water depth, and visual assessment of human influences. At the bottom of each reach, temperature, dissolved oxygen, conductivity, pH, and stream discharge were measured. A YSI 85 field meter was used to measure dissolved oxygen and conductivity during macroinvertebrate sampling. The YSI 85 was calibrated using factory guidelines from the YSI operation manual. All habitat, substrate, and water quality parameters were measured using the procedures described by Plotnikoff and Wiseman (2001). The habitat data are included in electronic format on the CD that accompanies this report and in Excel files linked to the web version of this report (Appendices C.1–C.4).

3.4 Quality Assurance/Quality Control

Data were entered from field sheets and laboratory notebooks into Excel spreadsheets. Each month, the laboratory manager reviewed field and laboratory log books and spreadsheets for this project. At the end of the project, the laboratory manager verified at least 10% of the final data by tracking all numbers from the original log books to the final data set to identify and correct any data transcription or entry mistakes. The data used to calculate statistics were not screened to remove values below detection limits. These data may include negative numbers because the location assigned as zero for the calibration curve has some degree of associated error. Detection limits for each parameter (Table 2) were estimated based on the variance calculated from replicate low-level samples.

The following procedures were used to verify the accuracy and repeatability of the water quality data collected for this project:

- During each sampling period, duplicate samples were collected for at least 10% of the sites. These were used to estimate total precision including sample collection and analysis (Appendix D.1).

  Most replicates were similar or slightly greater than differences that resulted when splitting a sample in the laboratory. Two pairs of duplicates that resulted in unusually different values were the samples collected on May 10 for soluble reactive phosphate (171.7 and 11.4 μg-P/L) and on February 15 for fecal coliform (240 and 13 cfu/100 mL). These two pairs do not represent typical variability, but the cause of the discrepancy is not known.

- In the laboratory, 10% of the samples were analyzed in duplicate and the results were used to estimate variability associated with analytical procedures (Appendix D.2).

  The laboratory replicates were similar within each pair and the differences were typical of other results from our laboratory. Some of the results displayed as relative percent difference appeared large, but only because the concentrations were very low. In absolute terms, all differences were small.

- Two external check standards (20% and 80% of the calibration standard) were analyzed with each analytical run for nutrients. The results were used to verify that analytical precision and accuracy was acceptable using control charts. If results were unacceptable, a cause was identified and the sample was re-analyzed if necessary, or the associated sample results were not reported.

- Control charts were employed, in accordance with state accreditation procedures for the laboratory, to track and maintain a record of precision.

- Laboratory blank samples were analyzed during each analytical run for nutrients to identify possible contamination or other problems.

- The IWS laboratory participates in proficiency testing two times per year through an independent contractor as required within Washington Department of Ecology accreditation.

At the time of this project, there was no local or national accreditation process for macroinvertebrate taxonomic laboratories as there was for chemistry laboratories. However, in an effort to produce the highest quality data possible, the following procedures were used for the macroinvertebrate samples:

- In the laboratory, 10% of the sorted samples were identified independently by different IWS taxonomists. The small differences encountered were pursued by reanalyzing samples that contained the taxa of concern.
- To ensure comparability to other taxonomists' identifications, keys recommended by Plotnikoff and White (1996) were used whenever possible.
- Ten percent of the samples were sent to Ms. Wease Bollman, taxonomist at Rhithron Associates, Inc. Missoula, MT, for comparison identifications (Appendix D.3).

4 Results

4.1 Water Quality Results

4.1.1 Nutrients

In general, nutrient concentrations increased from the lake outlet (PD5) to the mouth of Padden Creek at Harris Avenue (PD1). Connelly Creek (PD3) had relatively high nutrient concentrations compared to most Padden Creek sites (Tables 3 and 4). These results were consistent with previous studies by Hachmöller (1989) and Uhlig (1991) that reported increasing nutrient concentrations in Padden Creek downstream from Connelly Creek. The small tributary to the lake (PD6) had low phosphorus but high nitrogen concentrations.

Nitrate+nitrite and total nitrogen concentrations were highest in Connelly Creek and the tributary to Lake Padden (see PD3 and PD6 in Tables 3–4 and Figures 2–5). Both of these sites collect drainage from areas where fertilizers are likely to be used regularly. Connelly Creek collects drainage from the community garden and Joe's Garden in Fairhaven, and the tributary to Lake Padden collects drainage from the Padden Creek Golf Course. In addition, the riparian vegetation at both sites includes dense stands of red alder (*Alnus rubra*), which fix N_2 in the root zone, and often leach soluble forms of nitrogen to adjacent streams.

The lake outlet (PD5) had the lowest concentration nitrate+nitrite and total nitrogen, probably due to uptake of nitrogen by phytoplankton. Concentrations increased slightly downstream from the lake (PD5), and increased dramatically downstream from the confluence with Connelly Creek (PD2). Nitrate+nitrite and total nitrogen concentrations increased at all sites in the fall and winter, most noticeably in Connelly Creek and in the lake tributary.

Ammonia concentrations (Figures 6 and 7) were generally near or below the working detection limit of 20 μg-N/L except during months with increased runoff (December, January, and February). The highest concentration (82.2 μg NH_3-N/L on 1/11/01) was measured in the lake tributary (PD6). The watershed upstream from this site is mostly forested but includes a public golf course and several swampy areas. Ammonia is rapidly converted to nitrate+nitrite under oxic conditions, so ammonia is rarely detectable in turbulent, highly aerated streams. The present of $>$80 μg-N/L of ammonia suggest a near-by source, possibly from commercial fertilizer applied to the golf course or from anaerobic soils along the stream banks.

Phosphorus concentrations generally increased downstream from the lake outlet, but unlike nitrogen, phosphorus concentrations were not elevated upstream from the lake. Connelly Creek (PD3) usually had the highest phosphorus concentrations (Figures 8–11). Two notable exceptions occurred, once in April when the total phosphorus at PD1 (Padden Creek at Harris Avenue) was 230 μg-P/L, and again in May when the soluble reactive phosphate at PD1 was 172 μg-P/L. These unusually high concentrations were verified against laboratory analytical records to confirm that the sample was analyzed accurately. Although the laboratory QC records indicated that the two outliers were accurately analyzed, a soluble reactive phosphate field replicate collected in May at the Harris Avenue site was only 11.4 μg-P/L. Because the source of variability could not be attributed to analytical or sampling error, both outlier values were retained in the data file.

4.1.2 Other Water Quality Parameters

Maintaining cool stream temperatures can be challenging in residential areas because of removal and alteration of riparian vegetation. In the Padden Creek watershed, this problem is compounded by the lake, which discharges warm, epilimnetic water at the lake outlet and causes warmer stream temperatures in the summer and fall. However, because much of the Padden Creek riparian zone is vegetated, stream temperatures did not exceed 15°C during our sampling period (Figures 12 and 13). The warmest site was the lake outlet (PD5), which had a mean temperature of 8.2°C. The warming influence of the lake was particularly apparent in October 2000 (Figure 12). Between the lake outlet (PD5) and the site upstream from Connelly Creek (PD4), the stream temperature decreased by 3°C.

The highest temperature measured during 2000/2001 was 15.7°C on September 26, 2000 in Connelly Creek. The highest water temperature measured by Hachmöller (1989) for Connelly Creek was 18.5 °C and the highest Connelly Creek temperature measured by Uhlig (1991) was 18.8°C. The cooler temperatures in 2000 may be the result of shading providing by the restored riparian zone along Connelly Creek, or may reflect natural variation.

All sites except Connelly Creek (PD3) had dissolved oxygen $>$9 mg/L throughout the sampling period (Figures 14 and 15). The lowest dissolved oxygen concentration we measured was 8.5 mg/L on July 31 in Connelly Creek.

Conductivities increased abruptly in Padden Creek downstream from Connelly Creek (Figures 16 and 17). The source of the increase appears to be largely from Connelly Creek, which is consistent with the results reported by Hachmöller (1989) and Uhlig (1989). The increased conductivities at the downstream Padden Creek sites and Connelly Creek are probably the result of runoff from urban areas. Carbonates and other ionic compounds are transported to the stream in runoff from parking lots, streets, and lawns. The pH values also increased downstream from Connelly Creek (Figures 18 and 19). The pH measured at all sites ranged from 7.2 to almost 8.0, which is within acceptable limits for most aquatic organisms.

The highest turbidity values were measured during February, March, and April (Figures 20 and 21) in Connelly Creek (PD3) and the downstream Padden Creek sites (PD1 and PD2). Except for the lake outlet (PD5), all sites had elevated turbidities at some point during the study. The low turbidities at the lake outlet was expected because the slower water velocities in the lake cause particulates to settle out of the water column. The February–April turbidities were probably the result of increased storm water runoff. The lake inlet (PD6) had elevated turbidities during June and July 2001, at a time when all other sites had relatively low turbidities.

The fecal coliform counts were much higher in Connelly Creek (PD3) and downstream from Connelly Creek (PD2 and PD1) compared to the upstream sites (Figures 22 and 23). The highest counts were measured during rain events at PD2 (Padden Creek at Fairhaven Park) on February 15 (440 cfu/100 mL) and March 15 (420 col/100 mL). On these two dates it rained 0.6 cm and 1.4 cm, respectively (Appendix C.4). Many pets and other wildlife use the riparian areas in Fairhaven Park. Masses of animal hair were noticed in the benthic samples collected for macroinvertebrate analysis, and septic odors have been noticed at both PD1 and PD2 during the winter.

4.1.3 Overview of Water Quality

The water quality in Padden Creek is influenced by the surrounding land use, and, in particular, by the comparatively poorer water quality in Connelly Creek. Connelly Creek adds significant quantities of nitrogen, phosphorus, dissolved solids, and coliforms. Because Connelly Creek drains residential and agricultural areas, it very likely adds pesticides and other contaminants commonly found in residential and agricultural storm runoff. Pesticides were measured recently in this watershed by Washington Department of Ecology (Seiders, K, 2001). Ecology detected 18 out of 207 targeted pesticides at four sites (PD2, PD3, PD4, and PD5) during four sampling events from April to June, 2001. The most frequently detected pesticides were dichlobenil, diuron, diazinon, MCPP (Mecoprop), 2,4-D, trichlopry, and pentachlorophenol.

The tributary to Lake Padden (PD6) also drains a residential area, and may contribute pesticides and residential pollutants to Lake Padden and Padden Creek. For most parameters, however, the water quality at PD6 was at least as good as the other sites upstream from Connelly Creek.

The lake acts as a sedimentation basin, which very likely removes some of the nutrients and pollutants that enter from the upper watershed, but it also exports particulate organic matter and algae. The lake warms the water, resulting in elevated temperatures at the outlet, but because the downstream portion of Padden Creek is largely shaded by riparian vegetation, the lake's effect on stream temperatures is minimal.

4.2 Benthic Macroinvertebrates

4.2.1 Habitat Characterization

The physical habitat, stream substrate, and water quality were characterized at each site during the last two weeks of September 2000 to describe the macroinvertebrate habitat at each site. In general, the riparian area is shaded well throughout most of the Padden Creek watershed, as represented by the percent canopy cover measurements (Tables 5–6). The water quality is influenced by the effects of residential runoff downstream from the confluence with Connelly Creek. The September stream temperatures were considerably warmer (2-5°C higher) at most sites compared to October 12, 2000, when the monthly water quality monitoring began (Table 7 and Figure 12). The moderating influence of Lake Padden was apparent because the September-October temperature difference at PD5 was only 0.4°C. The September water temperatures were very similar to temperatures measured on July 31, 2001, the last water quality monitoring date. The conductivities in September 2000 were generally similar to October 2000 and July 2001 (Table 7 and Figure 16). At PD6 (lake inlet) the conductivities were higher in September, October, and July compared to the rest of the year, probably due to low stream flows during those months. Dissolved oxygen concentrations were lower in September than October, probably due to water temperature differences[2], but were similar to the July 31, 2001 results (Table 7 and Figure 14).

Upstream from Lake Padden (PD6), and at the lake outlet (PD5) the Padden Creek substrate consisted mostly of course and fine gravel or cobbles (Figure 24). Near the confluence with Connelly Creek (PD4) the substrate shifted toward smaller size classes dominated by sand and fine or coarse gravel. The Fairhaven Park site (PD2) has a very rocky substrate dominated by boulders, cobbles, and coarse gravel. Near the mouth of Padden Creek the substrate was quite diverse, consisting of sand, fine and coarse gravel, and cobbles. Connelly Creek site (PD3), dominated by sand and fine gravel, had the poorest benthic habitat of all the sites sampled. Connelly Creek (PD3) and Padden Creek upstream from Connelly (PD4) had the highest percentage of fine-grained sediments, which generally provides poor habitat for a macroinvertebrate community.

[2]Oxygen solubility increases in colder water.

The mean wetted width of the stream channels ranged from 1.65 m (PD6) to 4.18 m (PD2). The maximum depth measured during macroinvertebrate sampling was 0.25 m at site PD4. The steepest gradient (13%) was measured at the lake outlet (PD5). All other sites had gradients that ranged from 0.5% to 4% slope. The greatest velocity at 60% depth (2.05 ft/s, 0.625 m/s) was also at site PD5. The maximum velocity at 60% of depth at the other sites ranged from 0.41 ft/s (0.125 m/s) at PD6 to 1.52 ft/s (0.463 m/s) at PD1.

4.2.2 Macroinvertebrate Assemblage

To assess differences in the macroinvertebrate communities between sites, the following biometric indices were calculated:

Taxa Richness = $\sum \text{Unique Taxa}$

EPT Index = $\sum \text{Unique (Ephemeroptera + Plecoptera + Trichoptera) Taxa}$

% Ephemeroptera (not Baetidae) = $\frac{\sum \text{Ephemeroptera}}{\text{Total Count}} \times 100$

% Plecoptera = $\frac{\sum \text{Plecoptera}}{\text{Total Count}} \times 100$

% Baetidae = $\frac{\sum \text{Baetidae}}{\text{Total Count}} \times 100$

% Chironomidae = $\frac{\sum \text{Chironomidae}}{\text{Total Count}} \times 100$

Macroinvertebrate taxonomic richness (the number of different benthic taxa collected at a site) is an indicator of the overall habitat complexity. The tributary to the lake (PD6) and Padden Creek upstream from the confluence with Connelly Creek (PD4) had the highest taxonomic richness (Figure 25). Richness was lower in Connelly Creek (PD3) and all Padden Creek sites downstream from Connelly Creek (PD2 and PD1). Richness at the lake outlet (PD5) was also low. Several characteristics make site PD5 different than the other sites farther downstream. It has much steeper gradient (13%) and it receives its main flow either from the surface of the lake, when the lake level is high enough to overtop the outlet weir, or from the pipe that drains from the lake.

One of the most commonly used indicators of stream disturbances is the EPT index, which is the number of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) taxa in the macroinvertebrate sample. These three orders of macroinvertebrates contain many species that are intolerant or only marginally tolerant of water pollution, but are relatively abundant in clean streams. In Padden Creek, the EPT indices were highest in the tributary to the lake and upstream from the confluence with Connelly Creek (PD6, PD5, and PD4; Figure 26). The EPT indices decreased downstream from Connelly Creek (PD2 and PD1), and were very low in Connelly Creek itself (PD3). These results were similar to the richness results, except at the lake outlet (PD5).

Although it is somewhat redundant with the EPT index, the percentage of Ephemeroptera (mayflies) or Plecoptera (stoneflies) may also be used as indicators of clean water. Organisms from the family Baetidae are not included in the Ephemeroptera index because they are much more pollution tolerant than most other Ephemeroptera. Baetidae are so much more tolerant of pollution that a separate index of percent Baetidae is used to indicate poor water quality.

The Ephemeroptera and Plecoptera indices were consistent with the EPT indices for all sites except the lake outlet (Figures 27–28). The tributary to Lake Padden (PD6) and upstream from Connelly Creek (PD4) had the largest percentages of Ephemeroptera and Plecoptera, while Connelly Creek and the downstream Padden Creek sites had much lower values. The lake outlet (PD5) was variable, with a large percentage of Plecoptera but few Ephemeroptera. The Ephemeroptera at PD5 were almost entirely represented by a single genus, *Paraleptophlebia*, which may indicate habitat limitations due to the unusual water quality, higher stream velocities, and dense shading that limits attached algae growth at this site. The outlet had large numbers of *Sweltsa* and *Zapada* plecopterans, and a variety of Trichoptera, which explains the high EPT index. *Sweltsa* was the most abundant Plecoptera at all sites except Connelly Creek (PD3), where it was completely absent from the macroinvertebrate samples. *Skwala*, a predaceous plecopteran, was present at all sites except the lake outlet (PD5).

Matthews, et al., (1991) and Hachmöller, et al. (1991) reported similar patterns for the Ephemeroptera, Plecoptera, and Trichoptera in Padden Creek. Tolerant taxa were common downstream from Connelly Creek, while upstream from Connelly Creek had a diverse community dominated by the Ephemeroptera, Plecoptera, and Trichoptera. Hachmöller (1989) and Uhlig (1991) found more plecopteran taxa in Padden Creek than we collected in June 2000; however, their samples were collected throughout the year rather than on a single sampling date, so their taxonomic list should include more species.

A high percentage of Baetidae in the total macroinvertebrate count can indicate degraded habitat because organisms from this family are relatively tolerant of water pollution. In Padden Creek, the sites farthest downstream (PD1 and PD2) had the largest percentage of Baetidae (Figure 29). Connelly Creek (PD3) also had a high percentage of Baetidae, while sites in the upper watershed (PD6, PD5, and PD4) had low percentages. *Paraleptophlebia* was the most abundant Ephemeroptera taxon upstream from Connelly Creek, while downstream from Connelly Creek, *Baetis tricaudatus* was the most abundant. Hachmöller, et al. (1991) reported similar findings for Padden Creek.

At sites PD5 and PD6, the most abundant trichopterans were from the family Ryacophilidae. Most species in this family require unpolluted water, and many are predaceous. Downstream, this family was less common, and none were collected at PD1. Limnephilidae, a leaf shredding trichopteran found in headwater streams, was only collected at site PD6. Taxa from the families Hydropsychidae, which spin nets to collect organic matter from the water, and Glossosomatidae, which graze on diatoms and fine organic particulates, were found at all sites. The trichopteran *Polycentropus* was found at PD1, PD2, and PD6. This taxon is predaceous and often found in association with chironomids. In general, the distribution of Trichoptera taxa in Padden Creek indicated a shift from shredders and predators in the upper watershed, with filter feeders in the lower watershed. A similar pattern was reported by Hachmöller, et al. (1991).

A large percentage of chironomids at a site can indicate excessive sedimentation and nutrient enrichment. Chironomids were very abundant at the lake outlet (PD5) (Figure 30). This site receives a large amount of fine particulate organic matter and algae from the lake, which provides a good environment for filter feeding organisms such as chironomid larvae. The other sites had lower percentages of chironomids, particularly the next site downstream, PD4. Surprisingly, the Harris Avenue site (PD1), which by longitudinal position along the stream would be expected to receive the most fine organic matter, had low chironomid dominance compared to the other sites. Many oligochaetes and amphipods were present at PD1, however, and these organisms thrive on fine organic matter and tolerate degraded habitats.

All of the macroinvertebrate indices suggest that the Connelly Creek site (PD3), and both Padden Creek sites downstream from Connelly Creek (PD2 and PD1) have degraded habitats (Table 8). The best Padden Creek habitat, as indicated by the diversity of the macroinvertebrate community, was upstream from Connelly Creek at PD4 and upstream from Lake Padden at PD6.

