San Juan County Monitoring Project
Final Report

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October 2, 2000

*Funding for this project was provided by San Juan County Health and Community Services through a grant from the Department of Ecology. We thank Judy Kincaid King, Annie Chapman, Sara Waddell, Ryan Toohey, and Mike LeMoine from Western Washington University for assistance with this project. We also thank the landowners that permitted access to the sampling sites. Mark Tompkins and Vicki Heater from the San Juan County Health and Community Services provided essential logistical support.

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1 Introduction

1.1 Background

San Juan County encompasses an archipelago between Vancouver Island, British Columbia and mainland Washington State (Figure 1, page 38). There are about 12,500 permanent residents on the islands. San Juan, Orcas, and Lopez Islands are the largest in the archipelago and have the largest human populations (Table 1, page 19). As the population of the county increases, there has been concern about protecting the water quality on these islands. As a result, San Juan County Health and Community Services acquired Centennial Clean Water Funds from the Washington State Department of Ecology to develop a countywide watershed action plan (Garland 1996). A major goal of the watershed action plan will be to identify and help prevent adverse impacts upon water quality in the county. Therefore, the major objective of our monitoring project was to provide data that could be incorporated into the final watershed action plan.

1.2 Objectives

The objectives of the San Juan County Monitoring Project were to evaluate water quality at selected freshwater and marine sites on San Juan, Orcas, and Lopez Islands; to provide an overview of current water quality conditions; and to help identify long-term water quality monitoring goals.

2 Previous Water Quality Studies

In 1988, the Puget Sound Cooperative River Basin Team surveyed water quality conditions in thirteen priority watersheds in San Juan County with an emphasis on agricultural and livestock impacts (Verburg and Associates, 1988). Watersheds discharging into the following water bodies were identified as being impacted:

- False Bay, San Juan Island
- Friday Harbor, San Juan Island
- Westcott/ Garrison Bays, San Juan Island
- West Sound, Orcas Island
- Mud/Hunter Bays, Lopez Island

Fecal coliform samples collected in the 1990s (WSDHS, 1998) revealed relatively high concentrations in Shoal Bay (Lopez Island) and Coon Hollow (East Sound, Orcas Island). Buck Bay (Orcas Island) had intermittently high coliform counts, but overall the site met Class AA standards. These results were not definitive because fewer than 30 samples were collected at most locations.

Joy (1995) summarized a number of earlier water quality surveys in San Juan County. Two surveys in Friday Harbor were conducted in order to evaluate the effects of wastewater effluent from the Friday Harbor wastewater treatment plant. Singleton and Joy (1983) found unacceptable fecal coliform bacteria concentrations in Friday Harbor, and attributed the high levels to poor effluent disinfection and improper boat waste disposal. In 1986, Determan and Kendra concluded that the wastewater treatment plant no longer contributed significantly to bacterial problems in Friday Harbor. However, they found that boat waste discharges were still causing fecal coliform bacteria problems in the harbor. In 1988, a Puget Sound bacterial water quality investigation was conducted by the Washington Department of Health Shellfish Section (Seabloom et al., 1989). Water and shellfish were collected twice; once with fewer than 20 boats per day, and once with more than 40 boats per day. Water fecal coliform levels were within Class AA standards. When more than 40 boats were present, 67% of the shellfish tissue fecal coliform concentrations exceeded commercial shellfish standard of 230 cfu[1]/100 grams. Bacterial contamination was also found in the sediments.

Newton (1995a) summarized San Juan County water quality investigations from the Marine Water Monitoring program of the Ambient Monitoring Section of the Washington State Department of Ecology. Sampling stations were located in East Sound, Georgia Strait, Haro Strait, Lopez Sound, and San Juan Channel. Documents contributing to the summary include Janzen (1992), Newton (1995b), Newton (in press), and OWEA (1995). None of the reports found persistent fecal coliform problems; however, it was suggested that fecal coliform contamination would probably occur at sites located in enclosed and poorly flushed inlets, bays and harbors with anthropogenic input. Although most of the dissolved oxygen concentrations were below Class AA standards (7 mg/L), this was generally attributed to natural upwellings. East Sound on Orcas Island had exceedingly low dissolved oxygen concentrations that may have been caused by anthrogogenic inputs. In East Sound, most dissolved oxygen concentrations were around 3 mg/L, with one value of 1.9 mg/L. It was noted that other enclosed and poorly flushed inlets similar to East Sound may also have low dissolved oxygen concentrations. Very high dissolved ammonia concentrations ($>$20 mg-N/L) were observed at the San Juan Channel and Haro Strait stations during the summer of 1979, and high values were detected sporadically through the 1980s. Ammonia concentrations higher than 0.03 mg/L may imply anthropogenic impacts.

From 1997 through 1998, San Juan County initiated a study that assessed eighteen watersheds in the county (SJCHCS, 2000). They measured total bacteria, fecal coliform bacteria,

[1]cfu=colony forming units

nitrate, pH, conductivity, total suspended solids, dissolved oxygen, and water temperature. This study resulted in the identification and prioritization of the following watersheds that had poor water quality:

- East Sound/Buck Bay, Orcas Island
- Friday Harbor, San Juan Island
- Westcott-Garrison Bays, San Juan Island
- Fisherman Bay, Lopez Island
- Roche Harbor, San Juan Island
- Hunter/Mud Bay, Lopez Island
- Westsound, Orcas Island
- Deer Harbor, Orcas Island
- False Bay, San Juan Island

3 Study Area Description

3.1 Climate

The county encompasses most of the Level IV San Juan Islands ecoregion within the Level III Puget Lowland ecoregion (Pater et al., 1998). Maritime air masses from the Pacific Ocean moderate the climate of San Juan County. The Cascade Mountain range to the east protects this region from most of the continental air masses and associated extreme temperatures. The average minimum/maximum temperatures ranges for this region are 36/46° F in January and 52/62° F in July (Pater et al., 1998). Precipitation is relatively low compared to other areas in the Puget Sound lowlands due to a "rain shadow" effect from the Olympic Mountain range. As a result, the islands range from mesic to xeric, with a mean annual precipitation of 20–35 inches (Pater et al., 1998). Precipitation generally increases from south to north as the distance from the Olympic Mountains increases. Precipitation also increases with elevation. Mean annual precipitation is greatest on Mt. Constitution (Orcas Island) and lowest on the southern portions of San Juan and Lopez Islands. In Western Washington, including San Juan County, about 85% of the annual precipitation falls during a seven month period from October through April (Dietrich, 1975).