5 Summary

SITE PD1: This site was located near the mouth of Padden Creek upstream from the salt water influence. The site was characterized by having large numbers of tolerant *Baetis tricaudatus*, as well as many tolerant non-insect taxa (oligochaetes and amphipods). The macroinvertebrate taxonomic richness was low and all macroinvertebrate indices suggested degraded habitat. This site was the least shaded of all sites, with an average canopy cover of 78%, and had a finer substrate than the other Padden Creek sites. Nutrients, conductivity, and coliform counts were elevated compared to the Padden Creek sites upstream from Connelly Creek.

SITE PD2: This site was located in Fairhaven Park and was the downstream from the confluence with Connelly Creek. Nutrients, conductivity, and coliform counts were elevated compared to the Padden Creek sites upstream from Connelly Creek. This site had the highest fecal coliform counts of all the sites including Connelly Creek. Dense amounts of animal hair were observed in the benthic samples, suggesting a high density of animals in the immediate vicinity. All of the macroinvertebrate indices suggested degraded habitat.

SITE PD3: Site PD3 was located in Connelly Creek just upstream from where it flows into Padden Creek. The riparian vegetation in this area was replanted approximately 10 years ago and young trees now shade the reach (100% canopy cover). Much of Connelly Creek is low gradient, and the creek flows through wetlands, low density residential areas, and community or commercial gardens. This site had elevated concentrations of nutrients, conductivity, and fecal coliforms, as well as lower oxygen levels compared to most sites in Padden Creek. The macroinvertebrate community was dominated by taxa that tolerate degraded habitat, including large percentages of *Baetis tricaudatus*, chironomids, and oligochaetes.

SITE PD4: This site was located in Padden Creek upstream from the confluence with Connelly Creek. The water quality at PD4 was very good, with low concentrations of nutrients, low conductivities and turbidities, and low coliform counts. The macroinvertebrate indices confirmed that the benthic habitat at this site was excellent.

SITE PD5: Site PD5 was located about 900 m downstream from Lake Padden. This site had the highest water velocity of all the sites and had the steepest gradient. The site was intensely shaded from the forest canopy (100% canopy cover). During the summer months a noticeable sulfide smell emanated from the pipe that drains the bottom of Lake Padden. Lake Padden stratifies during the summer, and the hypolimnion becomes anaerobic (unpublished IWS data). The water that emerges from the pipe is high is iron, as evidenced by the thick growth of iron bacteria at the discharge point, and is probably high in phosphorous, ammonia, and other chemicals associated with anoxic lake water. In October 2000 the dissolved oxygen concentrations at PD5 were slightly lower than the next downstream site (PD4), but the difference was <1 mg/L, so the anoxic pipe water had been sufficiently aerated that low oxygen was not a problem at this site. The pipe provided most, if not all, of the flow to Padden Creek during dry periods. The water quality at PD5 was somewhat similar to PD4; however, the macroinvertebrate results indicated a lower taxonomic richness, greater chironomid dominance, fewer Ephemeroptera, and a larger percentage of chiromonids.

SITE PD6: This site was selected as a reference site for the study. It was located upstream from Lake Padden in a forested area next to a trail that receives hiker, biker, and a small amount of horse traffic. It also collects drainage from the golf course. The water quality results indicated elevated nitrogen concentrations, similar to concentrations in Connelly Creek. The high nitrogen concentrations were not matched with high phosphorus concentrations and coliform counts, as in the downstream Padden sites and Connelly Creek, so the nitrogen may be coming from natural sources such as the upstream wetlands, alder-dominated riparian zone, or pet waste from the Lake Padden park. The golf course may also be a source, particularly if phosphorus-free fertilizers are being used in the Lake Padden watershed[3]. The macroinvertebrate results indicated high quality habitat as measured by taxonomic richness and EPT index or related metrics. The percentage of chironomids was fairly high, but this could be related to the low flow conditions that occur during the summer.

6 Conclusions and Recommendations

The water chemistry and benthic macroinvertebrate data indicated degraded habitat in Connelly Creek and in Padden Creek downstream from Connelly Creek. Connelly Creek appears to be a major source of nutrient contamination in the lower Padden Creek watershed. Connelly Creek collects drainage from a commercial and community garden on 32nd Avenue and flows through a residential area. Much of the Padden Creek watershed downstream from Connelly Creek is residential. We suggest reviewing fertilizer and pesticide applications in the Connelly Creek watershed, as well as in the lower Padden watershed (downstream from Connelly Creek). The elevated fecal coliform counts in Fairhaven Park should also be investigated, particularly because a sewage smell was noted at this site and people have direct access to the creek at Fairhaven Park.

Because Padden Creek is fed by Lake Padden, the lake establishes the quality of water at the outlet. Although the nutrient concentrations were relatively low at PD5, the benthic community was less taxonomically diverse, and showed other signs of impairment compared to the other Padden Creek sites upstream from Connelly Creek. The macroinvertebrate community at this site is probably influenced by the anoxic water from the lake bottom pipe, the algae and organic matter flowing from the lake, as well as the steep, deeply shaded habitat. Lake Padden is a biologically productive lake, which is a strong factor influencing the habitat at PD5. In particular, the water from the pipe is the primary flow during summer. The bottom of Lake Padden was 6.8°C cooler than the surface water on July 27, 2001 (19.9 and 13.1°C; unpublished IWS data), indicating that the lake was stratified. Discharging cool hypolimnetic water may provide some benefit to stream organisms as long as it has a chance to become oxygenated.

[3]Use of phosphorus-free fertilizer has been encouraged in the Lake Whatcom watershed, and in other areas where runoff may drain into a lake or stream

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8 Tables

Site ID	Site Location	Elev.	GPS Coordinates
PD1	Padden Creek 100 m upstream from Harris Ave	9 m	48° 43’10” N 122° 30’22” W
PD2	Padden Creek near tennis courts in Fairhaven Pk	24 m	48° 42’ 54” N 122° 29’49” W
PD3	Connelly Creek at mouth 10 m upstream from confluence with Padden Creek	36 m	48° 42’56” N 122° 28’54” W
PD4	Padden Creek 20 m upstream from confluence with Connelly Creek	36 m	48° 42’56” N 122° 28’54” W
PD5	Padden Creek 900 m downstream from from Lake Padden outlet	132 m	48° 42’20” N 122° 27’ 59” W
PD6	Unnamed creek upstream from Lake Padden, south of the golf course	142 m	48° 41’48” N 122° 26’21” W

Table 1: Padden Creek watershed site descriptions.

Parameter	APHA Method[†]	Description	Precision[‡]	Detection Limit[‡]	Working Limit[§]
pH	4500-H^+	pH meter	±0.1	NA	NA
Temperature (°C)	2550	Thermometric	±0.5	NA	NA
Conductivity (μS/cm)	2510	Meter	±2.2	2	2
Turbidity (NTU)	2130	Nephelometric	NA	NA	NA
Dissolved oxygen (mg/L)	4500-O C. 4500-O G.	Winkler titration Membrane electrode	±0.10 ±0.10	0.10 0.10	0.1 0.1
Ammonia-N (μg-N/L)	4500-NH3 G.	Automated phenate	±12.5	14.3	20
Nitrate+nitrite-N(μg-N/L)	4500-NO3 I.	Automated Cd reduction	±4.6	6.4	10
Total nitrogen (μg-N/L)	4500-N C.	Persulfate oxidation, automated Cd reduction	±26.3	11.0	20
Soluble reactive phosphate (μg-P/L)	4500-P G.	Auto colorimetry	±2.2	1.5	3
Total phosphorus (μg-P/L)	4500-P H.	Persulfate oxidation, auto colorimetry	±3.4	2.6	5
Fecal coliforms (cfu/100 mL) (City of Bellingham lab)	9220 D.	Membrane filtration	NA	NA	NA

[†] American Public Health Association (1998).
[‡] Analytically derived from replicate sample analyses.
[§] Conservative detection limit that accounts for changes in methodologies.

Table 2: Analytical methods, precision estimates, and detection limits.

	Padden at Harris (PD1)					
Parameter	Mean	Median	SD	Max	Min	N
Conductivity (μS/cm)	161.8	155.5	23.1	209	136.9	10
Dissolved oxygen (mg/L)	11.4	11.5	1.3	13.1	9.3	10
pH	7.8	7.8	0.1	7.9	7.7	10
Temperature (°C)	7.5	7.6	4.6	14.2	0.9	10
Turbidity (NTU)	6.2	5.9	4.1	13.6	2.2	10
Ammonia (μg-N/L)	$<$20	$<$20	14.7	43.1	$<$20	10
Nitrate+nitrite (μg-N/L)	466.1	485.3	181.3	685	191.3	10
Total nitrogen (μg-N/L)	789.3	778.5	305.7	1407.7	404.6	9
Soluble reactive phosphate (μg-P/L)	33.9	19	48.9	171.7	10.7	10
Total phosphorus (μg-P/L)	60.9	37.1	64.2	229.5	24.9	9
Fecal coliform (cfu/100 mL)	132.3	85	94.6	255	22	9

	Padden at Fairhaven (PD2)					
Parameter	Mean	Median	SD	Max	Min	N
Conductivity (μS/cm)	151.7	151.2	18.5	185.4	125.5	10
Dissolved oxygen (mg/L)	11.3	11.4	1.2	13.1	9.7	10
pH	7.8	7.8	0.1	8	7.6	10
Temperature (°C)	7.8	7.7	4.3	14	1.5	10
Turbidity (NTU)	4.8	3	3.2	10.5	1.9	10
Ammonia (μg-N/L)	$<$20	$<$20	18.5	57.5	$<$20	10
Nitrate+nitrite (μg-N/L)	431.7	454.2	158.2	642.1	189.6	10
Total nitrogen (μg-N/L)	705.5	732.4	201.9	985.4	388.4	9
Soluble reactive phosphate (μg-P/L)	16.7	14.8	5.1	25.9	11.3	10
Total phosphorus (μg-P/L)	37.4	42.1	10.9	48.5	20.5	9
Fecal coliform (cfu/100 mL)	207.6	192	140	440	53	9

	Connelly Creek (PD3)					
Parameter	Mean	Median	SD	Max	Min	N
Conductivity (μS/cm)	220	236	34	253	164.9	10
Dissolved oxygen (mg/L)	10.5	10.6	1.3	12.3	8.5	10
pH	7.7	7.7	0.1	7.9	7.5	10
Temperature (°C)	7.9	7.9	4.2	14.5	1.9	10
Turbidity (NTU)	6.6	4.2	5.2	15.6	2	10
Ammonia (μg-N/L)	23.9	30.7	21.8	53.8	$<$20	10
Nitrate+nitrite (μg-N/L)	835.8	919.4	298.7	1371.4	341.7	10
Total nitrogen (μg-N/L)	1137.8	1351.9	372	1601.1	515.9	9
Soluble reactive phosphate (μg-P/L)	25.6	21.2	8.8	42.4	18.2	10
Total phosphorus (μg-P/L)	54.6	52	15.2	76	30.3	9
Fecal coliform (cfu/100 mL)	110.4	86	89.6	285	8	9

Table 3: Water quality summary statistics for sites PD1–PD3, October 2000–June 2001.

Parameter	Padden at Connelly (PD4)					
	Mean	Median	SD	Max	Min	N
Conductivity (μS/cm)	104	105.1	6.6	112.1	88.3	10
Dissolved oxygen (mg/L)	11.2	11.3	1.3	13.1	9.6	10
pH	7.6	7.6	0.1	7.7	7.5	10
Temperature (°C)	8.1	7.6	4.6	14.9	2	10
Turbidity (NTU)	4.1	2.7	3.2	12.3	1.5	10
Ammonia (μg-N/L)	$<$20	$<$20	15.6	37.3	$<$20	10
Nitrate+nitrite (μg-N/L)	245.8	263.8	115.7	381.3	71.2	10
Total nitrogen (μg-N/L)	512	504.4	139.6	706.2	266.1	9
Soluble reactive phosphate (μg-P/L)	10.5	8.4	5.3	23.2	5.8	10
Total phosphorus (μg-P/L)	27.5	23.6	9.8	49.4	15.9	9
Fecal coliform (cfu/100 mL)	32.8	17	35.5	120	4	9

Parameter	Lake Padden outlet (PD5)					
	Mean	Median	SD	Max	Min	N
Conductivity (μS/cm)	92.5	93.3	7.8	104	73.6	10
Dissolved oxygen (mg/L)	11.1	11.4	1.3	12.9	9	10
pH	7.5	7.6	0.1	7.7	7.3	10
Temperature (°C)	8.7	7.9	4.3	14.5	3	10
Turbidity (NTU)	2.8	2.5	1.2	5.6	1.8	10
Ammonia (μg-N/L)	23.8	$<$20	19.4	56.7	$<$20	10
Nitrate+nitrite (μg-N/L)	157	158.1	97.1	288.3	34.3	10
Total nitrogen (μg-N/L)	461	464.9	110.6	592.9	262	9
Soluble reactive phosphate (μg-P/L)	8.6	6.7	5.2	20.9	4.5	8
Total phosphorus (μg-P/L)	27.2	20.7	14.3	62.9	16.6	9
Fecal coliform (cfu/100 mL)	14.4	5	17	46	1	9

Parameter	Tributary to Lake Padden (PD6)					
	Mean	Median	SD	Max	Min	N
Conductivity (μS/cm)	111.9	97.1	32.3	179.5	86.1	10
Dissolved oxygen (mg/L)	10.9	11.1	1.1	12.4	9.2	10
pH	7.5	7.4	0.2	7.8	7.2	10
Temperature (°C)	7.5	6.8	4	13.5	2.5	10
Turbidity (NTU)	6.5	4.3	4.4	16.8	3.8	10
Ammonia (μg-N/L)	30.1	24.7	26.8	82.2	$<$20	10
Nitrate+nitrite (μg-N/L)	733.9	702.8	403.6	1285.4	185.8	10
Total nitrogen (μg-N/L)	1081.7	1052	355.5	1519.4	509.5	9
Soluble reactive phosphate (μg-P/L)	10.1	8.1	4.1	18.9	6.6	9
Total phosphorus (μg-P/L)	36.3	28.2	19.2	77.4	21.6	9
Fecal coliform (cfu/100 mL)	17.8	12	22.4	74	1	9

Table 4: Water quality summary statistics for sites PD4–PD6, October 2000–June 2001.

Parameter	**Padden at Harris (PD1)** Mean	Median	SD	Max	Min	N
Wet width (m)	3.13	2.95	0.57	3.90	2.70	4
Bankfull (m)	4.70	5.20	1.15	5.40	3.00	4
Max. depth (m)	0.12	0.14	0.04	0.15	0.06	4
Depth at sample (m)	0.07	0.07	0.01	0.08	0.05	4
Pct. gradient	2.40	2.50	0.27	2.60	2.00	4
Velocity bottom (ft/sec)	0.96	0.98	0.23	1.18	0.70	4
Velocity 0.6 (ft/sec)	1.19	1.19	0.28	1.52	0.84	4
Pct. canopy cover	77.93	86.00	28.23	100.00	39.70	4
Pct. fines	8.50	7.00	9.29	20.00	0.00	4

Parameter	**Padden at Fairhaven (PD2)** Mean	Median	SD	Max	Min	N
Wet width (m)	4.18	3.85	0.83	5.40	3.60	4
Bankfull (m)	5.20	5.45	1.08	6.20	3.70	4
Max. depth (m)	0.18	0.18	0.04	0.22	0.13	4
Depth at sample (m)	0.10	0.11	0.05	0.15	0.05	4
Pct. gradient	1.75	1.00	1.50	4.00	1.00	4
Velocity bottom (ft/sec)	0.99	1.05	0.64	1.70	0.16	4
Velocity 0.6 (ft/sec)	1.08	1.23	0.65	1.70	0.17	4
Pct. canopy cover	97.43	97.80	3.04	100.00	94.10	4
Pct. fines	1.00	0.00	2.00	4.00	0.00	4

Parameter	**Connelly Creek (PD3)** Mean	Median	SD	Max	Min	N
Wet width (m)	1.75	1.65	0.58	2.50	1.20	4
Bankfull (m)	2.45	2.75	0.80	3.00	1.30	4
Max. depth (m)	0.09	0.10	0.03	0.12	0.06	4
Depth at sample (m)	0.06	0.06	0.02	0.08	0.03	4
Pct. gradient	0.78	0.80	0.21	1.00	0.50	4
Velocity bottom (ft/sec)	0.23	0.19	0.12	0.40	0.15	4
Velocity 0.6 (ft/sec)	0.40	0.43	0.08	0.46	0.28	4
Pct. canopy cover	100.00	100.00	0.00	100.00	100.00	4
Pct. fines	22.00	18.00	16.73	44.00	8.00	4

Table 5: Habitat characterizations for PD1–PD3, September 2000.

Parameter	Padden at Connelly (PD4)					
	Mean	Median	SD	Max	Min	N
Wet width (m)	3.00	2.80	0.69	4.00	2.40	4
Bankfull (m)	3.48	3.40	0.62	4.30	2.80	4
Max. depth (m)	0.18	0.19	0.07	0.25	0.11	4
Depth at sample (m)	0.07	0.07	0.02	0.09	0.05	4
Pct. gradient	1.63	1.75	0.48	2.00	1.00	4
Velocity bottom (ft/sec)	0.56	0.53	0.28	0.92	0.25	4
Velocity 0.6 (ft/sec)	0.92	0.75	0.37	1.47	0.70	4
Pct. canopy cover	100.00	100.00	0.00	100.00	100.00	4
Pct. fines	15.50	18.00	6.40	20.00	6.00	4

Parameter	Lake Padden outlet (PD5)					
	Mean	Median	SD	Max	Min	N
Wet width (m)	3.75	3.55	1.21	5.40	2.50	4
Bankfull (m)	5.10	4.80	1.15	6.60	4.20	4
Max. depth (m)	0.11	0.09	0.06	0.19	0.06	4
Depth at sample (m)	0.07	0.05	0.04	0.12	0.04	4
Pct. gradient	6.25	4.50	4.57	13.00	3.00	4
Velocity bottom (ft/sec)	0.94	1.00	0.38	1.27	0.49	4
Velocity 0.6 (ft/sec)	1.41	1.36	0.49	2.05	0.86	4
Pct. canopy cover	100.00	100.00	0.00	100.00	100.00	4
Pct. fines	5.50	0.00	11.00	22.00	0.00	4

Parameter	Tributary to Lake Padden (PD6)					
	Mean	Median	SD	Max	Min	N
Wet width (m)	1.65	1.60	0.90	2.80	0.60	4
Bankfull (m)	2.93	2.45	1.34	4.90	1.90	4
Max. depth (m)	0.03	0.03	0.01	0.05	0.02	4
Depth at sample (m)	0.02	0.02	0.01	0.03	0.02	4
Pct. gradient	2.75	2.50	0.96	4.00	2.00	4
Velocity bottom (ft/sec)	0.14	0.07	0.19	0.41	0.01	4
Velocity 0.6 (ft/sec)	0.14	0.07	0.19	0.41	0.01	4
Pct. canopy cover	100.00	100.00	0.00	100.00	100.00	4
Pct. fines	5.50	4.00	5.97	14.00	0.00	4

Table 6: Habitat characterizations for PD4–PD6, September 2000.

Site	Date	Temp (°C)	Cond (μS/cm)	pH	DO	Flow (f^3/sec)	Flow (m^3/sec)
PD1	Sept 15, 2000	15.4	177.1	7.84	9.24	1.45	0.0411
PD2	Sept 16, 2000	15.0	160.7	7.90	10.02	1.25	0.0354
PD3	Sept 26, 2000	15.7	255.0	7.66	8.76	0.28	0.0079
PD4	Sept 26, 2000	13.5	106.0	7.64	10.00	0.99	0.0280
PD5	Sept 28, 2000	14.4	99.0	7.27	9.85	0.87	0.0246
PD6	Sept 28, 2000	12.2	215.0	7.75	9.47	0.03	0.0008

Site	Date	Water Clarity	Water Odors	Sediment Odors	Surface Film	Weather	Land Use
PD1	Sept 15, 2000	Cloudy	Absent	Absent	Absent	Clear	Residential
PD2	Sept 16, 2000	Clear	Absent	Absent	Absent	Overcast	Park
PD3	Sept 26, 2000	Clear	Absent	Absent	Absent	Clear	Residential
PD4	Sept 26, 2000	Clear	Absent	Absent	Absent	Clear	Residential
PD5	Sept 28, 2000	Clear	Organic	Organic	Foam	Overcast	Forest
PD6	Sept 28, 2000	Clear	Absent	Absent	Absent	Clear	Park

Table 7: Supplemental water quality data and habitat characterizations for PD1–PD6, September 2000.

	PD1 Harris Ave.	PD2 Fairhaven Park	PD3 Connelly Creek	PD4 Padden Creek near Connelly	PD5 Outlet of Lake	PD6 Tributary to Lake
Taxa Richness	**13–17***	**14–20***	**12–17***	19–26	**13–17***	18–26
EPT Index	**4–8***	**7–11***	**4–8***	11–14	**7–8***	10–13
Pct. Ephemeroptera	**0–3***	**1–13***	**8–23***	16–41	**1–4***	36–56
Pct. Plecoptera	**2–11***	**3–6***	**0–1***	17–52	19–42	12–29
Pct. Baetidae	**22–49***	**21–63***	**4–28***	1–7	0	0–5
Pct. Chironomidae	1–6	**4–23***	**4–18***	2–9	**41–71***	**14–29***

*These values may indicate degraded habitat.

Table 8: Summary and comparison of results of macroinvertebrate metrics.

9 Figures

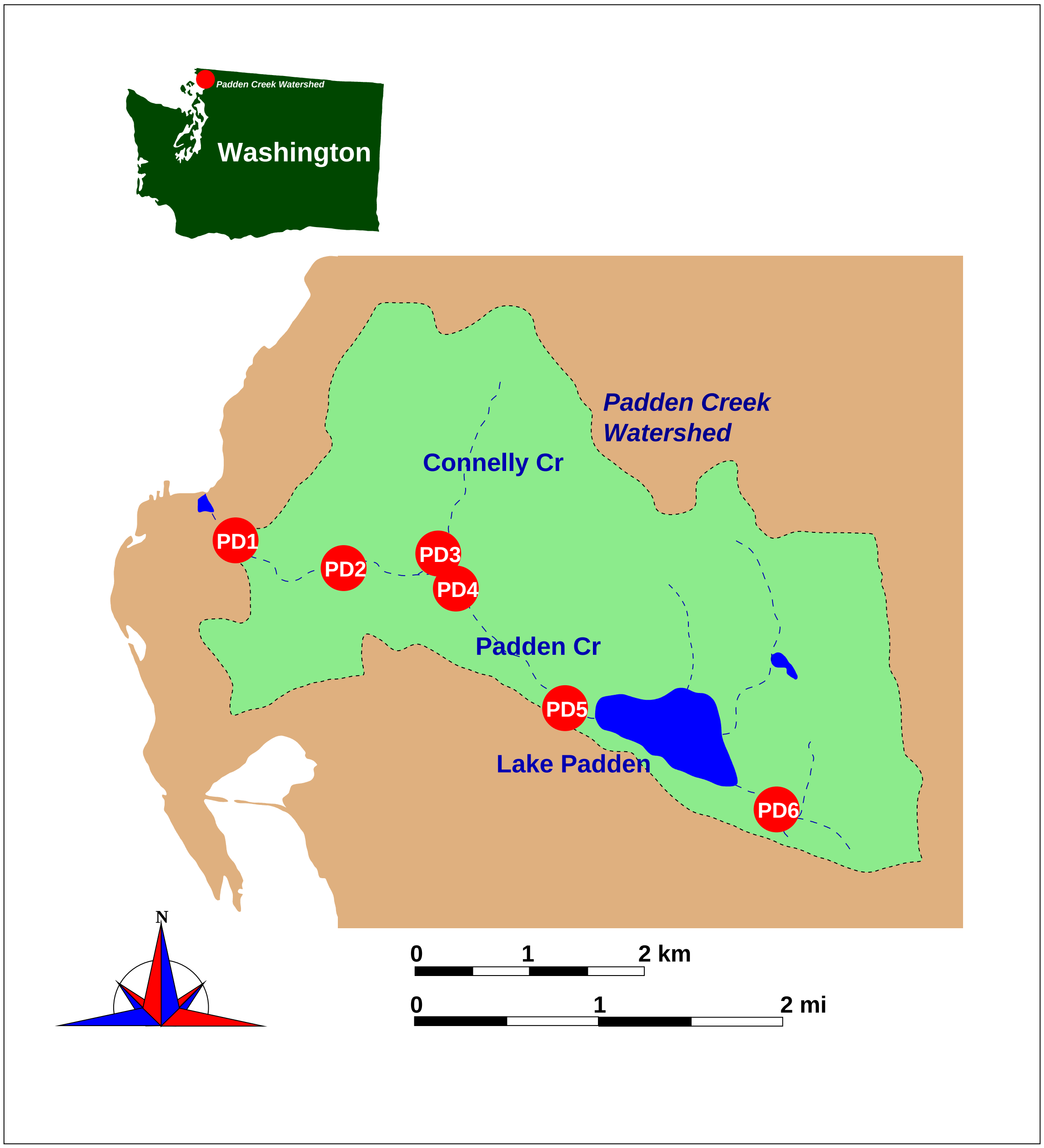

Figure 1: Padden Creek sampling site locations.

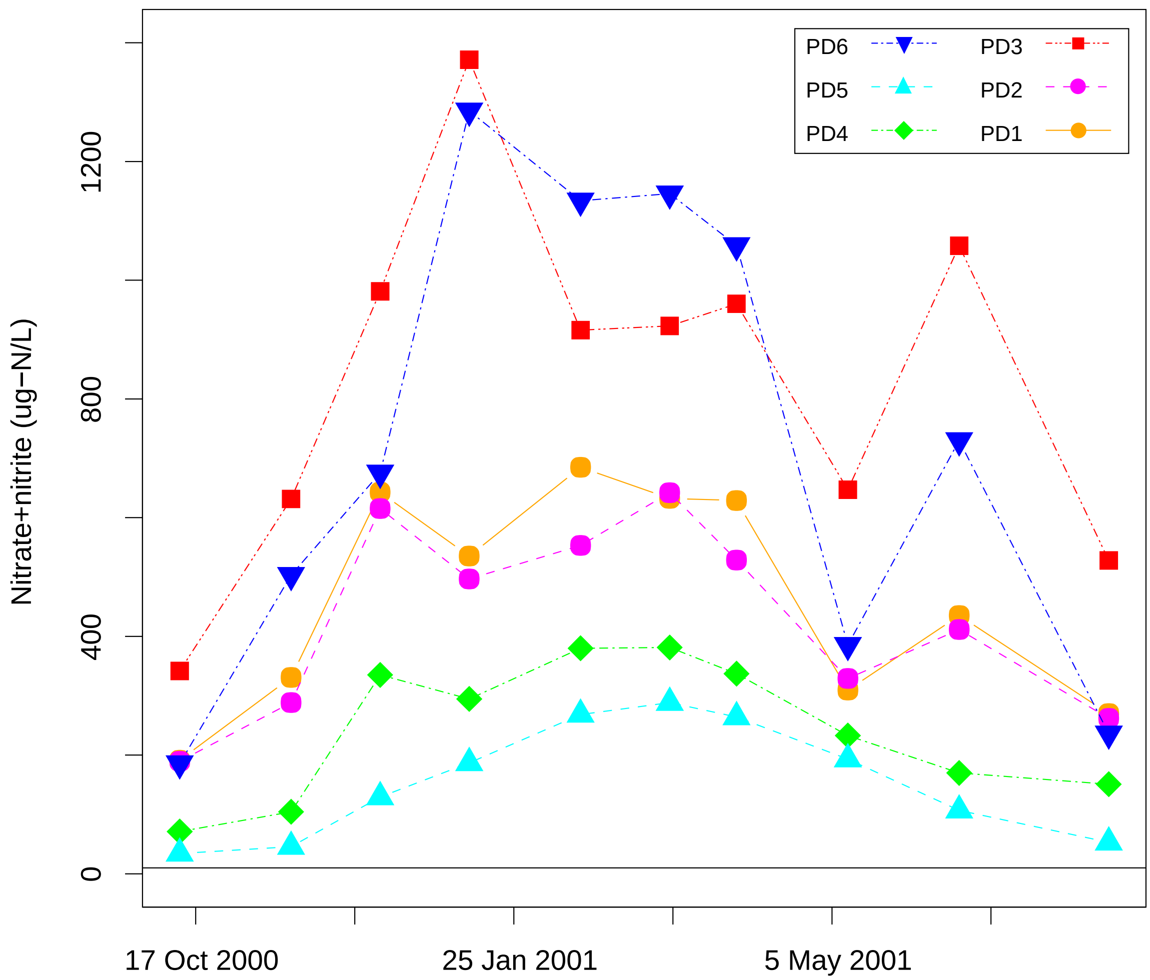

Figure 2: Nitrate+nitrite concentrations at each sampling site from October 2000 to June 2001. Horizontal line indicates detection limit for this analysis.

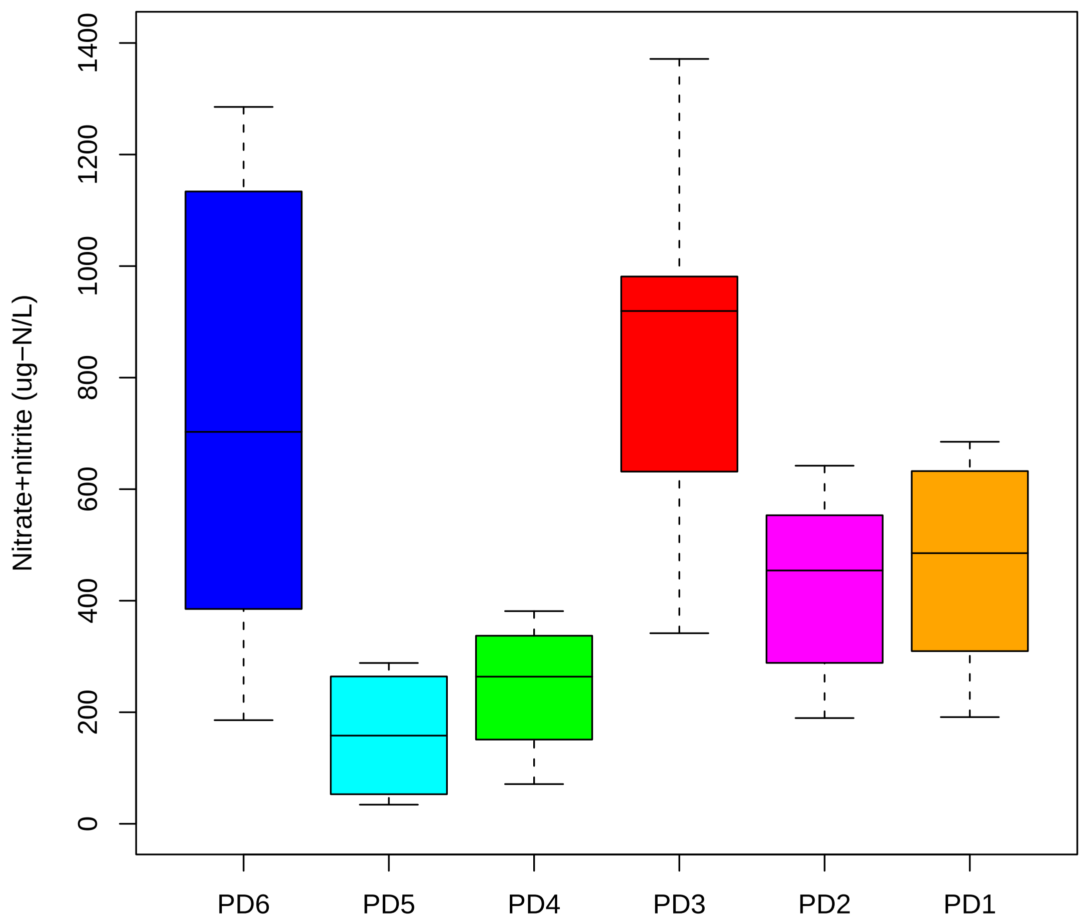

Figure 3: Boxplot summarizing nitrate+nitrite data for Padden Creek from October 2000 to June 2001. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are greater than or equal to 1.5 × interquartile range.

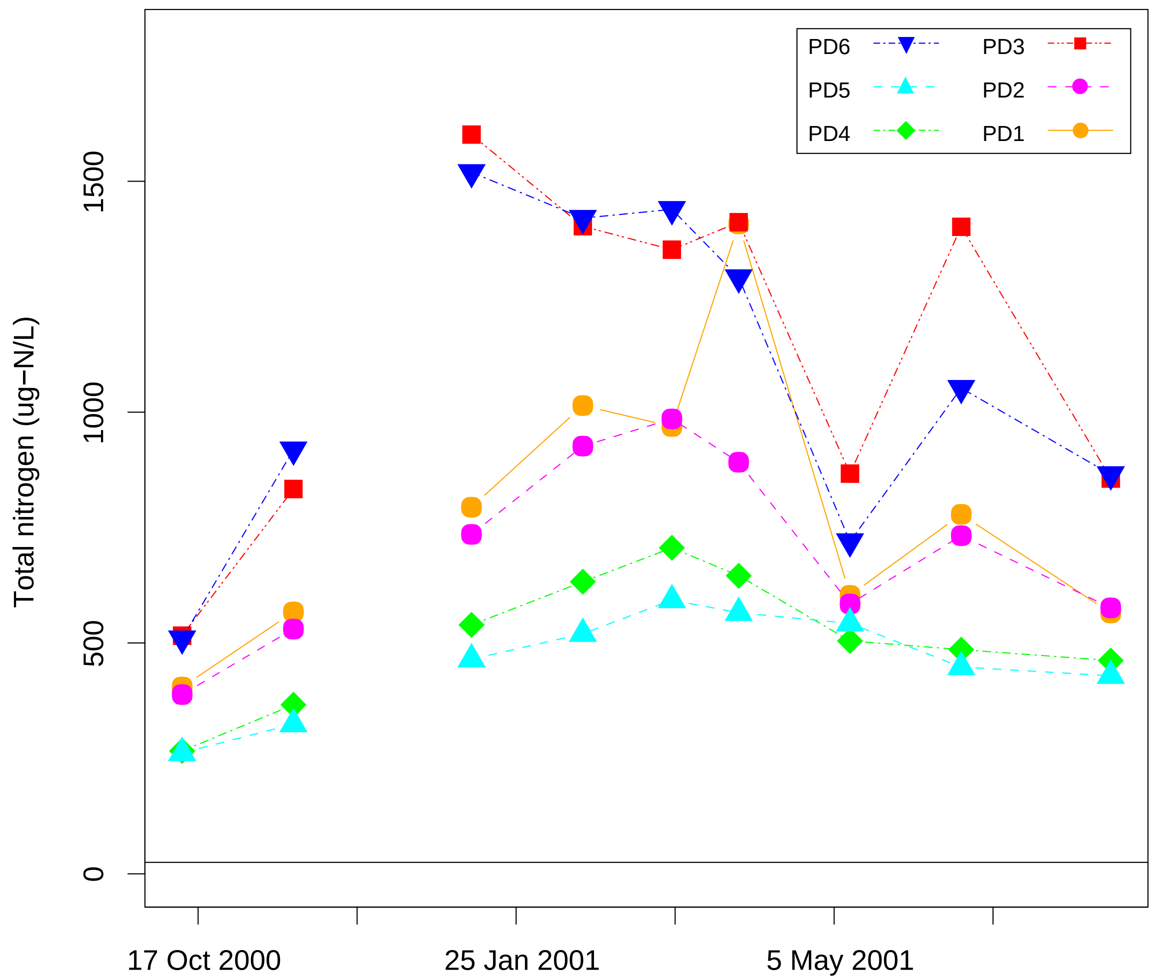

Figure 4: Total nitrogen concentrations at each sampling site from October 2000 to June 2001. Horizontal line indicates detection limit for this analysis.

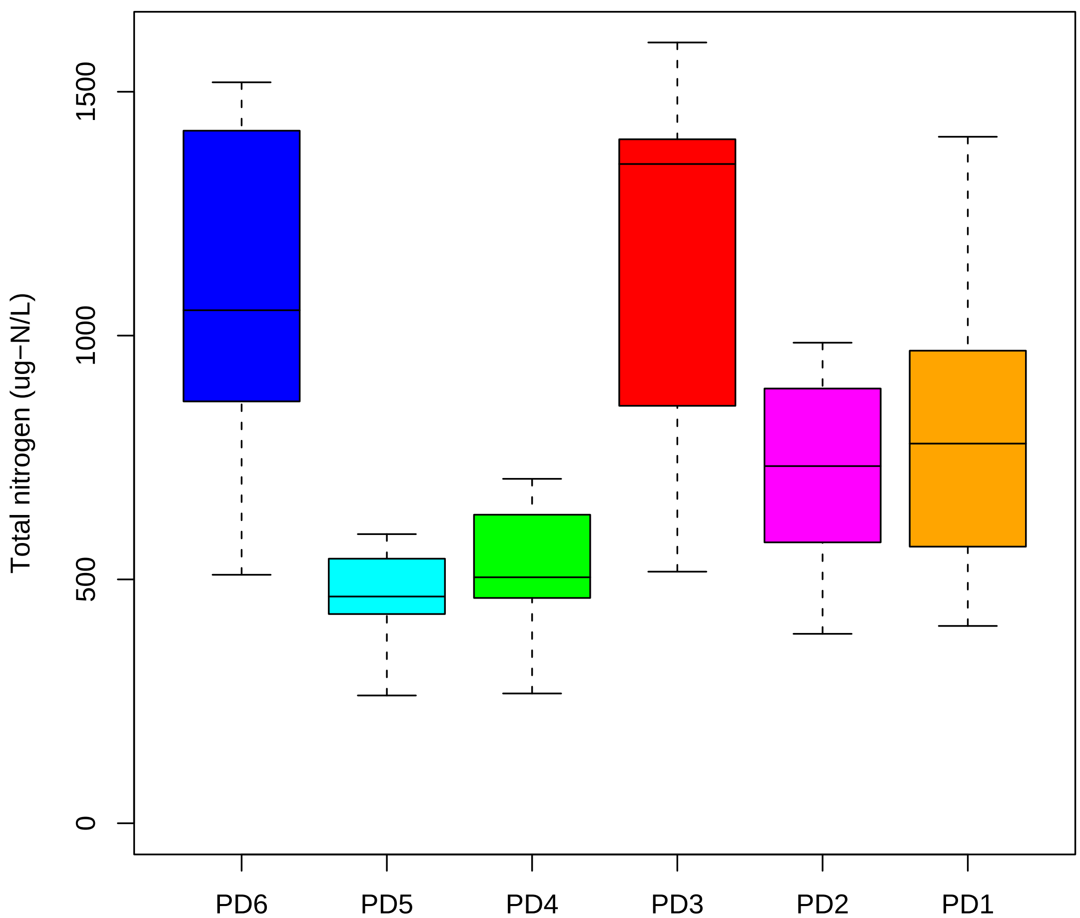

Figure 5: Boxplot summarizing total nitrogen data for Padden Creek from October 2000 to June 2001. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are greater than or equal to 1.5 × interquartile range.