3.2 Topography and Geology

The islands in San Juan County are primarily glacially scoured, with small, intermittent streams and limited amounts of surface water. Elevations on the islands range from 0–2400 ft. Soils are typically well drained and shallow, consisting primarily of very gravelly silt loam to gravelly loam. The surficial material and bedrock are composed of Mesozoic and Paleozoic sedimentary rock. Soil orders are primarily Spodosols (Haplorthods), Alfisols

(Palexeralfs), Inceptisols (Xerochrepts), and Andisols (Melanoxerands, Vitraquands) (Pater et al., 1998).

3.3 Land Use

The natural vegetation is primarily Douglas fir (*Pseudotsuga menzieii* (Mirb.) Franco), grand fir (*Abies grandis* (Dougl.) Lindl.), some oak woodlands (*Quercus* spp.), grasslands, and western red cedar (*Thuja plicata* Donn). Land cover includes coniferous forests, oak woodlands, crop and pasture land, recreational sites, rural residential development, and urban residential development (Pater et al., 1998).

3.4 Water Resources

At least 45 lakes and reservoirs and 28 streams have been identified in San Juan County (Wolcott, 1965; Dietrich, 1975). Stream discharges varies considerably as a function of watershed size, local relief, surficial geology, and local precipitation. The mean annual runoff is greatest in streams draining Mt. Constitution on Orcas Island, and lowest in low relief areas of southern San Juan and Lopez Islands (Dietrich, 1975).

Stream discharge is ultimately a function of local precipitation and climate. A portion of local rainfall is lost due to interception, evaporation, and evapotranspiration. The remaining precipitation may flow directly into streams or lakes via surface or subsurface flow, or may enter the ground water, thereby elevating the water table. From May through early October, San Juan County is typically in a phase of ground water deficit. More water is lost from the soil due to evapotranspiration than is added from precipitation. As a result, the water table recedes throughout this dry period. As the water table drops, most streams in San Juan County go completely dry. In late October through April, precipitation exceeds interception, evaporation, and evapotranspiration, and the water table rapidly decreases in depth. Eventually, base flow resumes in the intermittent streams until the following May or June. When the county streams are flowing, the magnitude of discharge in each stream fluctuate widely, in response to local precipitation events.

San Juan County has a wealth of marine habitats. The open marine waters in San Juan County are well flushed (Erickson et al., 1995). Strong tidal currents constantly mix local marine waters with adjacent water bodies (the Strait of Georgia and Juan de Fuca). As a result, all San Juan County marine waters are designated Class AA.

4 Methods

4.1 Study Design

Freshwater sites were selected that were geographically representative of the different county watersheds, identified as having elevated fecal coliform counts in previous studies, or were identified as a concern by the San Juan County Watershed Management Committee. Site selection was also limited to streams that could be accessed and had enough drainage area to flow most of the year. Marine sites were selected based on presence of high boat traffic, low flushing rates, and sensitive marine resources. Site locations are shown on Figure 2 (page 39) and described in Appendix A.

All freshwater sites (Sites 1–24) were sampled monthly during the wet season (March through June and November through February). Most streams were dry from July through October 1999, and, as a result, only seven freshwater sites were sampled during this period. This represents an increase from our original sampling plan, in which we proposed to sample five perennial sites (Sites 13, 14, 16, 23, and 24). Site 22 was also scheduled to be sampled, but access was terminated in August[2]. The two additional perennial sites were added as part of a thesis research project conducted by Chad Wiseman (Sites 12 and 18). All regular water quality measurements were collected at Sites 12 and 18 except fecal coliform bacteria.

The following water quality parameters were measured at all of the freshwater sites: temperature, dissolved oxygen, conductivity, pH, turbidity, total phosphorus, ammonia, nitrate/nitrite, and fecal coliform bacteria. When possible, stream discharge was also measured.

During the summer and fall, when many of the freshwater sites were dry, we sampled nine marine sites (Sites 25–33). The marine sites were sampled from June through October, which encompassed the period of maximum recreational activity by boats visiting the county. Marine samples were collected at 2 m (6 ft) depths, below the halocline, and analyzed to determine temperature, dissolved oxygen, conductivity, pH, turbidity, soluble reactive phosphate, nitrate/nitrite, fecal coliform bacteria, and secchi depths.

4.2 Field Sampling

Temperature, dissolved oxygen, conductivity, and discharge were measured in the field using the procedures described in Table 2 (page 20). From March through November, pH was measured in the field using an Orion 290A meter. This meter proved to be difficult to operate and unreliable, so beginning in December pH was measured in the laboratory

[2] All data collected prior to August at Site 22 have been retained in this report.

immediately after each day's sampling effort using the VWR 8000 meter. The YSI temperature thermistor was checked before and after each daily sampling event using a calibrated mercury thermometer. The YSI dissolved oxygen meter was checked by recording percent saturation at each site. If the percent saturation deviated more than 5% from 100% saturation, the meter was recalibrated. The YSI dissolved oxygen membrane was checked for wrinkles and fouling at each site. In addition, Winkler dissolved oxygen samples were collected at 20% of the sites to compare to the YSI results. The YSI conductivity probe was calibrated once a month before each sampling event.

Water samples were collected for fecal coliform, turbidity, nitrate/nitrite, ammonia, and total phosphorus. Fecal coliform samples were collected in sterile 125 mL bottles. Water samples sample for turbidity, nitrate/nitrite, ammonia, and total phosphorus were collected in clean, acid-washed (2 N HCL) 500 mL polyethylene bottles. Glass 300 mL BOD bottles were used to collect water samples for Winkler dissolved oxygen samples. All sample bottles, with the exception of those used for bacterial analyses, were rinsed three times with stream water and filled carefully from below the surface of the water, avoiding sediment contamination from the stream bottom. Marine samples were collected at 2 m (6 ft) using a Van-Dorn sampler. After sample collection, all bottles were transported back to the laboratory on ice.