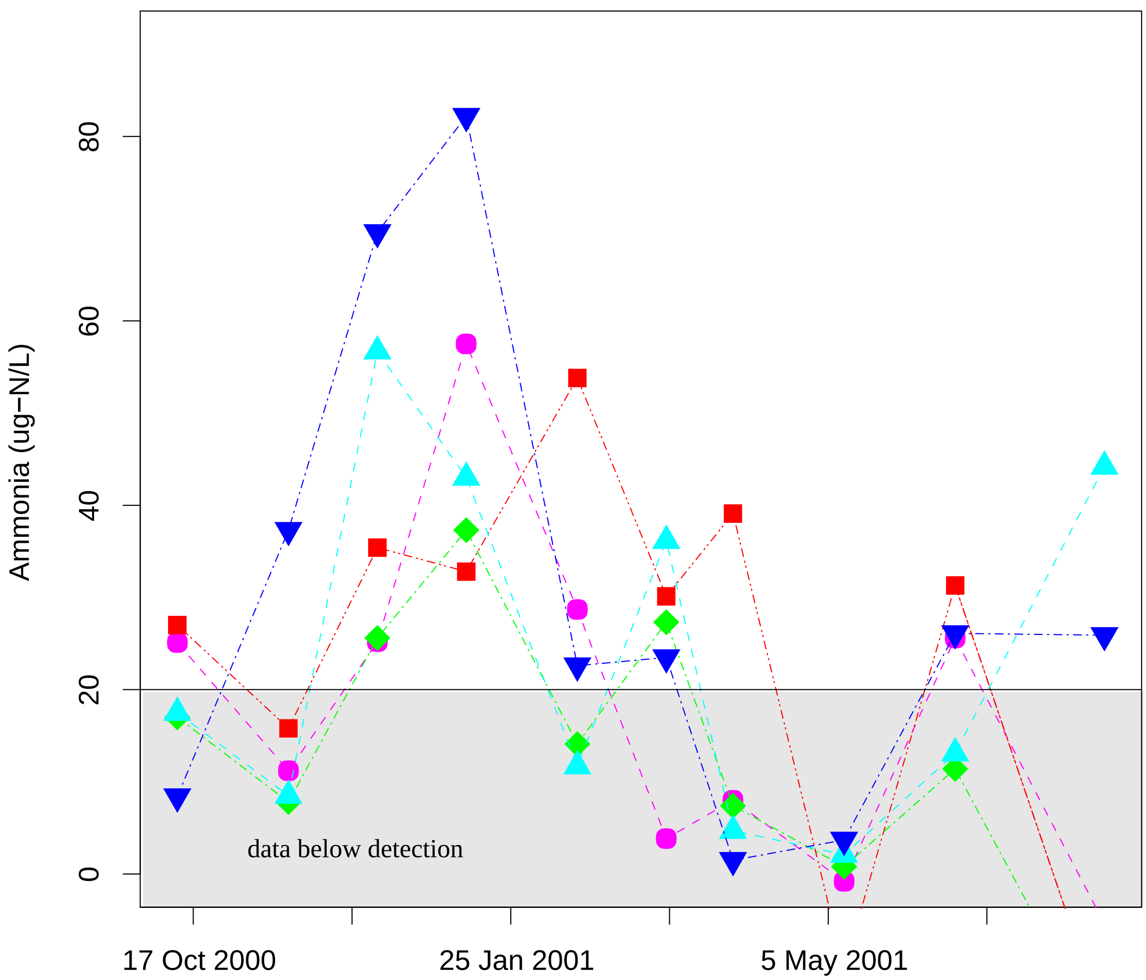

Figure 6: Ammonia concentrations at each sampling site from October 2000 to June 2001. Horizontal line indicates detection limit for this analysis.

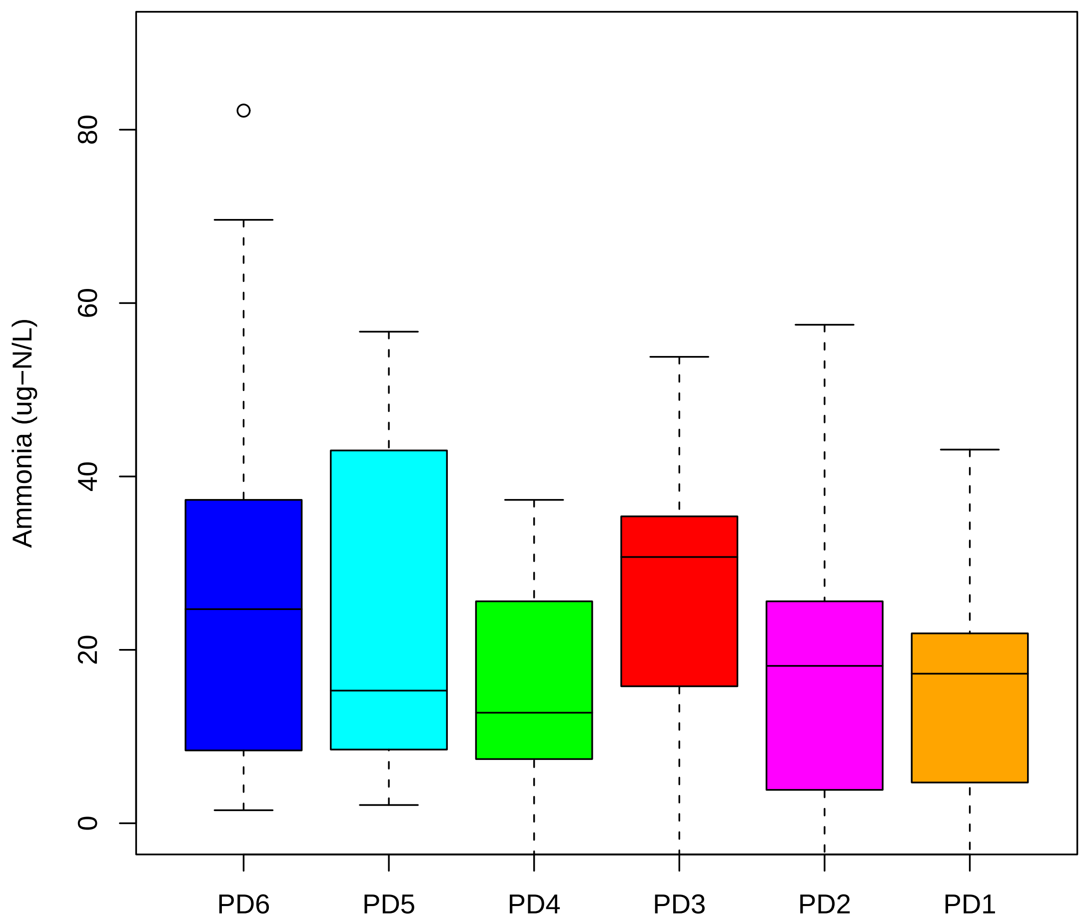

Figure 7: Boxplot summarizing ammonia data for Padden Creek from October 2000 to June 2001. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are greater than or equal to 1.5 × interquartile range.

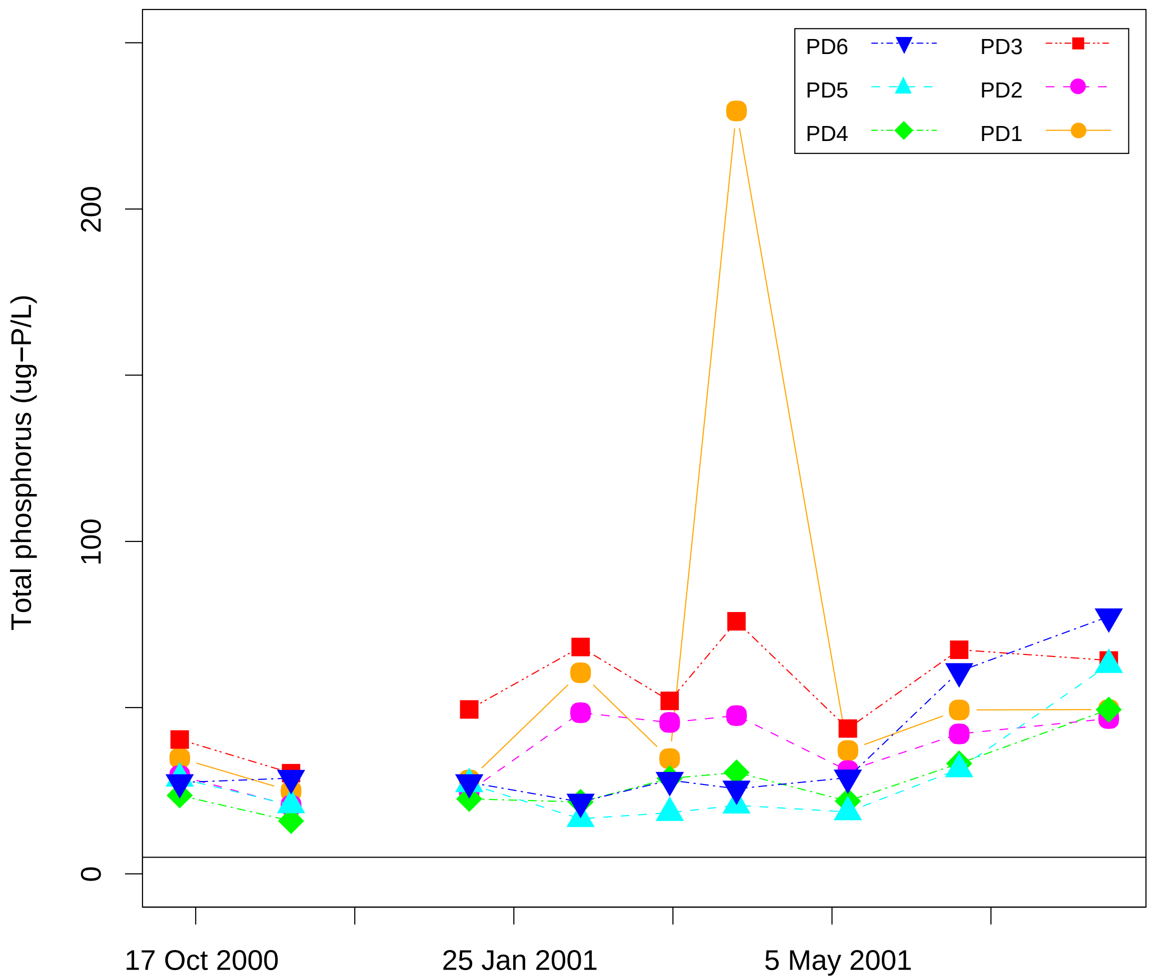

Figure 8: Total phosphorus concentrations at each sampling site from October 2000 to June 2001. Horizontal line indicates detection limit for this analysis.

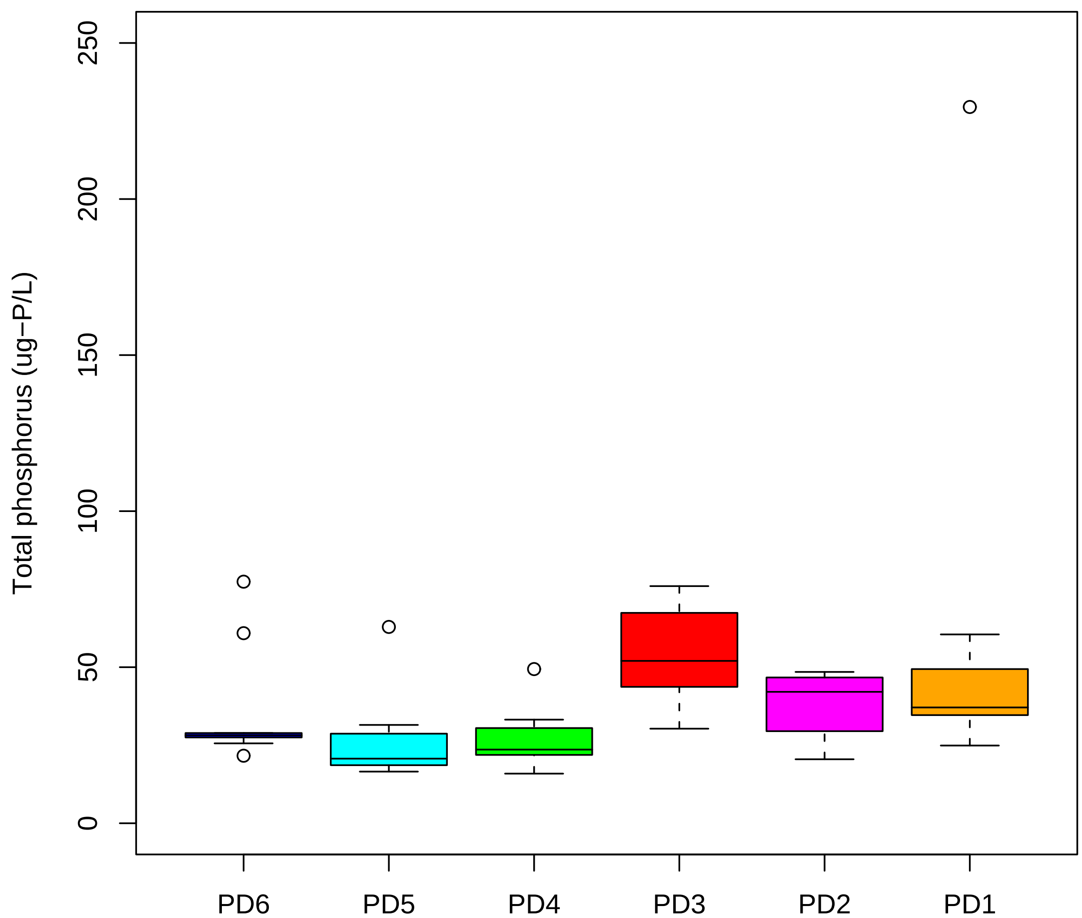

Figure 9: Boxplot summarizing total phosphorus data for Padden Creek from October 2000 to June 2001. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are greater than or equal to 1.5 × interquartile range.

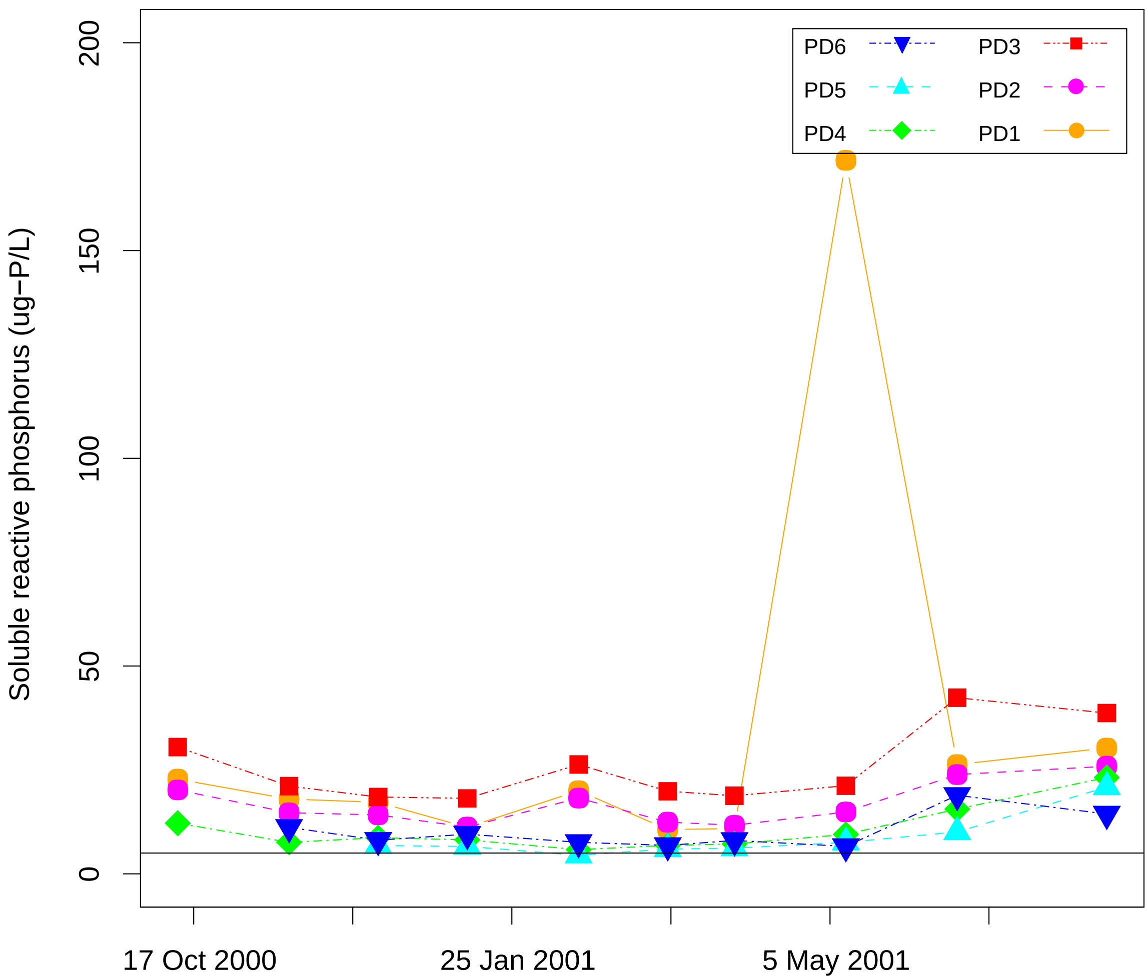

Figure 10: Soluble reactive phosphate concentrations at each sampling site from October 2000 to June 2001. Horizontal line indicates detection limit for this analysis.

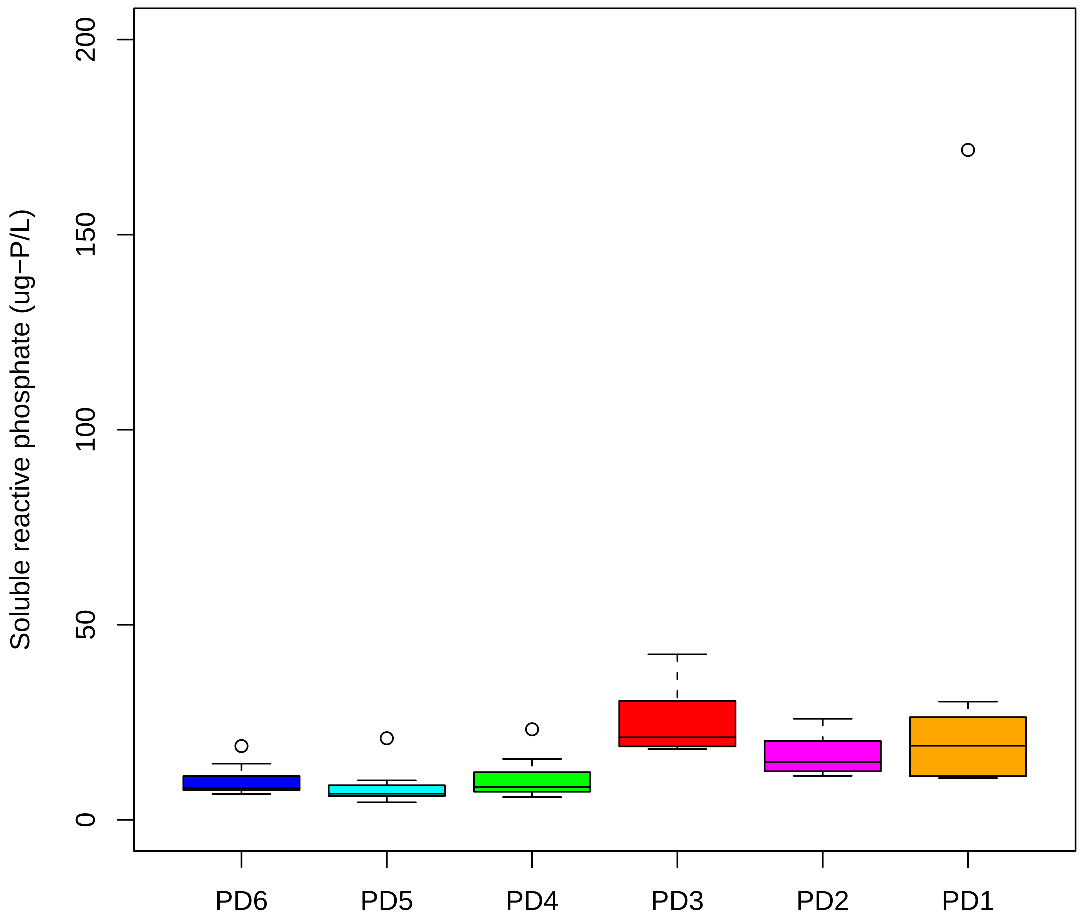

Figure 11: Boxplot summarizing soluble reactive phosphate data for Padden Creek from October 2000 to June 2001. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are greater than or equal to 1.5 $\times$ interquartile range.