Stream discharge measurements were made at all freshwater sites, except Sites 8, 11, and 17. Site 8 had an irregular bedrock stream bed that made it impossible to collect accurate discharge measurements. Sites 11 and 17 were located in barred culverts that had rocky bases, which also made accurate discharge measurements impossible. At the other sites, discharge measurements were occasionally omitted due to time constraints. Due to the difficult nature of measuring low flow, four different methods were employed to capitalize on different site features at different discharge levels (Table 2).

4.3 Analytical Methods

The methods for each chemical analysis are summarized in Table 2 (page 20). Turbidity (all months) and pH (December 1999 through February 2000) were measured in the Friday Harbor Laboratories within twelve hours of collection. Prior to December 1999, pH was measured in the field using the Orion 290A meter. Fecal coliform samples were analyzed by Avocet Environmental Testing, a Washington State Department of Health accredited laboratory. Transportation logistics prevented some fecal coliform samples from being processed within twenty-four hours; however, all samples were processed within a maximum of 30 hours. Marine nitrate/nitrite samples were analyzed at the Shannon Point Marine Center. Soluble reactive phosphate, total phosphorus, ammonia, and freshwater nitrate/nitrite were analyzed at the Institute for Watershed Studies (IWS), a Washington State Department of Ecology accredited laboratory.

4.4 Data Analysis and Quality Control

Data were entered from field sheets and laboratory notebooks into EXCEL spreadsheets and verified by checking 10% of the data from each month. The raw data were plotted and all outlying data points exceeding 5% discordancy test critical values for each site and parameter were verified (APHA 1992). Except for fecal coliform data, which were censored by Avocet, the data were not screened to remove values below detection limits. As a result, some parameters had negative values due to the use of calibration curves. Detection limits for each parameter are listed in Table 2. The detection limits for each parameter were estimated based on recommended lower detection ranges, instrument limitations, and analyst judgment on the lowest repeatable concentration for each test.

Matrices of standard water quality compliance were created for fecal coliform, dissolved oxygen, temperature, and pH. Water quality standards for surface waters of the state of Washington (WSDOE, 1997, Chapter 173–201A WAC) were used. Descriptive statistics (mean, standard deviation, median, minimum, maximum, and N) were computed to identify sites that had water quality problems. Nonparametric correlation analysis[3] (Kendall's τ) was used to detect linear associations between water quality parameters and month, site, or islands. Boxplots were generated to show water quality parameters and discharge by month and site.

To assure accuracy of the analytical results, the following procedures were used to help assess the quality of data being produced. At least 15% of all samples collected were field duplicates, which tests the precision associated with sample collection. In the laboratory, 10% of the samples were analyzed in duplicate, which tests the precision associated with analytical procedures. Two internal check standards (20% and 80% of the calibration curve) were analyzed with each analytical run for nutrients to verify that analytical precision and calibration bias were acceptable using control charts. A detailed discussion of the quality control results is included in Appendix B. All water quality, discharge, and quality control data are included in Appendix C and are available on CD in ascii and EXCEL formats. An ascii README file that described the data file contents is also included on the CD.

5 Results and Discussion

The water quality data for freshwater sites are displayed in Figures 3–22, pages 40–59 and Tables 3–8, pages 27–11. The water quality data for marine sites are displayed in Figures 23–40, pages 60–77, and Tables 9–11, pages 21–8.

[3] Nonparametric statistics were used whenever possible because they are unaffected by the inclusion of below detection data.

5.1 Freshwater Sites

5.1.1 Stream Discharge

Discharge responded to climactic conditions in a predictable fashion in all the streams measured for this project. Discharge decreased from the beginning of the sampling period (March 1999) through the summer (Figure 3, page 40; Tables 3–8, pages 21–26). Most streams went dry during the summer and fall, although the duration of flow varied among streams. Sites 1, 2, 3, 5, 6, 10, 19, and 21 were dry for the majority of the summer and fall. Some streams persisted in a low flow or seep-like condition, with flow often alternating along the stream's longitudinal axis between surface and subsurface flow. Sites 9, 16, and 18 were of this type. Sites 12, 13, 14, 23, and 24 had stable base flow throughout the 12-month sampling period. In November, and throughout the remainder of the sampling period, all streams had measurable discharges.

There was a wide variation in discharge rates at the different sites (Figure 13, page 50). During the summer and fall, discharges ranged from $<$0.05 cfs to $\sim$0.50 cfs. In the winter, discharges were often $<$0.5 cfs under base flow conditions (no recent precipitation) in sites located in small catchments. During storm events in the larger catchments, discharge rates were as high as 33 cfs. The large degree of variation between sites was probably due to catchment size, surficial geology, slope and aspect, and variation in local precipitation patterns.

5.1.2 Water Quality

The pollution indicators ammmonia, coliforms, phosphorus, temperature, and turbidity all tended to be high at polluted sites, and were therefore positively correlated (Tables 12 and 13, pages 30 and 31). Dissolved oxygen tended to be low at polluted sites, and was negatively correlated with the other pollution indicators. The most consistent water quality indicators in our study were dissolved oxygen and fecal coliforms.

Water temperatures increased in the summer and early fall at the freshwater sites (Figure 4). Dissolved oxygen solubility is negatively related to temperature, so dissolved oxygen decreased in the summer and early fall (Figure 7). The remaining water quality parameters showed no specific seasonal trends.

San Juan County streams do not have specific Washington State Department of Ecology WAC 173–201A–130 water quality classifications. The receiving marine waters in the county are classified as AA marine waters; therefore, San Juan County streams are designated Class AA by default. Fecal coliform bacteria, temperature, and dissolved oxygen in many of the streams failed to meet the WAC criteria (Table 14, page 32). There was seasonal and site to site variation associated with compliance to these criteria (Tables 15–18, pages 33–36). Class AA standards were exceeded most often in the summer and early fall. During this time, Class A dissolved oxygen may actually reflect natural conditions more accurately than Class AA. Some sites (1, 18, 19, 23 and 24) exceeded temperature and dissolved oxygen classifications to the extent that it probably reflects impacted rather than natural conditions.

5.2 Marine Sites

Water temperatures decreased in October (Figure 23, page 60). Dissolved oxygen decreased in September and October, falling below Class AA standards (Figure 26, page 63). The period of low oxygen coincided with an increase in nitrate/nitrite (Figure 28, page 65) which suggests that there may have been an upwelling in the San Juan County region in late September and October. Upwelling from the lower strata of the Puget Sound Basin or via the Strait of Juan de Fuca would advect nutrient rich, cold, low-oxygen water to the surface of San Juan County marine waters. These results concur with Newton (1995a), who found that regional dissolved oxygen concentrations in the 5–7 mg/L range was due to upwelling, particularly in the late summer.

Most sites had water quality similar to other samples collected in the Puget Sound area (Shannon Point Marine Center web site, www.ac.wwu.edu/∼spmc/). Sites 30 and 33, however, had distinctive water quality, characterized by high dissolved oxygen and low nitrate/nitrate and soluble phosphate (Figures 35, 37, and 38, pages 72, 74, and 75; Tables 9–11, pages 27–29). These two sites were located in Roche Harbor (Site 30) and Westcott Bay (Site 33). Low flushing rates and the large biomass of macroalgae that we observed could explain these anomalous conditions. The shallow bathymetry lends these sites well to macroalgae production. Although the low nutrient concentrations suggests low anthropogenic nutrient pollution, we sampled during the daytime and at the peak algal growing season. Photosynthetic supersaturation of oxygen and rapid nutrient uptake could mask anthropogenic pollutant loading.

Friday Harbor met the Class AA water quality standards for fecal coliforms, which suggests that bacterial contamination may have decreased since the late 1970's and 1980's (Singleton and Joy 1983; Determan and Kendra 1986). Clearly, more sampling is needed to substantiate this apparent trend.

Dissolved oxygen concentrations in Cascade Bay, East Sound were much higher than the depleted conditions reported by Newton (1995a). Fecal coliform counts only met Class B standards, suggesting possible anthropogenic pollution.

6 Site Discussions

In the following qualitative site descriptions, statements describing “low” and “high” values are relative to each parameter mean (Tables 3–11, pages 21–29). When applicable, Chapter 173–201A WAC classifications are included in the site descriptions.

6.1 Freshwater Sites

SITE 1: Land use designations at this site included rural farm forest and agriculture. The site was dry from April through December. It met Class AA standards for pH and temperature. Water quality problems included high fecal coliform counts (Class B), chronically low dissolved oxygen concentrations (Class C and lower), and high total phosphorus and ammonia concentrations.

SITE 2: This site was located in the Hummel Lake drainage. Land use designations included agriculture and rural farm forest. The site was dry from June through December, 1999. It met Class AA standards for pH and temperature. Water quality problems included high fecal coliform counts (Class C or lower), low dissolved oxygen concentrations (Class B in November, 1999), and high total phosphorus concentrations.

SITE 3: This site drains wetlands and runs just north of Lopez Village. The land use designations included agriculture, rural farm forest, and village. The site was dry from April through December, 1999. It met Class AA standards for pH and temperature. Water quality problems included high fecal coliform counts (Class C or lower), low dissolved oxygen concentrations (Class B in November, 1999), and high total phosphorus concentrations.

SITE 4: Land use at this site included agriculture, rural farm forest, and forest. The duration of stream flow is unknown. It met Class AA standards for temperature. Water quality problems included high fecal coliform counts (Class C or lower), Class C pH designation in May, 1999, and chronically low dissolved oxygen concentrations (Class B to below C).

SITE 5: Land use designations included rural farm forest and forest. This site was dry from July through November, 1999. It met Class AA standards for pH and temperature. Water quality problems included high fecal coliform counts (Class B), occasional low dissolved oxygen concentrations (Class A or B), and high nutrient concentrations in the late fall.

SITE 6: Land use designations included rural farm forest and agriculture. This sites was dry from April through December. It met Class AA standards for pH and temperature. Water quality problems included high fecal coliform counts (Class B), low dissolved oxygen concentrations (Class B in March 1999), and high total phosphorus concentrations in the late fall, 1999.

SITE 7: The land use designations at this site included agriculture and rural farm forest. The duration of stream flow is unknown. This site met Class AA standards for pH and temperature and Class A standards for coliforms and dissolved oxygen. Nitrate/nitrite concentrations and total phosphorus concentrations were somewhat elevated.

SITE 8: This site was located in a stream that drains a series of wetlands, some cleared land, and areas with low density residential housing. Land use designations included rural farm forest and hamlet. The duration of stream flow is unknown. This site met Class AA standards for pH, temperature, and coliforms, and Class A standards for dissolved oxygen.

SITE 9: This site was located in a stream that drains Crow Valley. Much of the watershed is cleared. Land use designations included forest, agriculture, rural industrial, and rural farm forest. The duration of stream flow is unknown. The site met Class AA standards for pH and temperature. Water quality problems included high fecal coliform counts (Class C or lower), low dissolved oxygen concentrations (Class C), high ammonia concentrations, and high turbidities.

SITE 10: This site was located in a stream that drains a pond. Land use designations include forest and rural farm forest. This site was dry from June through November. It had chronically high nitrate/nitrite concentrations, which were probably caused by the presence of nitrogen-fixing alders (*Alnus rubra*) in the watershed. The site met Class AA standards for coliforms, pH, temperature, and dissolved oxygen.

SITE 11: This site was located in a stream that drains the East Sound area. The stream is ponded, enters a culvert, and discharges onto the beach. Land use designations included village, rural farm forest, and forest. The duration of flow at this site is unknown. It met Class AA standards for pH and temperature. Water quality problems included high fecal coliform counts (Class C or lower), slightly low oxygen concentration (Class A), and high conductivities.

SITE 12: Land use designations at this site included conservancy, rural farm forest, and rural industrial. This stream flowed throughout the sampling period. It met Class AA standards for coliforms, pH, and temperature, but had relatively low oxygen concentrations (Class A or B).