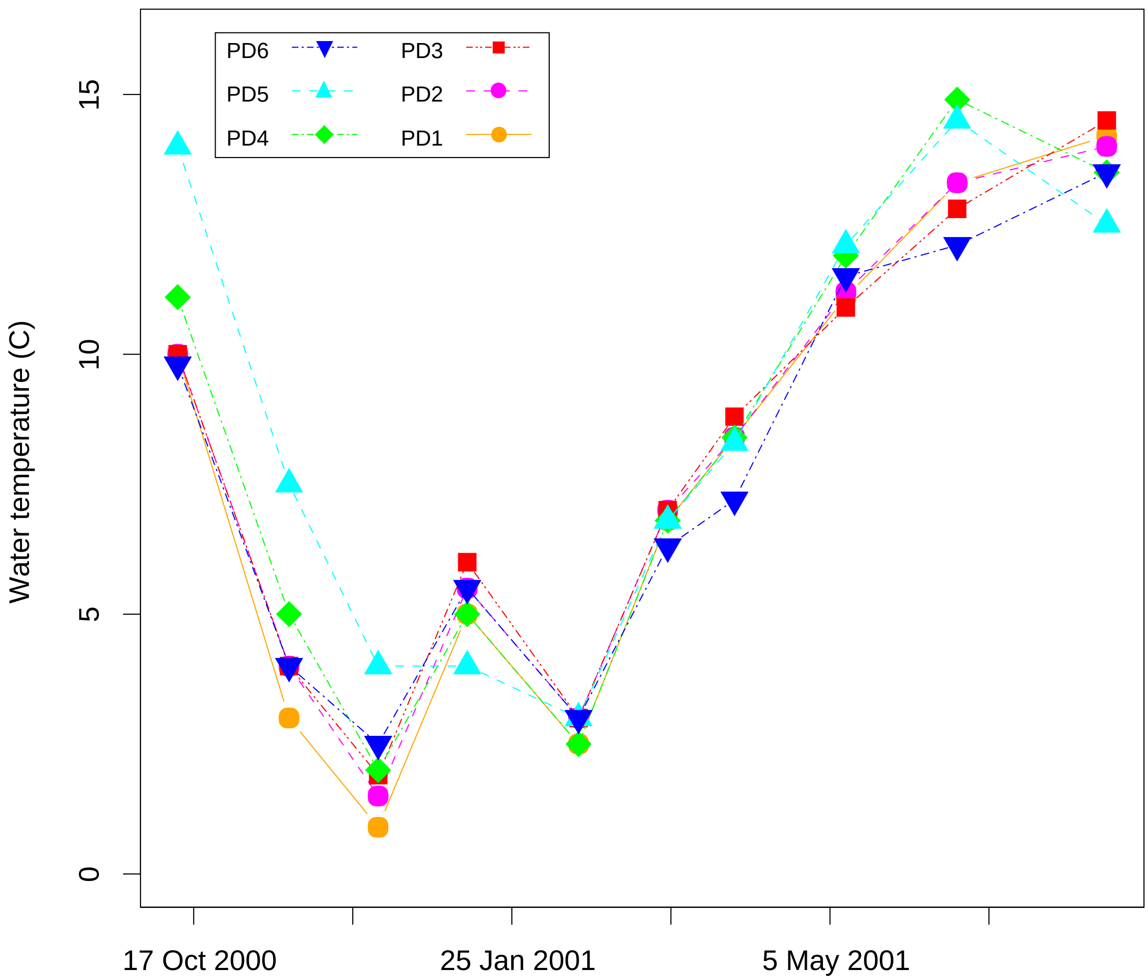

Figure 12: Water temperatures at each sampling site from October 2000 to June 2001.

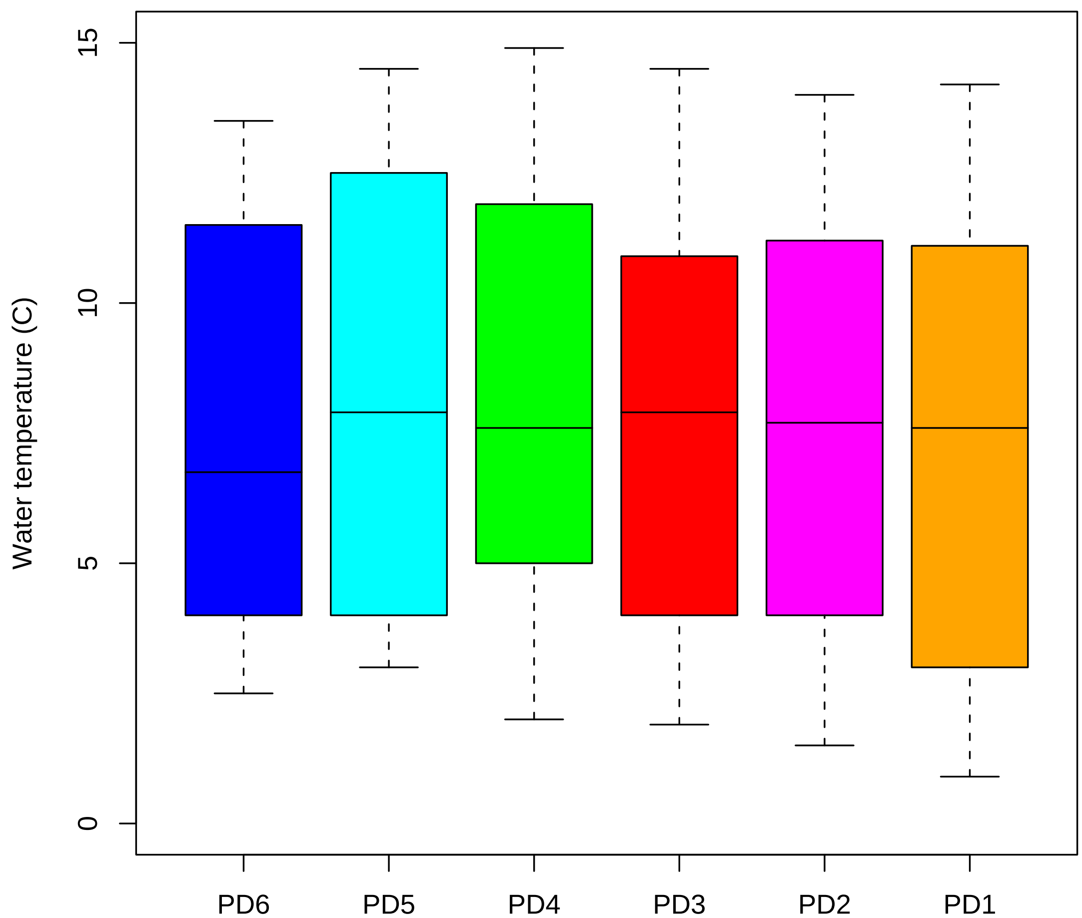

Figure 13: Boxplot summarizing water temperature data for Padden Creek from October 2000 to June 2001. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are greater than or equal to 1.5 $\times$ interquartile range.

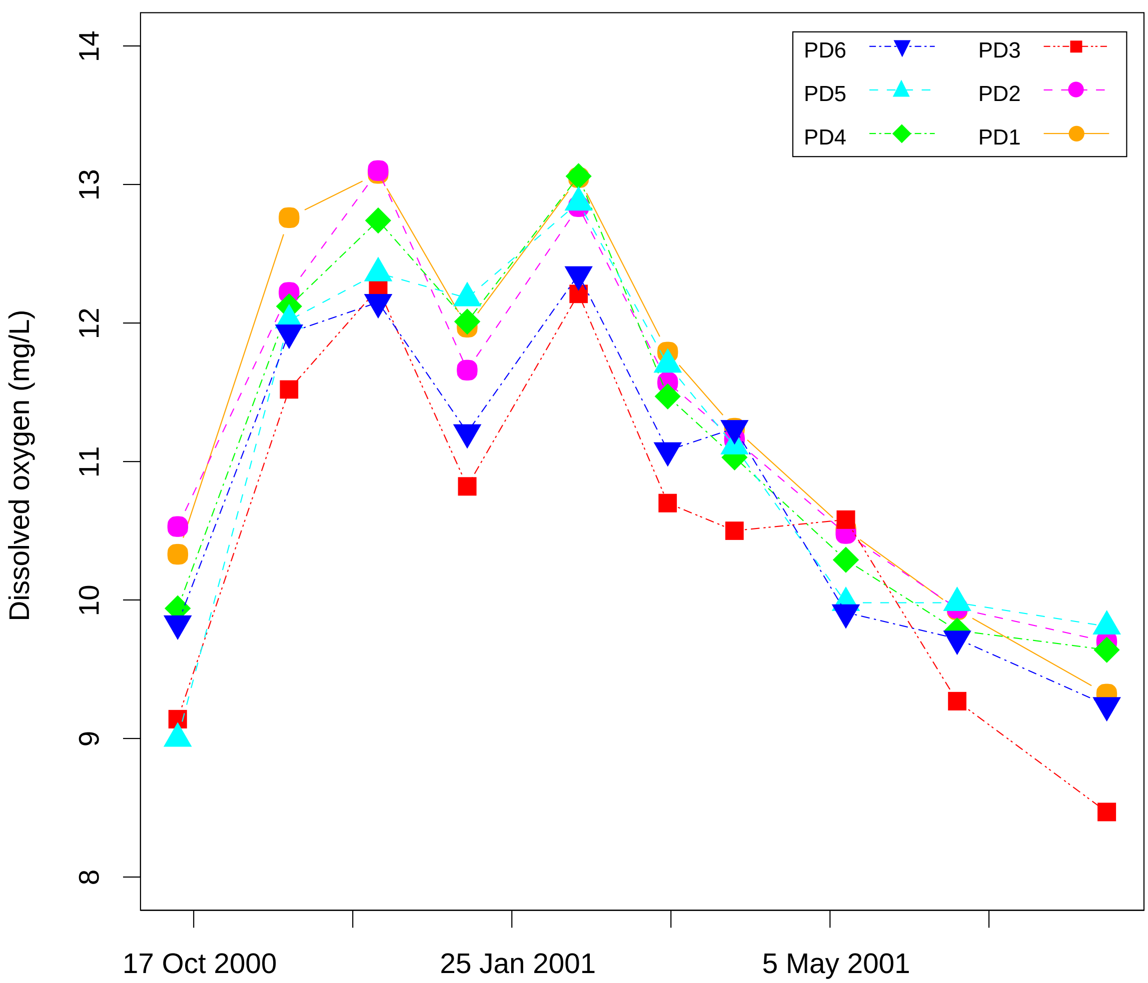

Figure 14: Dissolved oxygen concentrations at each sampling site from October 2000 to June 2001.

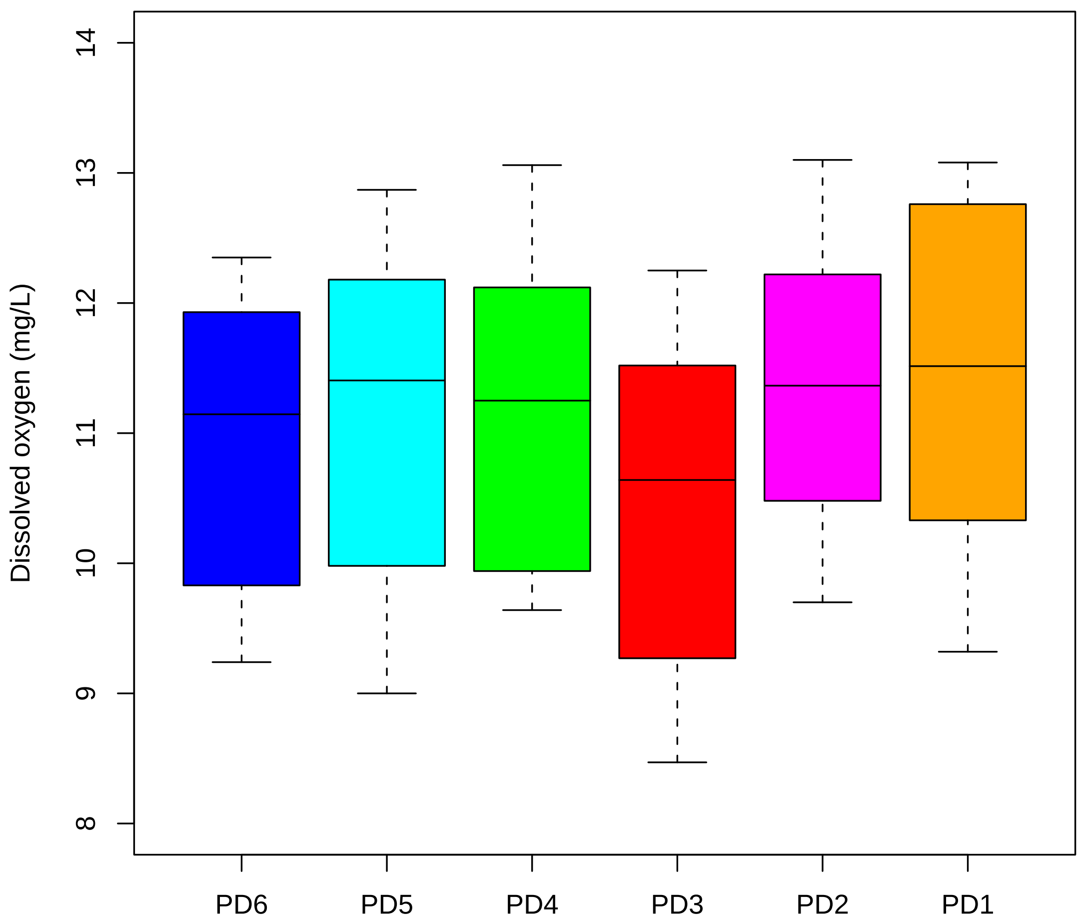

Figure 15: Boxplot summarizing dissolved oxygen data for Padden Creek from October 2000 to June 2001. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are greater than or equal to 1.5 $\times$ interquartile range.

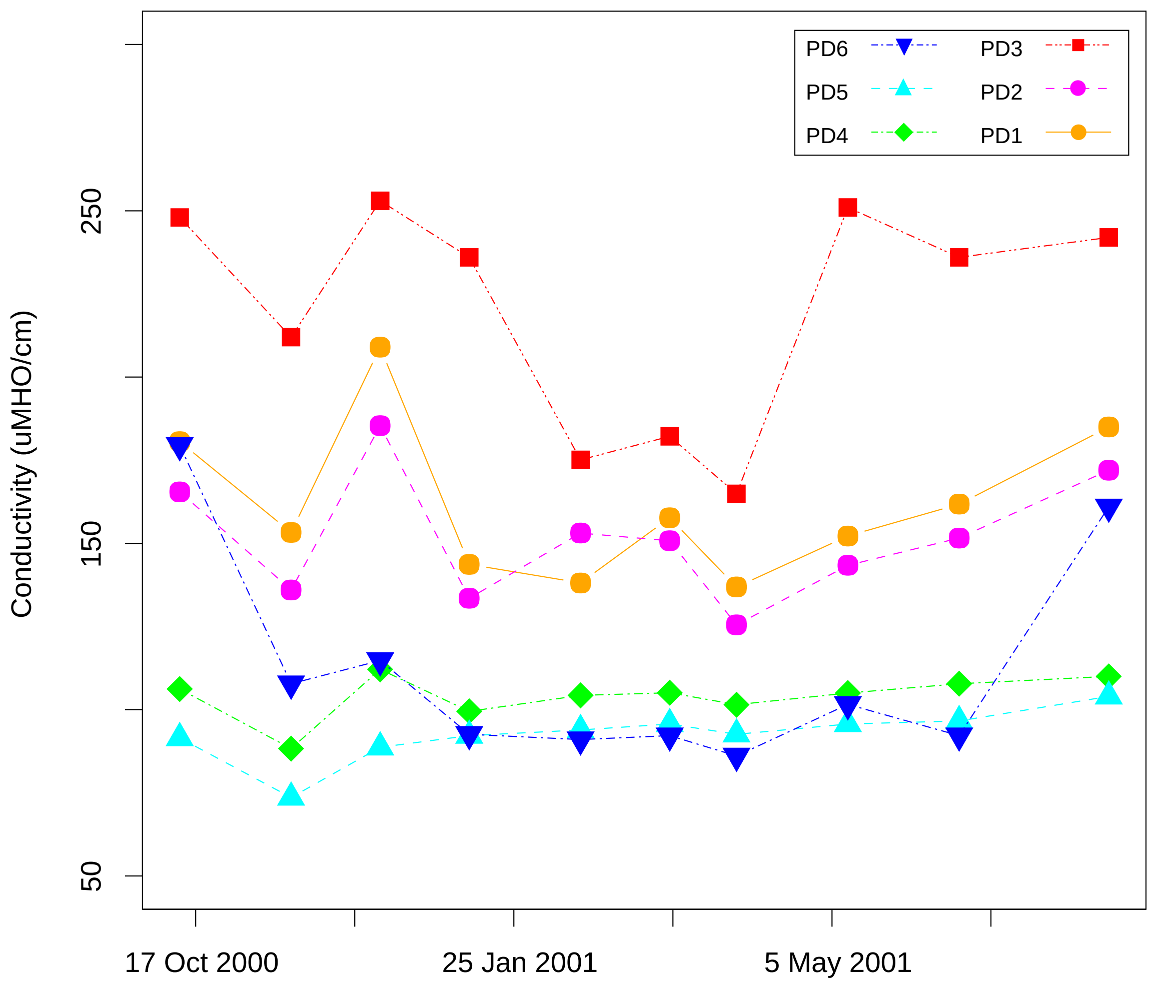

Figure 16: Conductivities at each sampling site from October 2000 to June 2001.