SITE 13: This site was located in Cascade Creek where it exits Moran State Park. The land use designation at this site was conservancy. This stream flowed throughout the sampling period. The site met Class AA standards for coliforms, pH, and temperature, and Class A for dissolved oxygen.

SITE 14: This site was located at the mouth of Cascade Creek. Land use designations included conservancy, forest, rural farm forest, and hamlet. This stream flowed throughout the sampling period. It met Class AA standards for pH and temperature, and Class A standards for dissolved oxygen. Water quality problems included high fecal coliform counts (Class B).

SITE 15: Land use designations included conservancy, forest, and rural farm forest. The duration of flow at this site is unknown. It met Class AA standards for pH and temperature, and Class A standards for coliforms. Water quality problems included low oxygen concentrations (Class B).

SITE 16: Land use designations included hamlet, rural farm forest, forest, and conservancy. This stream flowed throughout the sampling period, although discharge rates were very low and irregular during late summer and fall, 1999. It met Class AA standards for pH and temperature. Water quality problems included high fecal coliform counts (Class C or lower), low dissolved oxygen concentration (Class A or B), and high nitrate/nitrite concentrations in the fall of 1999.

SITE 17: This site was located at the Spring Street outfall into Friday Harbor. The duration of flow at this site is unknown. It met Class AA standards for pH and temperature, and Class A standards for dissolved oxygen. Water quality problems included chronically high fecal coliform counts (below Class C), high concentrations of nutrients, and high turbidities.

SITE 18: This site was located in a stream that drains Beaverton Valley. Land use designations included agriculture, rural farm forest, and natural. This stream flowed throughout the sampling period, although discharge rates were very low during the late summer and fall. It met Class AA standards for pH and temperature. Water quality problems included high fecal coliform counts (Class B) and variable oxygen concentrations (Class A to C).

SITE 19: This site was located in a stream that drains Sportsman's Lake. Land use designations included rural farm forest. The duration of flow at this site is unknown. It met Class AA standards for coliforms, pH and temperature. Water quality problems included chronically low dissolved oxygen (Class B to below C) and high ammonia concentrations.

SITE 20: Land use designations included rural farm forest and rural industrial. The duration of flow at this site is unknown. It met Class AA standards for pH and temperature, and Class A standards for coliforms and dissolved oxygen. Water quality problems included high total phosphorus in May and June, 1999.

SITE 21: This site was located in the Roche Harbor Reservoir outlet stream. Land use designations included rural farm forest. This stream was dry from July through November, 1999. It met Class AA standards for coliforms, pH and temperature, and Class A standards for dissolved oxygen. Water quality problems included a high nitrate/nitrite concentration in December, 1999.

SITE 22: This site was located in a stream that drains the Garrison Bay watershed. Land use designations included forest, rural farm forest, and agriculture. The duration of flow at this site is unknown. It met Class AA standards for pH. Water quality problems included high fecal coliform counts (Class B), high water temperatures (Class A and B), and low dissolved oxygen (Class B).

SITE 23: This site was located in San Juan Valley Creek, about 0.5 miles upstream from Zylstra Lake. Land use designations included forest, natural, rural farm forest, and agriculture. This stream flowed throughout the sampling period. It met Class AA standards for pH. Water quality problems included slightly elevated fecal coliform counts (Class A), high temperatures (Class A and B), and low dissolved oxygen concentrations (Class B and C).

SITE 24: This site was located in San Juan Valley Creek near False Bay. Land use designations included forest, natural, rural farm forest, and agriculture. This stream flowed throughout the sampling period. It met Class AA standards for pH. Water quality problems included chronically high fecal coliform counts (below Class C), high temperatures (Class A to below C), chronically low dissolved oxygen concentrations (Class C and below), high total phosphorus concentrations and high turbidities.

6.2 Marine Sites

SITE 25: This site was located in Fisherman's Bay, Lopez Island. This site met Class AA standards for fecal coliforms and pH, and Class A standards for temperature and dissolved oxygen.

SITE 26: This site was located in Fisherman's Bay, Lopez Island. This site met Class AA standards for fecal coliforms and pH, and Class A standards for temperature and dissolved oxygen.

SITE 27: This site was located in Deer Harbor, Orcas Island. This site met Class AA standards for fecal coliforms and pH, and Class A standards for temperature and dissolved oxygen.

SITE 28: This site was located in Deer Harbor, Orcas Island. This site met Class AA standards for fecal coliforms and pH, and Class A standards for temperature and dissolved oxygen.

SITE 29: This site was located in West Sound, Orcas Island. This site met Class AA standards for fecal coliforms and pH, and Class A standards for temperature and dissolved oxygen.

SITE 30: This site was located at Cascade Bay, East Sound, Orcas Island. This site had Class AA pH values and Class A temperature and dissolved oxygen values in the late summer and early fall. Water quality problems included high coliform counts (Class B). Nitrate/nitrite and soluble phosphorus concentrations were extremely low.

SITE 31: This site was located in Friday Harbor, San Juan Island. This site met Class AA standards for fecal coliforms and pH, and Class A standards for temperature. Water quality problems included low dissolved oxygen concentrations (Class B)

SITE 32: This site was located in Friday Harbor, San Juan Island. This site met Class AA standards for fecal coliforms and pH, and Class A standards for temperature. Water quality problems included low dissolved oxygen concentrations (Class B)

SITE 33: This site was located in Garrison Bay, San Juan Island. This site met Class AA standards for fecal coliforms and pH, and Class A standards for temperature and dissolved oxygen. Nitrate/nitrite and soluble phosphate concentrations were extremely low at this site.

7 Water Quality Monitoring Recommendations

The design of a long-term sampling regime should be contingent upon the goals of that program. We recommend that San Juan County set specific goals to which their sampling regime would be associated.

The following outline described one possible long-term monitoring scenario.

Identify problem areas: Stream water quality in our 1999–2000 study can be categorized as good, marginal, or obviously impaired based on Table 14 (page 32).

- Sites 8, 10, 12, 13, 20, and 21 had good water quality;
- Sites, 2, 3, 5, 6, 7, 14, 15, 18, 22, and 23 had marginal water quality;
- Sites 1, 4, 9,11, 16, 17, 19, and 24 had at least one parameter that was obviously beyond acceptable limits.

The sites with obvious impairment should be ranked highest as candidates for restoration and continued monitoring. The marginal sites should be ranked next. Within this marginal group, sites could be prioritized by more specific water quality concerns, or by presence of sensitive freshwater or receiving marine habitat.

Many of the marginal and obviously impaired watersheds identified in our study overlap with the "priority" watersheds identified in previous studies. All impacted watersheds identified in Verburg and Associates (1988) were also identified as impacted in our study. Similarly, many of the impacted watersheds identified by the San Juan County Health and Community Services (SJCHCS, 2000) overlapped with many of our impacted sites. Our study identified several additional impacted watersheds that were not listed by the county, including Swifts Bay (Site 2), Lopez Sound (Site 6), Mackaye Harbor/Davis Bay (Site 4), Shoal Bay (Site 1), Doe Bay (site 16), and San Juan Channel (Site 19) as impacted. The Deer Harbor watershed (Site 8) was unimpacted according to our data, but listed as impacted by the county.

The majority of the marine sites in our study had good water quality. However, we recommend that East Sound should be monitored because it has a history of low dissolved oxygen

(Joy 1995), high fecal coliform counts in recent sampling (WSDHS, 1998), and high fecal coliform counts in the present study. Similarly, Friday Harbor, which had good water quality in this study, should nevertheless be monitored because the municipal outfall discharging into Friday Harbor had very poor water quality. Westcott/Garrison Bay (currently good water quality) should be monitored because this water body has a low flushing rate, high boat traffic, and a tributary (Site 22) with marginal water quality. Shoal Bay should be monitored because Washington State Department of Health sampling (WSDHS, 1998) yielded high fecal coliform counts. In addition, Site 1 had poor water quality and discharges into Shoal Bay. Buck Bay should be monitored because Washington State Department of Health sampling (WSDHS, 1998) yielded high fecal coliform counts. In addition, Site 15 had marginal water quality and discharges into Buck Bay.

Identify the source of pollution: Our study did not attempt to identify specific sources of pollution. Source identification would require much more frequent sampling, possible targeting specific high priority watersheds. Direct field observations in the priority watershed could help identify discrete pollution sources. Working with the community could also help identify specific pollution sources.

Develop and implement specific restoration action plans and goals: The use of "best management practices" should be encouraged, particularly on dairy farms and other commercial lands that may contribute high concentrations of nutrients and fecal coliform bacteria. Programs that assist citizens with developing and maintaining best management practices should be instituted.

Pollution prevention should be encouraged when evaluating methods of treatment for drainages with non-point pollution problems. The elimination of pollutants before they can be introduced to surface water has proven to be more effective and less expensive than the "end-of-the-pipe" treatment of polluted waters. Pollution prevention also tends to save the public sector from paying for the pollutants introduced by individual polluters. Planners and landowners can refer to existing documents on pollution control practices (WSDOE 1994) and water quality management (WSDOE 1999).

Specific restoration projects such as tree plantings, bank stabilization, and the fencing off of riparian zones should be initiated. We recommend that the agricultural tributaries upstream from Sites 4, 9, and 24 be at the top of the list for this type of stream restoration.

Monitor restoration sites and identify new problem areas: Within our stream sites, there were many seasonal similarities in the water quality. In addition, we found that dissolved oxygen concentrations and fecal coliform bacteria were consistent indicators of poor water quality. Depending upon the desired balance between watershed coverage and sampling periodicity, a quarterly sampling regime that included (at least) temperature, dissolved oxygen, and fecal coliform counts may suffice. The sampling regime should include sampling events at the beginning and end of the low flow period (May through October), and during the high flow period (November through April). Timing of sampling should be customized for many of the streams due to the heterogeneity in flow periods. Although logistically difficult, storm event sampling may be a good compliment to this sampling regime.

It is important to keep in mind that our study was not comprehensive and did not include all archipelago watersheds and marine water bodies. In addition, we did not sample all kinds of pollutants. New sampling sites should be rotated into the sampling regime periodically to identify previously undisclosed problem areas. We also recommend a more comprehensive list of analytes be include on a regular basis, particularly if the county elects to use just coliforms and oxygen as water quality indicators.

8 Tables

Island	Est. 1996 Population	Size (mi^2)
San Juan	5,836	56.9
Orcas	3,802	55.3
Lopez	1,765	29.5

Table 1: Estimated 1996 population and size of San Juan, Orcas, and Lopez Islands. (Source: http://www.co.san-juan.wa.us/, 1999 and http://www.co.san-juan.wa.us/about.html, 2000)

Parameter	Method	Description	Det. Limits
Temperature (°C)	EPA (1979) #170.1	YSI 85 meter	NA
D. oxygen (mg/L)	EPA (1979) # 360.1	YSI 85 meter	0.1
Conductivity (μS/cm)	EPA (1979) #120.1	YSI 85 meter	2
pH	EPA (1979) #150.1	Orion 290A meter	NA
		VWR 8000 meter	NA
Turbidity (NTU)	EPA (1979) #180.1	Hach 2100P meter	0.2
Sol. phosphate (μg-P/L)	EPA (1979) #365.2	Ascorbic acid	5
T. phosphorus (μg-P/L)	EPA (1979) #365.2	Persulfate digestion, ascorbic acid	5
Ammonia (μg-N/L)	EPA (1979) #350.1	Auto. phenate	20
Nitrate/nitrite, freshw (μg-N/L)	EPA (1979) #353.2	Auto. Cd reduction	10
Nitrate/nitrite, marine (μg-N/L)	Parsons, et al., (1984)	Auto. Cd reduction	10
Fecal coliform (cfu/100 mL)	APHA (1992) #9222	Membrane filter	1–2*
Secchi depth (m)	Wetzel and Likens (1990)	Two point average	NA
Discharge (cfs)	Marsh-McBirney (1990)	0.4; 0.9 × Vmax; conduit; or volumetric	0.05

*Avocet's detection limits were 1–2 cfu/100 mL depending on sample run.