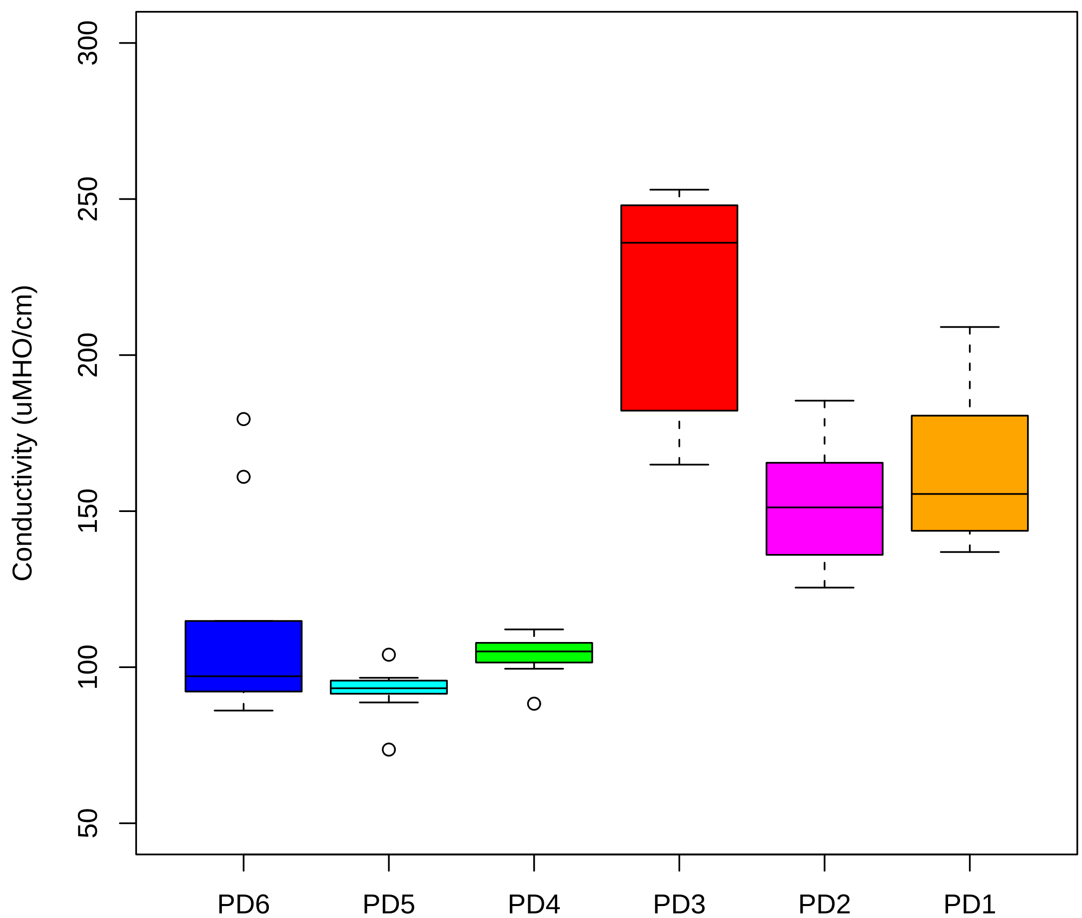

Figure 17: Boxplot summarizing conductivity data for Padden Creek from October 2000 to June 2001. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are greater than or equal to 1.5 × interquartile range.

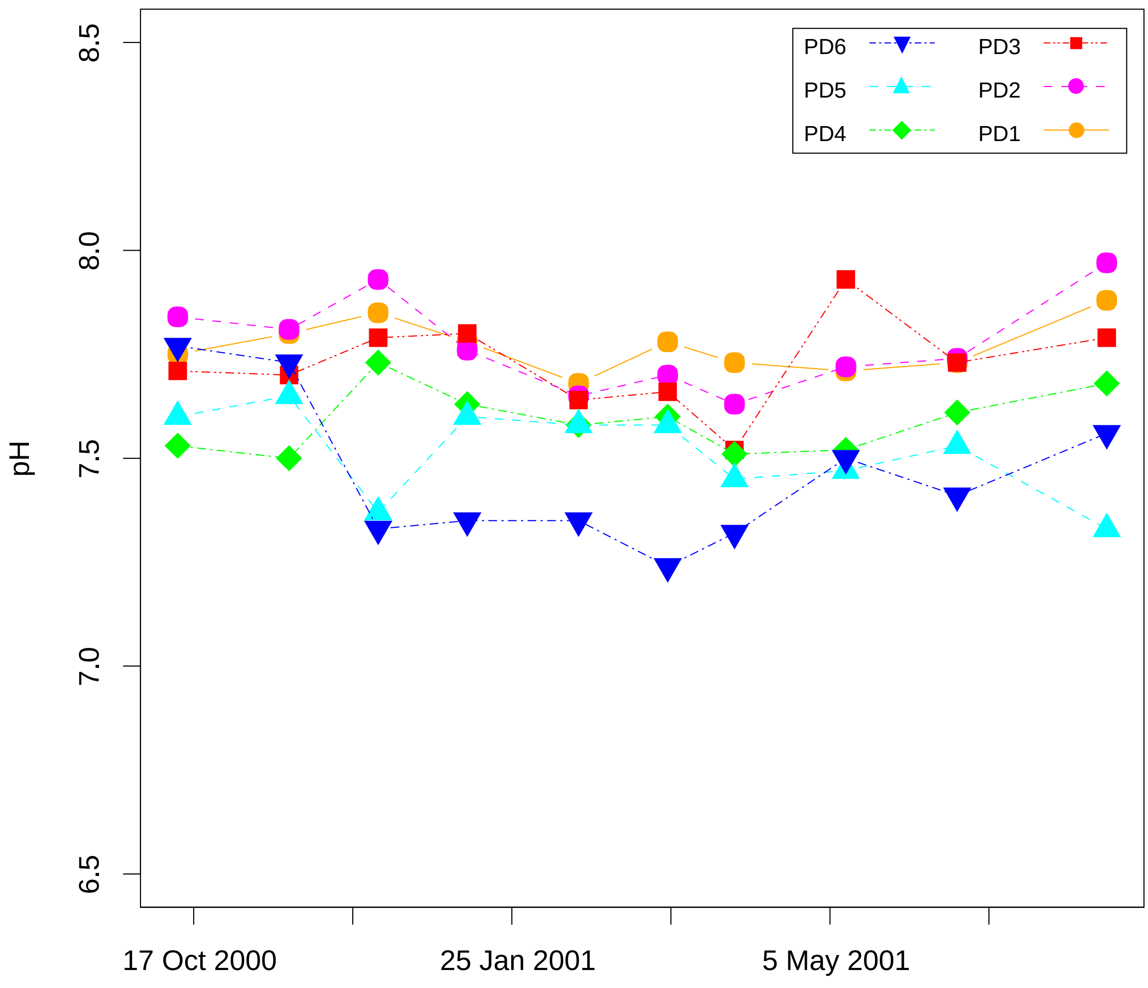

Figure 18: pH values at each sampling site from October 2000 to June 2001.

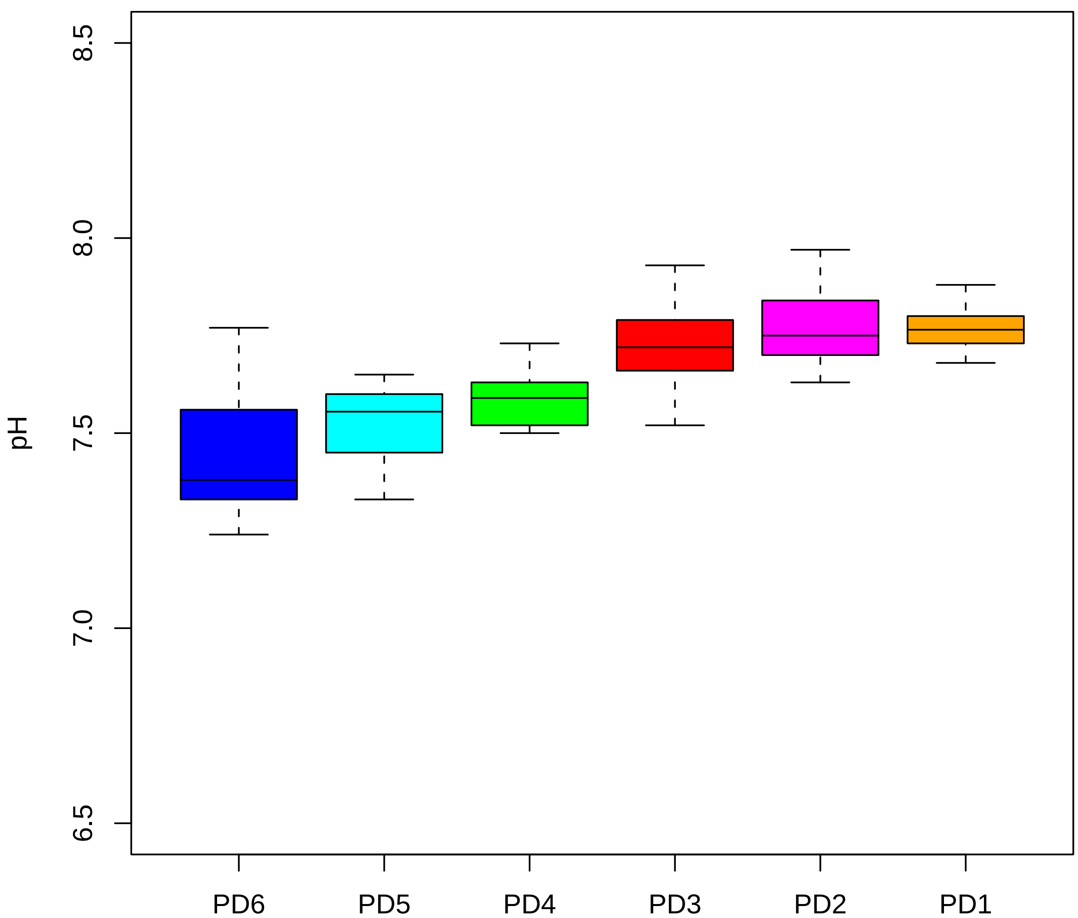

Figure 19: Boxplot summarizing pH data for Padden Creek from October 2000 to June 2001. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are greater than or equal to 1.5 × interquartile range.

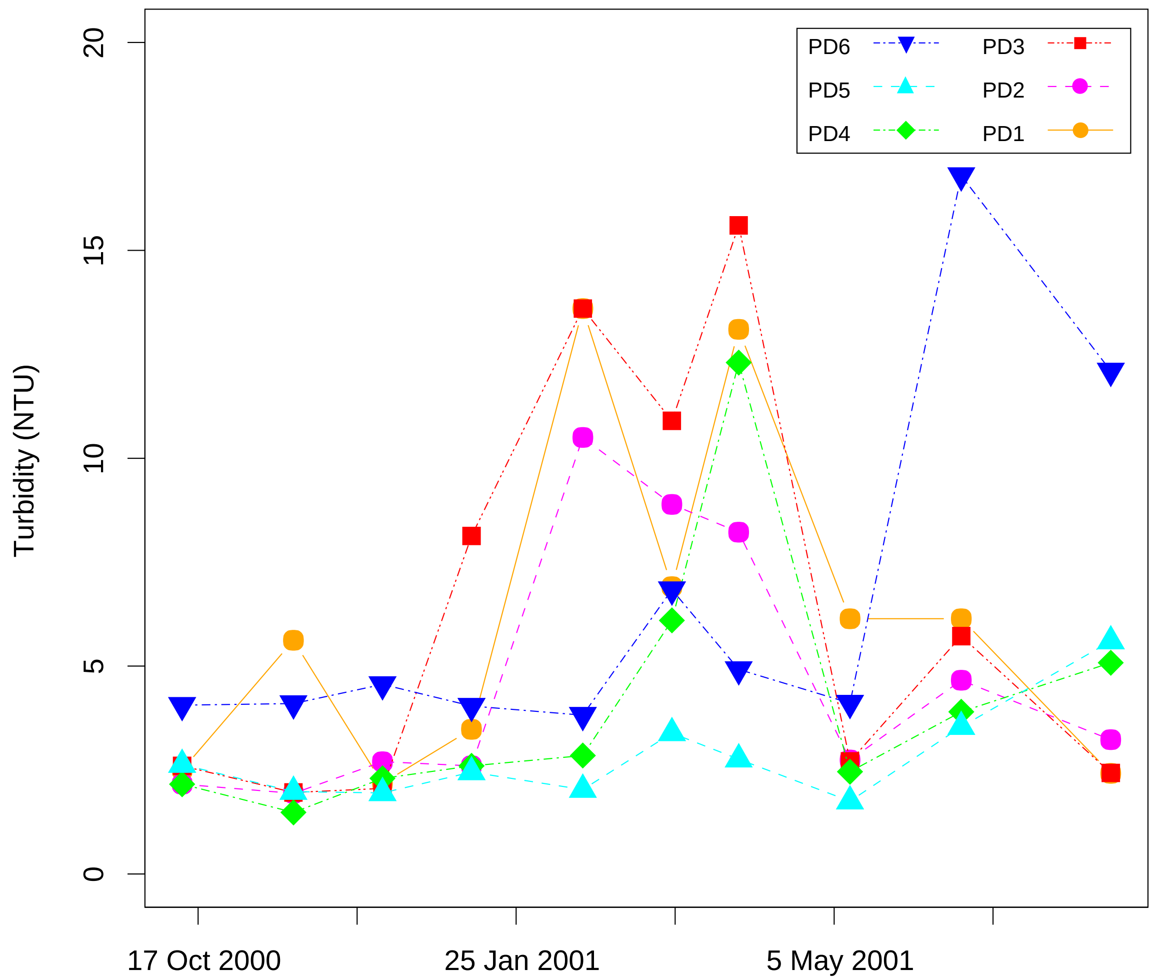

Figure 20: Turbidity concentrations at each sampling site from October 2000 to June 2001.

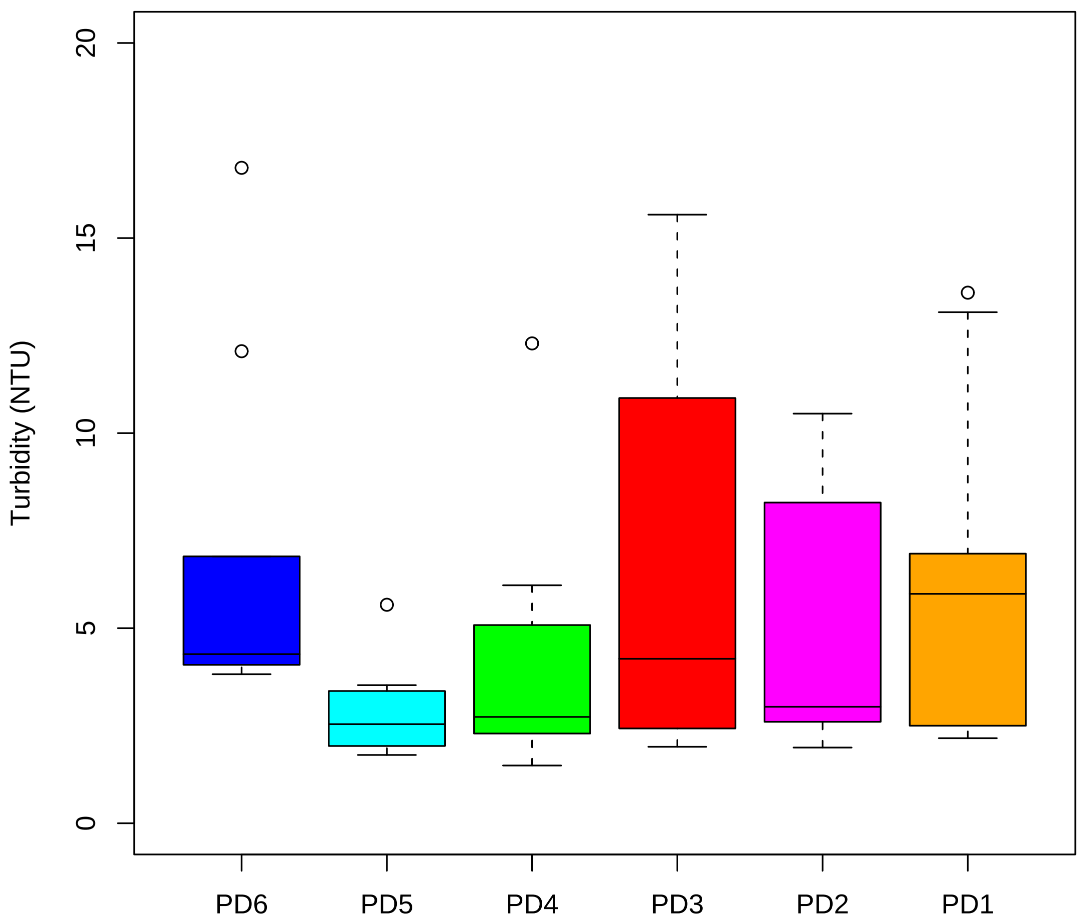

Figure 21: Boxplot summarizing turbidity data for Padden Creek from October 2000 to June 2001. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are greater than or equal to 1.5 × interquartile range.

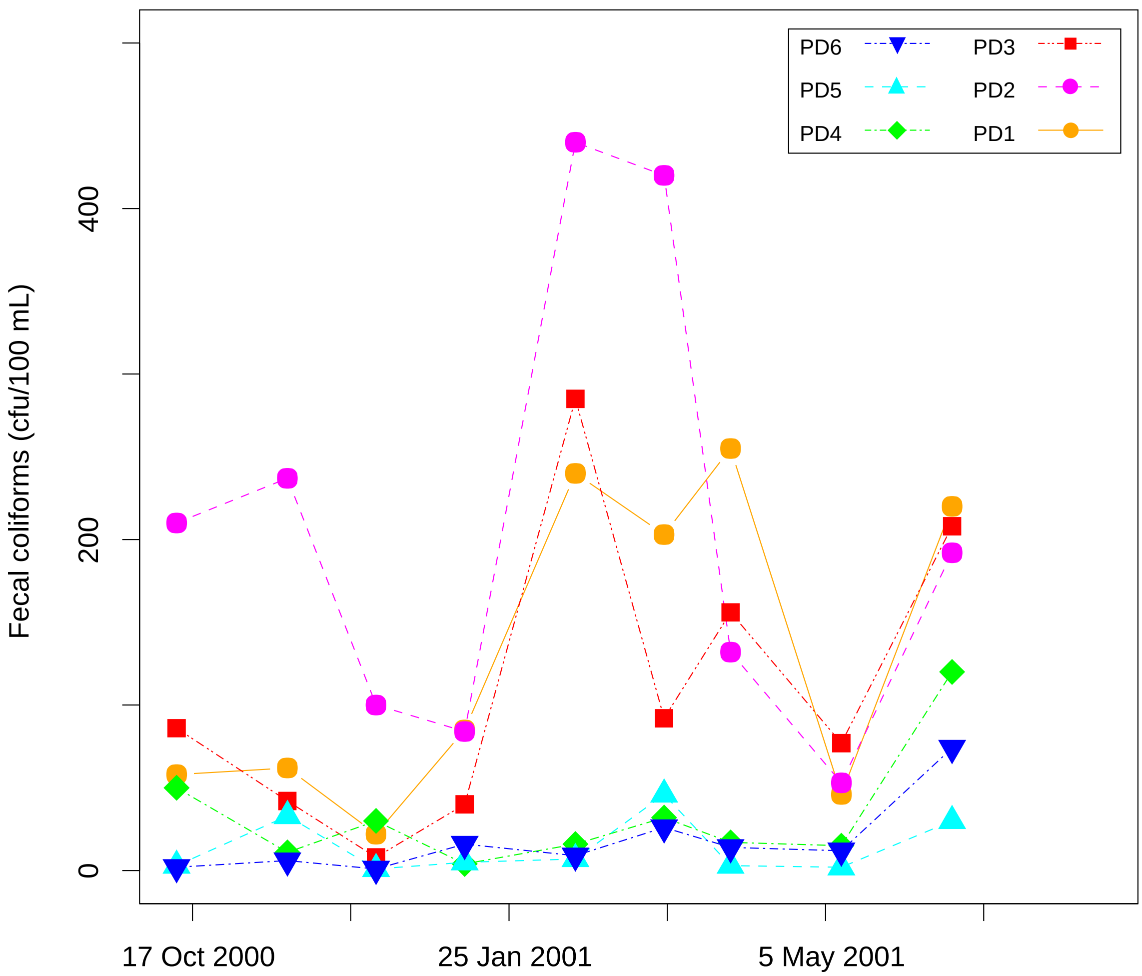

Figure 22: Fecal coliform concentrations at each sampling site from October 2000 to June 2001.

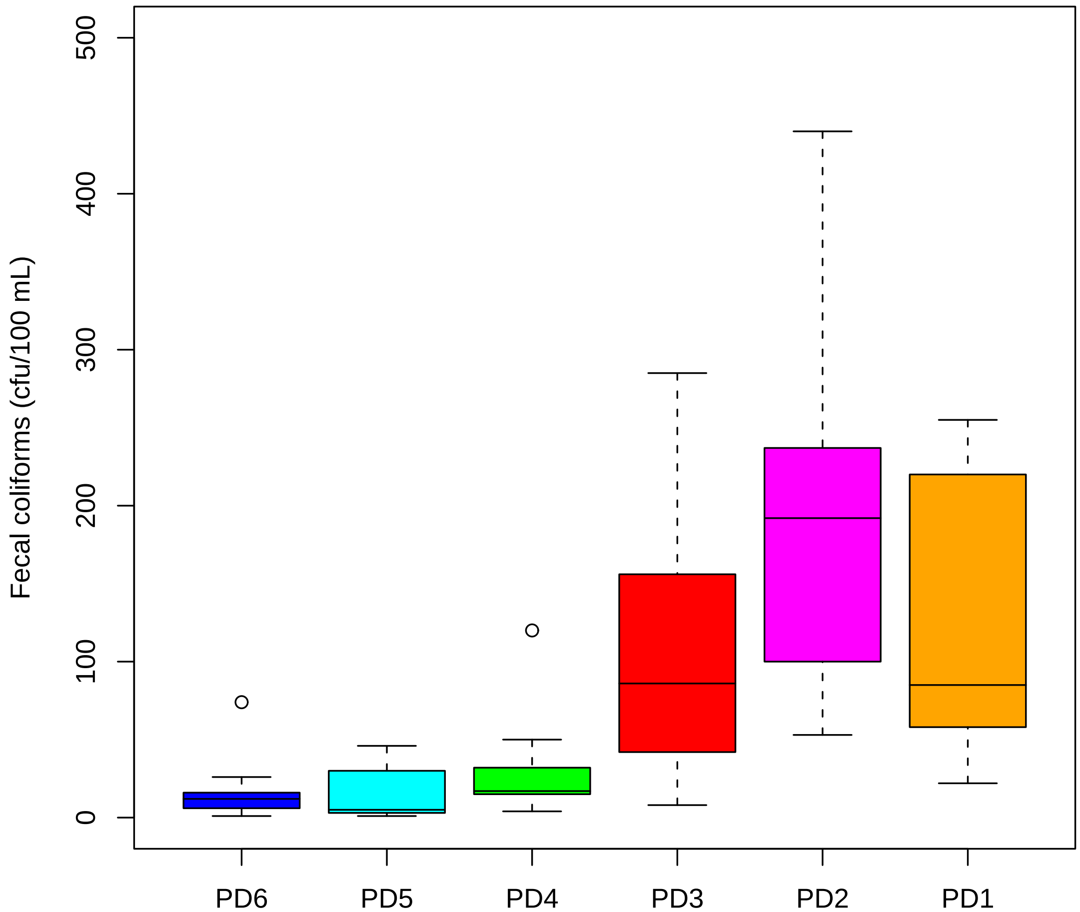

Figure 23: Boxplot summarizing fecal coliform counts for Padden Creek from October 2000 to June 2001. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are greater than or equal to 1.5 $\times$ interquartile range.

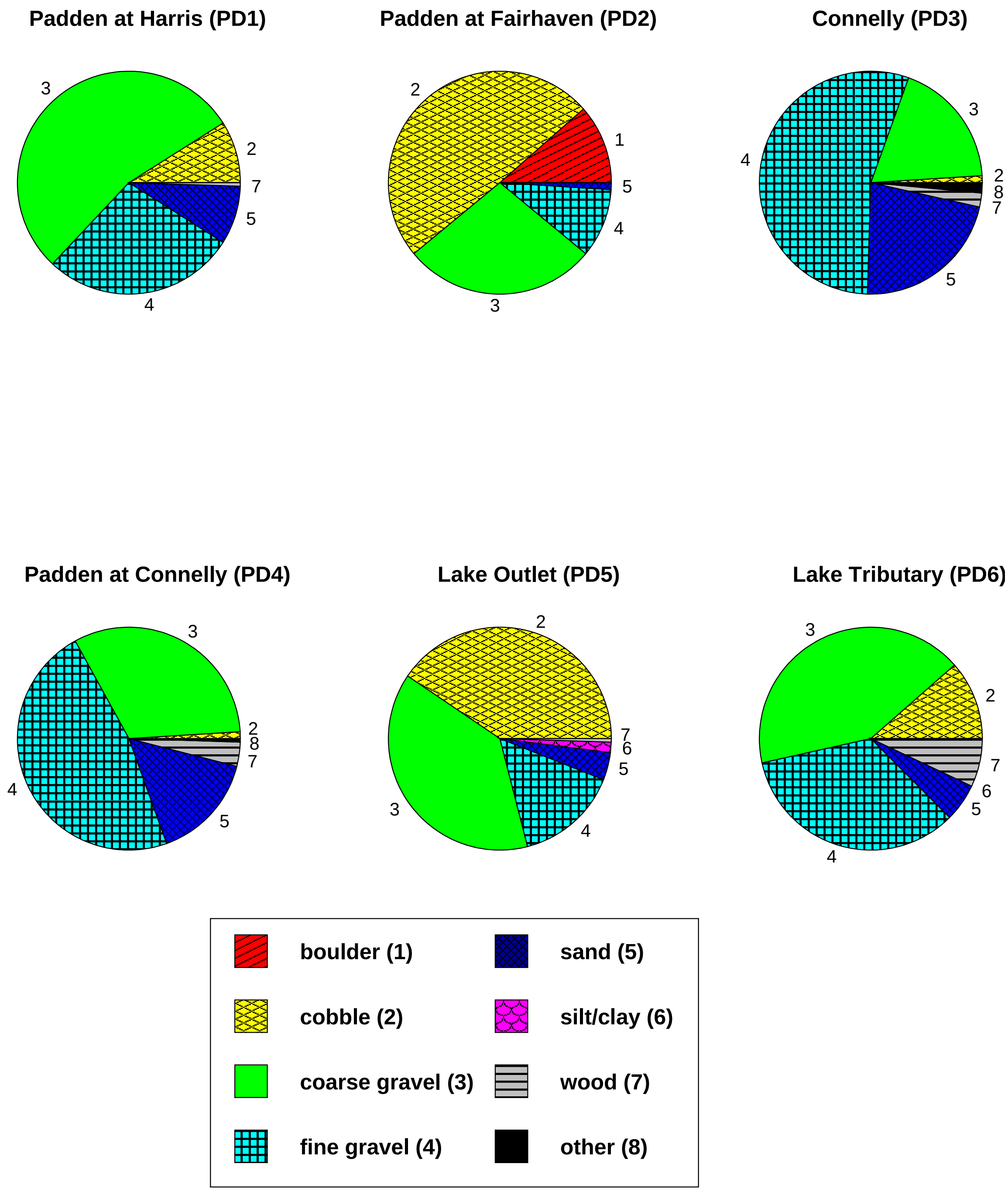

Figure 24: Particle size distributions for Padden and Connelly Creek sampling sites.

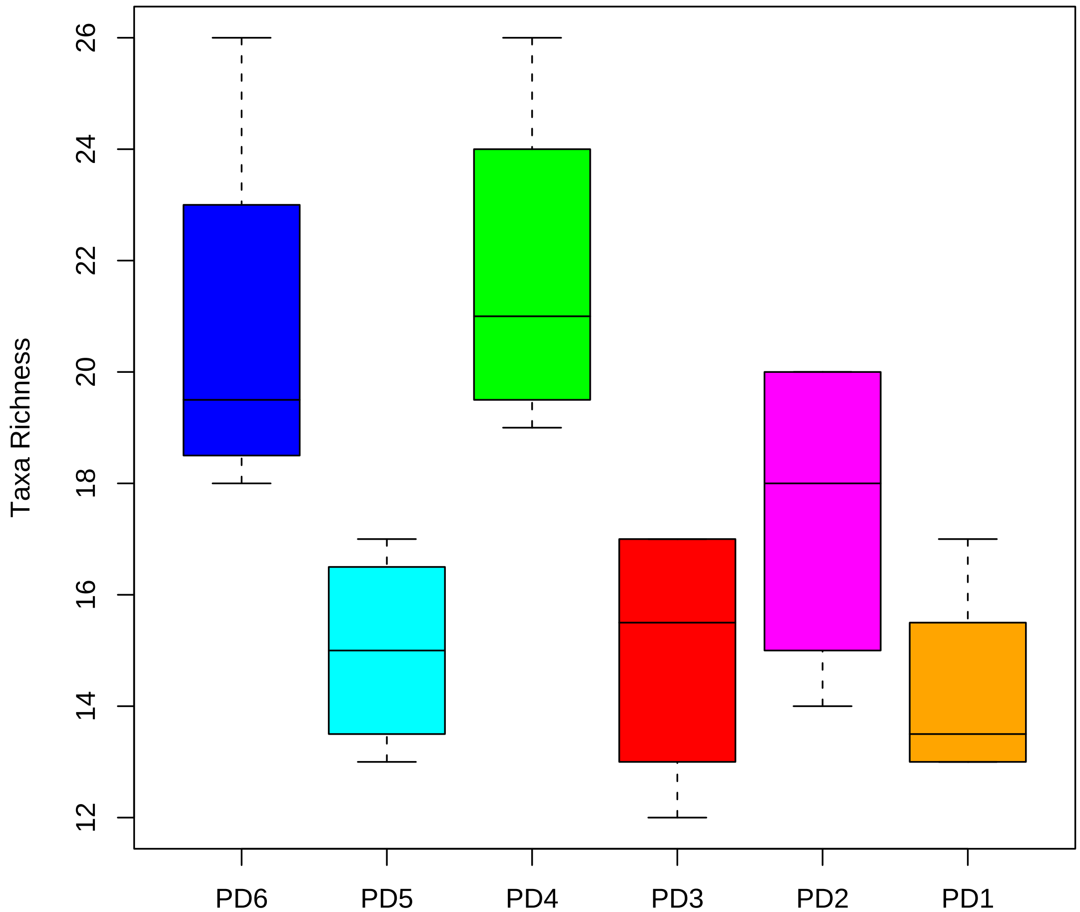

Figure 25: Boxplot summarizing macroinvertebrate taxonomic richness in Padden Creek from October 2000 to June 2001. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are greater than or equal to 1.5 × interquartile range.

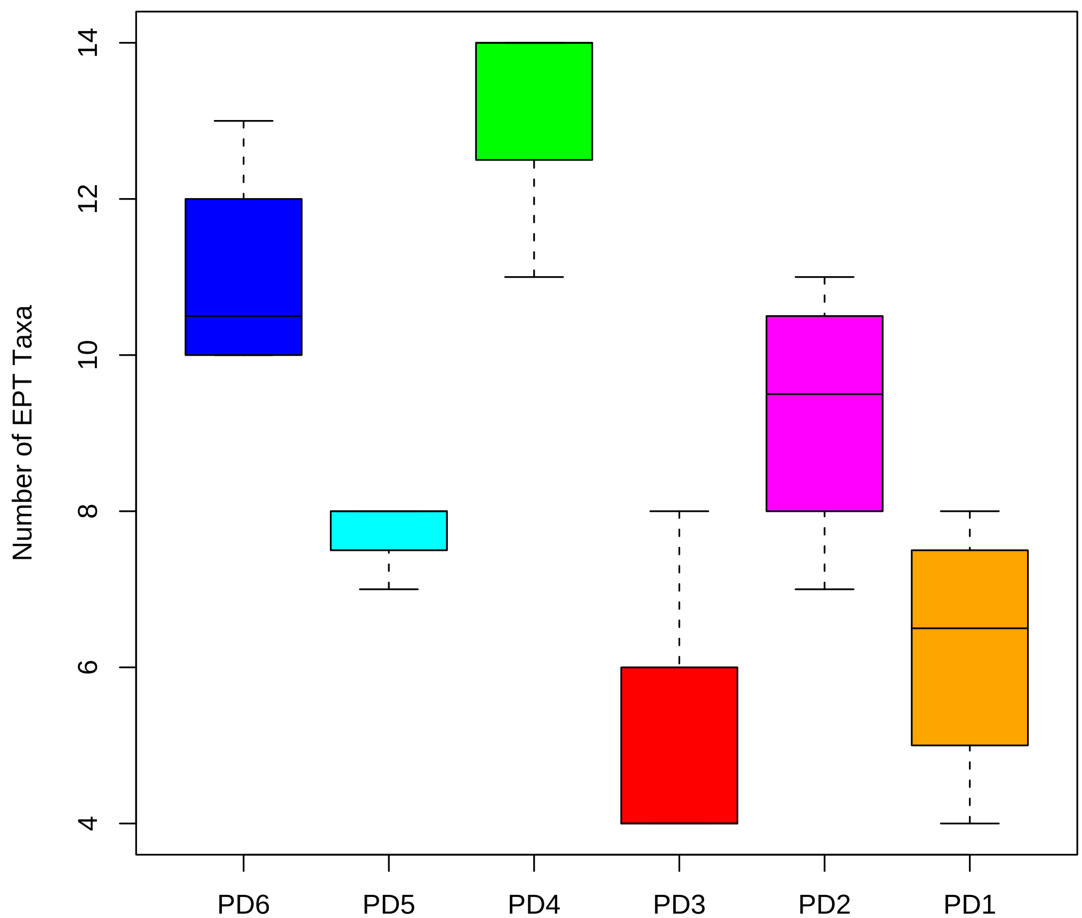

Figure 26: Boxplot summarizing the number of Ephemeroptera/Plecoptera/Trichoptera taxa in macroinvertebrate samples from Padden Creek, October 2000 to June 2001. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are greater than or equal to 1.5 $\times$ interquartile range.

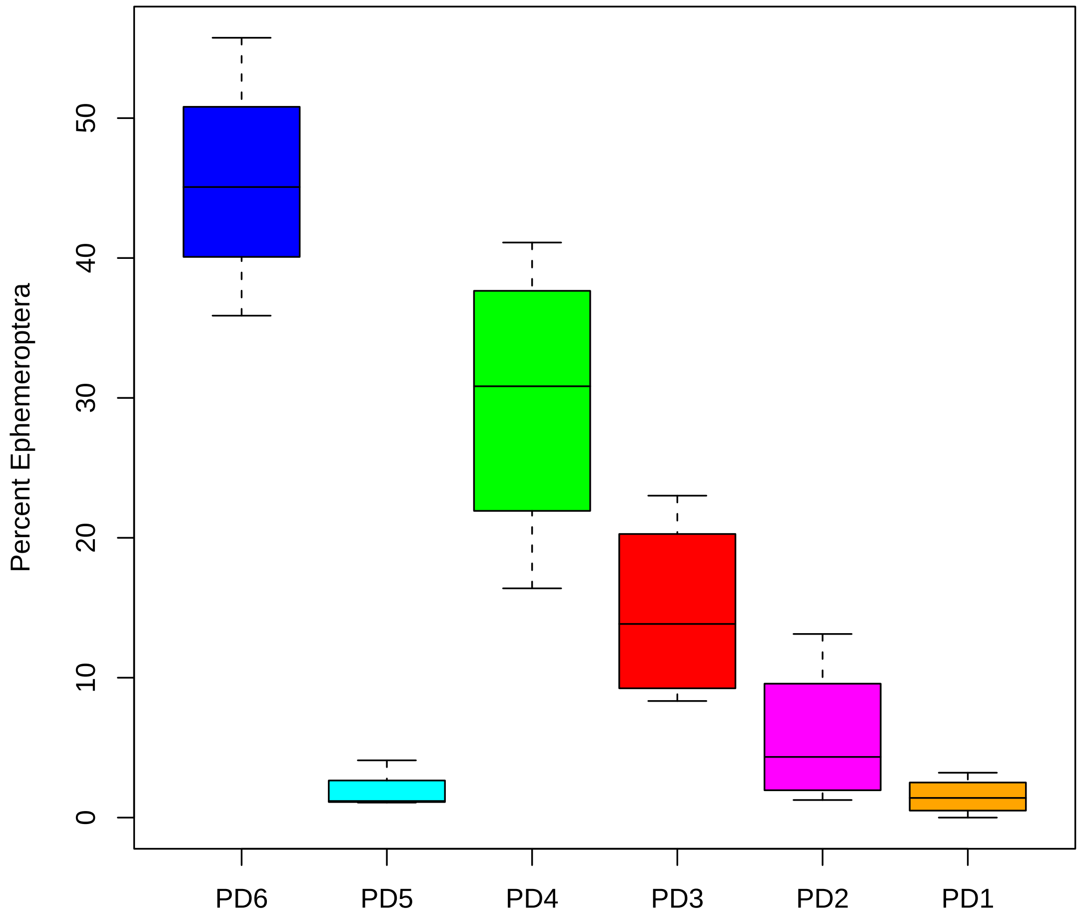

Figure 27: Boxplot summarizing the percent Ephemeroptera (excluding Baetidae) in macroinvertebrate samples from Padden Creek, October 2000 to June 2001. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are greater than or equal to 1.5 × interquartile range.

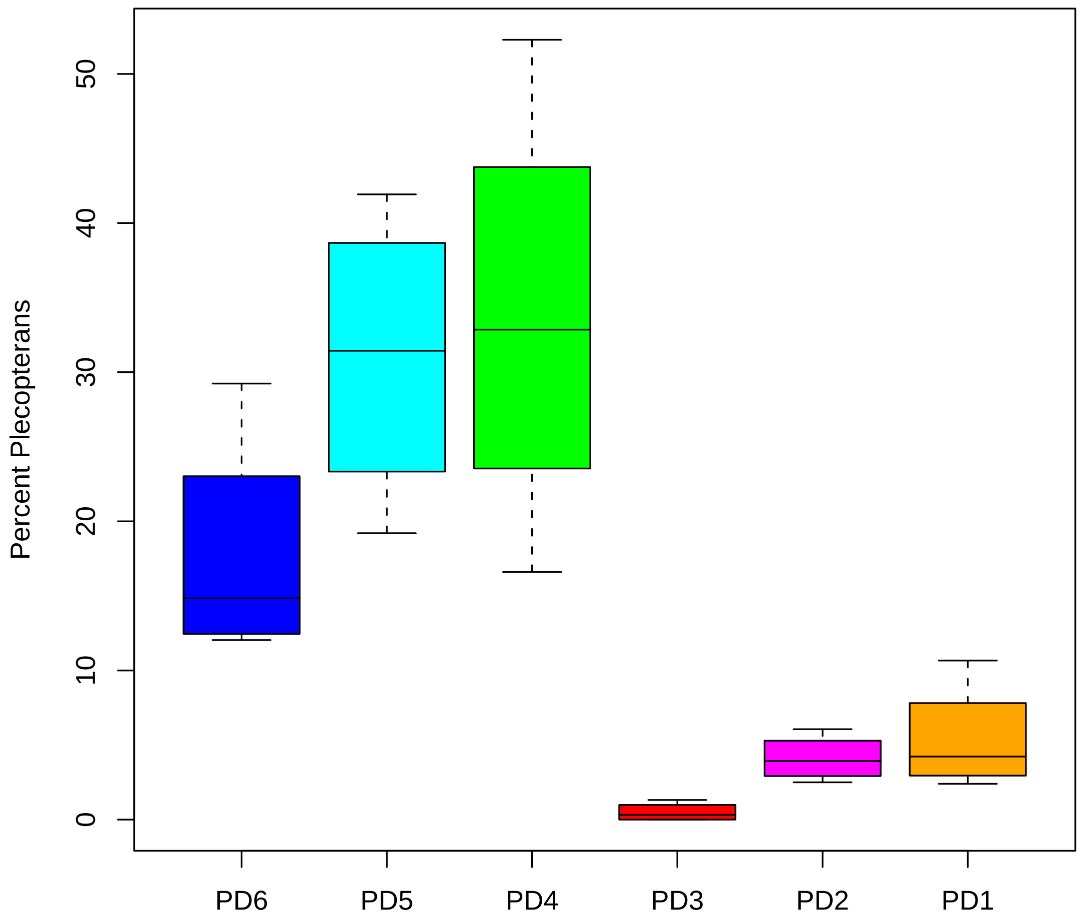

Figure 28: Boxplot summarizing the percent Plecoptera in macroinvertebrate samples from Padden Creek, October 2000 to June 2001. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are greater than or equal to 1.5 $\times$ interquartile range.