Table 2: Methods used to monitor San Juan County creeks and marine sites.

Site	Parameter	Mean	SD	Med	Min	Max	N
1	Conductivity (μS/cm)	299.3	75.4	333.1	171.4	357.5	7
	Discharge (cfs)	0.41	0.26	0.41	0.10	0.71	4
	D. oxygen (mg/L)	4.4	2.0	4.3	1.0	6.4	6
	Fecal coliform (cfu/100mL)	63	87	9	4	220	7
	Ammonia (μg-N/L)	173.9	242.5	129.8	$<$20	676.0	7
	Nitrate/nitrite (μg-N/L)	$<$10	12	$<$10	$<$10	33	7
	pH (units)	7.0	0.1	7.0	6.9	7.1	5
	Temperature (C)	8.2	2.9	7.1	4.6	13.2	7
	Total phosphorus (μg-P/L)	192.1	178.7	166.0	54.8	579.4	7
	Turbidity (NTU)	4.9	2.9	4.0	1.8	9.6	7
2	Conductivity (μS/cm)	151.3	18.7	152.2	118.6	173.0	7
	Discharge (cfs)	0.54	0.49	0.75	$<$0.05	1.17	7
	D. oxygen (mg/L)	9.7	1.4	9.7	7.3	11.4	7
	Fecal coliform (cfu/100mL)	121	162	72	2	430	7
	Ammonia (μg-N/L)	$<$20	19.6	$<$20	$<$20	41.0	7
	Nitrate/nitrite (μg-N/L)	138	132	114	$<$10	396	7
	pH (units)	7.1	0.2	7.1	6.8	7.3	6
	Temperature (C)	6.7	1.9	6.6	3.2	9.3	7
	Total phosphorus (μg-P/L)	92.8	44.9	74.2	37.1	166.6	7
	Turbidity (NTU)	10.4	8.5	7.5	2.2	22.9	7
3	Conductivity (μS/cm)	134.9	36.6	142.6	92.3	185.4	5
	Discharge (cfs)	0.80	0.80	0.60	0.13	1.88	4
	D. oxygen (mg/L)	10.2	1.5	10.4	7.6	11.8	5
	Fecal coliform (cfu/100mL)	572	1136	68	6	2600	5
	Ammonia (μg-N/L)	$<$20	22.6	$<$20	$<$20	28.0	5
	Nitrate/nitrite (μg-N/L)	32	46	23	$<$10	111	5
	pH (units)	7.1	0.3	7.3	6.7	7.3	5
	Temperature (C)	6.4	1.9	6.6	3.2	8.3	5
	Total phosphorus (μg-P/L)	119.9	49.9	136.9	64.0	179.2	5
	Turbidity (NTU)	17.2	8.7	13.8	7.1	26.6	5
4	Conductivity (μS/cm)	326.1	72.1	320.6	220.7	448.5	8
	Discharge (cfs)	1.44	1.83	0.84	$<$0.05	4.78	7
	D. oxygen (mg/L)	9.3	3.0	9.9	4.0	13.5	8
	Fecal coliform (cfu/100mL)	122	231	19	4	680	8
	Ammonia (μg-N/L)	29.9	47.1	23.0	$<$20	117.0	8
	Nitrate/nitrite (μg-N/L)	214	177	184	31	554	8
	pH (units)	7.7	0.5	7.6	7.2	8.7	8
	Temperature (C)	8.6	2.9	7.8	4.2	12.9	8
	Total phosphorus (μg-P/L)	94.0	52.8	67.1	51.5	194.0	8
	Turbidity (NTU)	6.4	5.4	4.6	2.0	18.7	8

Table 3: Water quality summary, freshwater sites 1–4.

Site	Parameter	Mean	SD	Med	Min	Max	N
5	Conductivity (μS/cm)	239.0	33.5	242.9	173.8	272.3	8
	Discharge (cfs)	0.34	0.49	0.14	<0.05	1.43	8
	D. oxygen (mg/L)	10.3	1.8	10.7	7.3	12.8	8
	Fecal coliform (cfu/100mL)	69	112	16	<2	330	8
	Ammonia (μg-N/L)	126.9	286.3	<20	<20	829.0	8
	Nitrate/nitrite (μg-N/L)	483	509	337	<10	1616	8
	pH (units)	7.4	0.4	7.5	6.9	8.0	7
	Temperature (C)	8.1	2.3	7.8	4.8	12.3	8
	Total phosphorus (μg-P/L)	54.6	54.8	31.5	15.8	176.5	8
	Turbidity (NTU)	6.6	3.2	6.0	3.3	12.7	8
6	Conductivity (μS/cm)	116.9	12.3	113.9	106.8	133.0	4
	Discharge (cfs)	0.10	0.07	0.09	<0.05	0.17	4
	D. oxygen (mg/L)	9.7	2.0	10.2	7.0	11.5	4
	Fecal coliform (cfu/100mL)	95	118	58	<1	264	4
	Ammonia (μg-N/L)	<20	11.0	<20	<20	<20	4
	Nitrate/nitrite (μg-N/L)	66	38	62	24	116	4
	pH (units)	6.9	0.2	6.8	6.7	7.2	4
	Temperature (C)	6.3	1.7	6.7	4.1	7.8	4
	Total phosphorus (μg-P/L)	102.8	18.4	102.5	85.7	120.4	4
	Turbidity (NTU)	18.6	6.5	17.5	11.8	27.4	4
7	Conductivity (μS/cm)	248.9	117.6	292.9	116.2	385.0	7
	Discharge (cfs)	0.37	0.26	0.39	<0.05	0.64	4
	D. oxygen (mg/L)	10.6	1.4	10.3	8.6	13.0	7
	Fecal coliform (cfu/100mL)	31	57	10	<2	160	7
	Ammonia (μg-N/L)	<20	15.1	<20	<20	28.5	7
	Nitrate/nitrite (μg-N/L)	876	721	839	115	1822	6
	pH (units)	7.4	0.3	7.3	7.1	7.7	7
	Temperature (C)	8.1	2.3	7.9	4.2	11.2	7
	Total phosphorus (μg-P/L)	82.5	29.6	78.2	49.8	128.7	7
	Turbidity (NTU)	9.2	5.7	6.5	5.2	21.1	7
8	Conductivity (μS/cm)	304.5	30.4	295.6	270.0	360.6	8
	Discharge	na	na	na	na	na	na
	D. oxygen (mg/L)	10.9	1.3	11.2	8.8	12.4	8
	Fecal coliform (cfu/100mL)	4	3	3	<1	10	8
	Ammonia (μg-N/L)	<20	17.0	<20	<20	38.0	8
	Nitrate/nitrite (μg-N/L)	132	159	72	<10	495	8
	pH (units)	8.1	0.1	8.0	7.9	8.3	7
	Temperature (C)	9.1	3.2	8.4	4.4	13.0	8
	Total phosphorus (μg-P/L)	24.8	13.4	26.8	<5	44.2	8
	Turbidity (NTU)	5.1	1.8	4.9	2.8	8.1	8