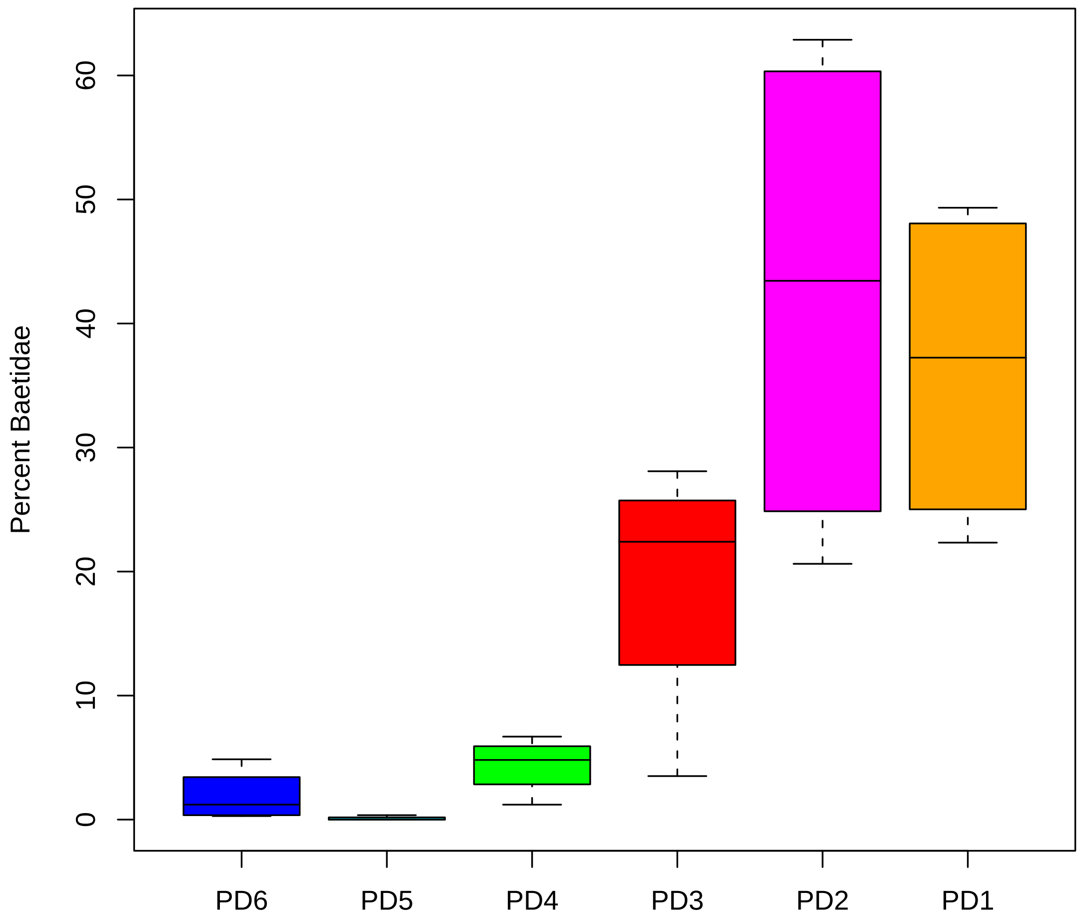

Figure 29: Boxplot summarizing the percent Baetidae (Ephemeroptera) in macroinvertebrate samples from Padden Creek, October 2000 to June 2001. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are greater than or equal to 1.5 × interquartile range.

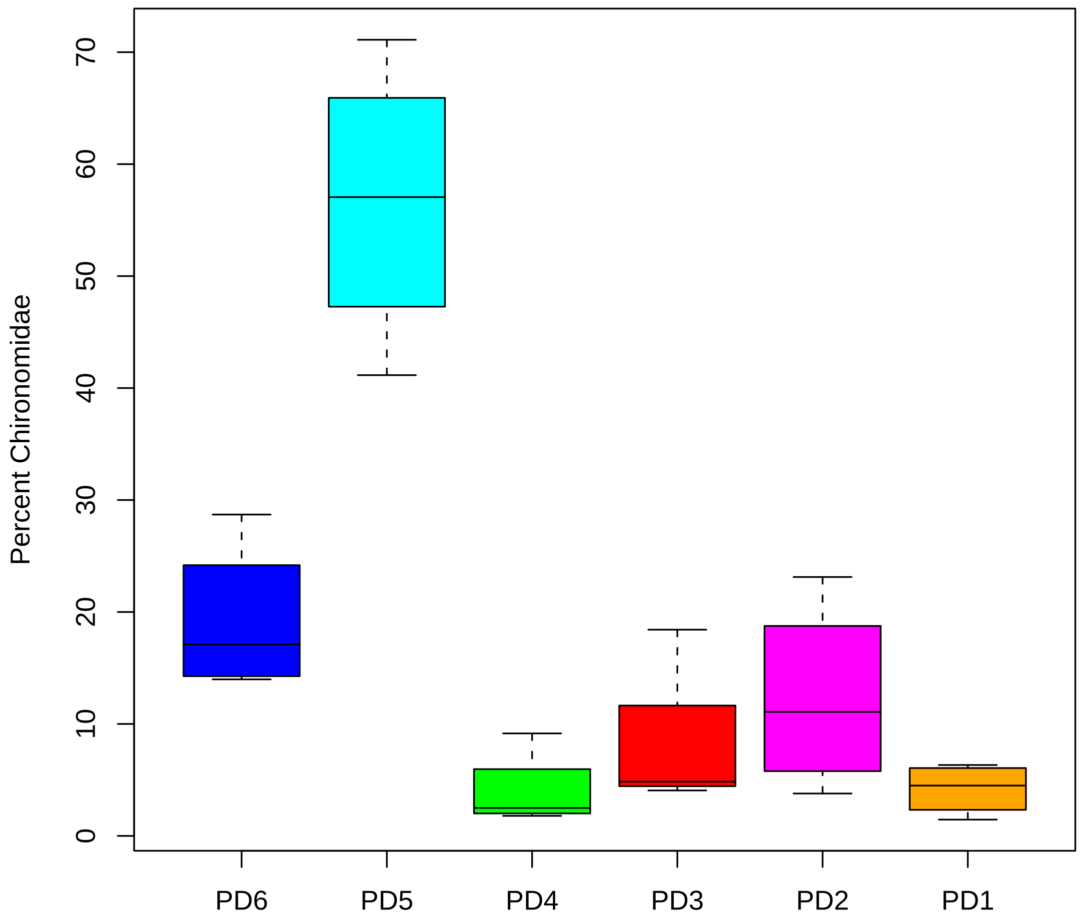

Figure 30: Boxplot summarizing the percent Chironomidae (Diptera) in macroinvertebrate samples from Padden Creek, October 2000 to June 2001. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are greater than or equal to 1.5 $\times$ interquartile range.

A Padden Creek Water Quality Data

The 2000/2001 Padden Creek water quality data are available in electronic format, either as Excel or ASCII data files. An electronic version of each file is included on the CD with the hardcopy version of this report and data files are posted with the web version of the report. For additional information, contact the Institute for Watershed Studies, Western Washington University, Bellingham WA.

A.1 Padden Creek Water Quality Data ASCII File (paddenwq.dat)

The file "paddenwq.dat" contains water quality data collected from six sites along Padden Creek and Connelly Creek from October 2000 through June 2001.

⇒ These data have not been censored to remove below detection values (see Table 2 for detection limits). Summary tables were generated using the original, uncensored data to preserve the variance associated with low-level data. It is essential that any new statistical or analytical results that are generated using these uncensored data be reviewed by a trained statistician or scientist familiar with statistical uncertainty associated with below detection data.

All missing values are entered as "NA."

```
paddenwq.dat variable list:
site           Site  PD1 = Padden Creek 100 m upstream from Harris Ave
                     PD2 = Padden Creek near tennis courst in Fairhaven Pk
                     PD3 = Connelly Creek at mouth
                     PD4 = Padden Creek 20 m upstream from confluence with Connelly Cr
                     PD5 = Padden Creek 900 m downstream from lake outlet
                     PD6 = unnamed tributary upstream from Lake Padden
type           Sample type (all are type 1, regular water quality samples)
month          Month
day            Day
year           Year
hour           Hour
min            Minute
temp           Temperature (C)
ph             pH
do             Dissolved oxygen (mg/L)
cond           Conductivity (uS/cm)
turb           Turbidity (NTU)
tp             Total phosphorus (ug-P/L)
tpn            Total persulfate nitrogen (ug-N/L)
srp            Soluble reactive phosphate (ug-P/L)
nh3            Ammonia (ug-N/L)
nos            Nitrate+nitrite (ug-N/L)
fc             Fecal coliforms (cfu/100 mL)
```

A.2 Padden Creek Water Quality Data Excel File (rawpaddenwq.xls)

The file “rawpaddenwq.xls” contains water quality data collected from six sites along Padden Creek and Connelly Creek from October 2000 through June 2001.

⇒ These data have not been censored to remove below detection values (see Table 2 for detection limits). Summary tables were generated using the original, uncensored data to preserve the variance associated with low-level data. It is essential that any new statistical or analytical results that are generated using these uncensored data be reviewed by a trained statistician or scientist familiar with statistical uncertainty associated with below detection data.

All missing values are entered as ”NA.”

```
rawpaddenwq.xls variable list:
site           Site  pd-1 = Padden Creek 100 m upstream from Harris Ave
                     pd-2 = Padden Creek near tennis courst in Fairhaven Pk
                     pd-3 = Connelly Creek at mouth
                     pd-4 = Padden Creek 20 m upstream from confluence with Connelly Cr
                     pd-5 = Padden Creek 900 m downstream from lake outlet
                     pd-6 = unnamed tributary upstream from Lake Padden
type           Sample type (all are type 1, regular water quality samples)
date           Month/day/year
time           Hour/minute
temp           Temperature (C)
pH             pH
do             Dissolved oxygen (mg/L)
cond           Conductivity (uS/cm)
turb           Turbidity (NTU)
tp             Total phosphorus (ug-P/L)
tn             Total persulfate nitrogen (ug-N/L)
srp            Soluble reactive phosphate (ug-P/L)
nh3            Ammonia (ug-N/L)
nos            Nitrate+nitrite (ug-N/L)
fc             Fecal coliforms (cfu/100 mL)
comments       Comments
```

B Padden Creek Macroinvertebrate Data

The September 2000 Padden Creek macroinvertebrate data are available in electronic format, either as Excel or ASCII data files. An electronic version of each file is included on the CD with the hardcopy version of this report and data files are posted with the web version of the report. For additional information, contact the Institute for Watershed Studies, Western Washington University, Bellingham WA.

B.1 Padden Creek Macroinvertebrate Data ASCII File (paddenbugs.dat)

The file "paddenbugs.dat" contains macroinvertebrate data collected from six sites along Padden Creek and Connelly Creek during September 2000 (9/17/00, 9/26/00, 9/28/00). All counts represent numbers of macroinvertebrates per 2 ft^2 D-frame net.

```
paddenbugs.dat variable list:
site            PD1 = Padden Creek 100 m upstream from Harris Ave
                PD2 = Padden Creek near tennis courst in Fairhaven Pk
                PD3 = Connelly Creek at mouth
                PD4 = Padden Creek 20 m upstream from confluence with Connelly Cr
                PD5 = Padden Creek 900 m downstream from lake outlet
                PD6 = unnamed tributary upstream from Lake Padden
rep             replicate samples
month           Month
day             Day
year            Year
ephem           Ephemeroptera
baetis          Baetis tricaudatus
ephlla          Ephemerella inermis/infrequens
heptaspp        Heptageniidae
cinyg           Cinygma sp.
epeo            Epeorus (Iron) sp.
rhith           Rhithrogena sp.
irono           Ironodes sp.
hepta           Heptagenia sp.
para            Paraleptophlebia sp.
swelt           Sweltsa sp.
desp            Despaxia sp.
nemo            Nemouridae
zapac           Zapada cinctipes
zapao           Zapada oregonensis
skwala          Skwala sp.
gloss           Glossosoma sp.
hydspp          Hydropsychidae
hydro           Hydropsyche sp.
para            Parapsyche sp.
hydato          Hydatophylax hesperus
poly            Polycentropus sp.
rhyaspp         Rhyacophilidae
rhyabru         Rhyacophila Brunnea grp.
rhyabet         Rhyacophila Betteni grp.
diptspp         Diptera
cerato          Ceratopogenidae
chiron          Chironomidae
```

dixa	Dixa sp.
chelif	Chelifera sp.
gluto	Glutops sp.
simul	Simuliidae
dicran	Dicranota sp.
tipula	Tipula sp.
dytlarv	Dytiscidae
dytadu	Dytiscidae adult
heter	Heterlimnius sp.
lara	Lara avara
narp	Narpus sp.
hemlar	Hemiptera
hemadu	Hemiptera adult
cran	Crangonyx sp.
coll	Collembola
pacif	Pacifasticus sp.
hirun	Hirudinea
ferris	Ferrissia sp.
nemorph	Nematomorpha
nematod	Nematoda
oligo	Oligochaeta
planor	Planorbidae
sphaer	Sphaeriidae
turbel	Turbellaria
union	Unionacea
acari	Acari
isopod	Isopoda
lymna	Lymnaeidae

B.2 Padden Creek Macroinvertebrate Data Excel File(rawpaddenbugs.xls)

The file "rawpaddenbugs.xls" contains macroinvertebrate data collected from six sites along Padden Creek and Connelly Creek during September 2000 (9/17/00, 9/26/00, 9/28/00). All counts represent numbers of macroinvertebrates per 2 ft^2 D-frame net.

This file shows the exact, unabbreviated macroinvertebrate taxonomic names and numerical abundance for each sample, and is the raw file from which paddenbugs.dat was derived. The Sample ID indicates the site number (PD1-6) and replicate (A-D).

C Padden Creek Site Characteristics

The 2000/2001 Padden Creek site characterization data files are available in electronic format, either as Excel or ASCII data files. An electronic version of each file is included on the CD with the hardcopy version of this report, and data files are posted with the web version of the report. For additional information, contact the Institute for Watershed Studies, Western Washington University, Bellingham WA.

C.1 Padden Creek Physical Site Descriptions Excel File (habitat.xls)

The file "habitat.xls" contains physical characterization information collected from six sites along Padden Creek and Connelly Creek during the September 2000 (9/17/00, 9/26/00, 9/28/00) macroinvertebrate sampling. The variables included in this file include:

```
habitat.xls variable list:
site                      PD1 = Padden Creek 100 m upstream from Harris Ave
                          PD2 = Padden Creek near tennis courst in Fairhaven Pk
                          PD3 = Connelly Creek at mouth
                          PD4 = Padden Creek 20 m upstream from confluence with Connelly Cr
                          PD5 = Padden Creek 900 m downstream from lake outlet
                          PD6 = unnamed tributary upstream from Lake Padden
date                      Month/day/year
wet width                 Wet width of stream (m)
bank width                Width to high water mark (m)
max depth                 Maximum depth of stream (m)
pct gradient              Percent gradient from head of riffle to foot of riffle
velocity bottom           Stream velocity at bottom (ft/sec)
velocity 0.6 from bottom  Stream velocity at 0.6 x depth (ft/sec)
pct canopy cover          Percent canopy cover
```

C.2 Padden Creek Substrate Data Excel File (substrate.xls)

The file "substrate.xls" contains substrate characterization information collected from six sites along Padden Creek and Connelly Creek during the September 2000 (9/17/00, 9/26/00, 9/28/00) macroinvertebrate sampling. The substrate characteristics were determined by placing a 50-point grid over the substrate and recording the grain size at each point. The variables included in this file include:

```
substrate.xls variable list:
site         PD1 = Padden Creek 100 m upstream from Harris Ave
             PD2 = Padden Creek near tennis courst in Fairhaven Pk
             PD3 = Connelly Creek at mouth
             PD4 = Padden Creek 20 m upstream from confluence with Connelly Cr
             PD5 = Padden Creek 900 m downstream from lake outlet
             PD6 = unnamed tributary upstream from Lake Padden
date         Month/day/year
depth        Water depth at location where macroinvertebrate samples were collected (m)
boulder      Number of grid points (out of 50) touching boulders (250-4000 mm diameter)
cobble       Number of grid points (out of 50) touching cobbles (64-250 mm diameter)
c-gravel     Number of grid points (out of 50) touching coarse gravel (16-64 mm diameter)
f-gravel     Number of grid points (out of 50) touching fine gravel (2-16 mm diameter)
sand         Number of grid points (out of 50) touching sand (0.06-2 mm diameter)
silt/clay    Number of grid points (out of 50) touching silt/clay (not gritty)
wood         Number of grid points (out of 50) touching wood (any size)
other        Number of grid points (out of 50) touching other types of substrate
total        Total number of grid points (50)
pct fines    Percent sand and silt
```

C.3 Supplemental Padden Creek Water Quality Data Excel File (extrawq.xls)

The file "extrawq.xls" contains supplemental water quality data collected from six sites along Padden Creek and Connelly Creek during the September 2000 (9/17/00, 9/26/00, 9/28/00) macroinvertebrate sampling. The variables included in this file include:

```
extrawq.xls variable list:
site           PD1 = Padden Creek 100 m upstream from Harris Ave
               PD2 = Padden Creek near tennis courst in Fairhaven Pk
               PD3 = Connelly Creek at mouth
               PD4 = Padden Creek 20 m upstream from confluence with Connelly Cr
               PD5 = Padden Creek 900 m downstream from lake outlet
               PD6 = unnamed tributary upstream from Lake Padden
date           Month/day/year
temp           Temperature (C)
cond           Conductivity (uS/cm)
pH             pH
flow           Stream discharge rate (ftˆ3/sec)
water clarity  Water clarity
wateroOdors    Water odor
sed odors      Sediment odors
surface film   Description of surface film
weather        Weather conditions
land use       Local land use
comments       Comments
```

C.4 Bellingham Precipitation, 10/12/2000–6/9/2001 Excel File (precipitation.xls)

The file “precipitation.xls” contains daily precipitation totals from Bellingham WA five days preceeding sampling events.

D Quality Control

The 2000/2001 Padden Creek quality control data are available in electronic format, either as Excel or ASCII data files. An electronic version of each file is included on the CD with the hardcopy version of this report, and data files are posted with the web version of the report. For additional information, contact the Institute for Watershed Studies, Western Washington University, Bellingham WA, 360-650-3510.

D.1 Padden Creek Field Duplicate Quality Control Data Excel File (fielddup.xls)

The file "fielddup.xls" contains field duplicate results for pH, dissolved oxygen, conductivity, turbidity, total phosphorus, total nitrogen, soluble reactive phosphate, ammonia, nitrate+nitrite, and fecal coliforms.

D.2 Padden Creek Laboratory Duplicate Quality Control Data Excel File (labdup.xls)

The file “labdup.xls” contains field duplicate results for pH, dissolved oxygen, conductivity, turbidity, total phosphorus, total nitrogen, soluble reactive phosphate, ammonia, nitrate+nitrite, and fecal coliforms.

D.3 Interlaboratory Taxonomic Comparison of Padden Creek Macroinvertebrate Samples Excel File (interlab.xls)

The file “interlab.xls” shows the results of the interlaboratory comparison of macroinvertebrate samples by IWS and Rhithron Associates, Missoula MT.