Table 4: Water quality summary, freshwater sites 5–8.

Site	Parameter	Mean	SD	Med	Min	Max	N
9	Conductivity (μS/cm)	210.2	40.5	221.1	148.5	261.0	8
	Discharge (cfs)	5.12	7.66	0.67	0.09	20.25	7
	D. oxygen (mg/L)	10.6	2.1	10.8	6.5	13.1	8
	Fecal coliform (cfu/100mL)	226	404	26	4	1100	8
	Ammonia (μg-N/L)	157.0	327.6	32.0	$<$20	953.5	8
	Nitrate/nitrite (μg-N/L)	146	132	115	11	367	8
	pH (units)	7.7	0.2	7.7	7.4	7.9	7
	Temperature (C)	8.1	2.7	7.6	4.2	12.7	8
	Total phosphorus (μg-P/L)	46.2	9.5	45.7	34.0	56.8	8
	Turbidity (NTU)	9.2	3.2	9.5	4.5	14.0	8
10	Conductivity (μS/cm)	152.2	21.5	148.0	126.5	192.8	7
	Discharge (cfs)	0.53	0.70	0.27	$<$0.05	1.81	6
	D. oxygen (mg/L)	11.2	1.2	11.8	9.0	12.0	7
	Fecal coliform (cfu/100mL)	2	1	2	$<$1	3	7
	Ammonia (μg-N/L)	$<$20	26.0	$<$20	$<$20	44.0	7
	Nitrate/nitrite (μg-N/L)	2261	2347	1520	953	7552	7
	pH (units)	7.4	0.3	7.3	7.1	7.9	6
	Temperature (C)	7.1	2.5	6.7	3.4	10.0	7
	Total phosphorus (μg-P/L)	9.5	4.5	8.9	$<$5	15.2	7
	Turbidity (NTU)	1.8	1.2	1.4	0.3	4.1	7
11	Conductivity (μS/cm)	391.2	45.1	383.8	345.0	471.4	8
	Discharge	na	na	na	na	na	na
	D. oxygen (mg/L)	10.8	1.1	11.1	9.1	12.0	8
	Fecal coliform (cfu/100mL)	65	148	13	1	430	8
	Ammonia (μg-N/L)	$<$20	15.8	$<$20	$<$20	$<$20	8
	Nitrate/nitrite (μg-N/L)	339	168	311	125	601	8
	pH (units)	7.8	0.2	7.8	7.5	8.1	7
	Temperature (C)	9.8	3.7	8.4	5.2	15.1	8
	Total phosphorus (μg-P/L)	36.5	19.9	30.5	11.2	66.3	8
	Turbidity (NTU)	3.7	2.5	2.3	1.5	8.0	7
12	Conductivity (μS/cm)	248.9	37.7	251.4	165.9	304.4	12
	Discharge (cfs)	0.51	0.76	0.22	$<$0.05	2.67	12
	D. oxygen (mg/L)	9.8	1.3	10.2	7.5	11.3	12
	Fecal coliform (cfu/100mL)	15	18	8	$<$1	48	8
	Ammonia (μg-N/L)	$<$20	13.7	$<$20	$<$20	24.0	12
	Nitrate/nitrite (μg-N/L)	260	152	196	115	629	12
	pH (units)	7.9	0.2	7.9	7.5	8.1	11
	Temperature (C)	9.3	2.6	10.0	5.2	13.6	12
	Total phosphorus (μg-P/L)	12.3	4.6	13.4	$<$5	18.1	12
	Turbidity (NTU)	3.8	1.1	3.5	2.3	6.0	11

Table 5: Water quality summary, freshwater sites 9–12.

Site	Parameter	Mean	SD	Med	Min	Max	N
13	Conductivity (μS/cm)	118.2	19.5	117.5	80.9	161.1	12
	Discharge (cfs)	4.83	7.05	1.75	0.25	22.18	10
	D. oxygen (mg/L)	10.8	1.2	10.6	8.1	12.5	12
	Fecal coliform (cfu/100mL)	3	2	3	$<$1	8	12
	Ammonia (μg-N/L)	$<$20	14.2	$<$20	$<$20	$<$20	12
	Nitrate/nitrite (μg-N/L)	209	72	205	119	378	12
	pH (units)	7.6	0.2	7.7	7.3	7.8	12
	Temperature (C)	9.3	3.5	9.6	4.6	15.3	12
	Total phosphorus (μg-P/L)	6.0	2.5	5.9	$<$5	10.6	12
	Turbidity (NTU)	0.9	0.6	0.7	0.4	1.9	12
14	Conductivity (μS/cm)	138.2	21.8	140.9	101.7	176.9	12
	Discharge (cfs)	5.22	9.89	1.31	0.23	33.07	11
	D. oxygen (mg/L)	10.9	1.3	11.0	8.8	12.3	12
	Fecal coliform (cfu/100mL)	49	67	29	$<$1	230	12
	Ammonia (μg-N/L)	$<$20	13.0	$<$20	$<$20	$<$20	12
	Nitrate/nitrite (μg-N/L)	345	104	327	196	546	12
	pH (units)	7.6	0.2	7.7	7.3	8.0	10
	Temperature (C)	9.2	2.9	9.4	4.8	14.4	12
	Total phosphorus (μg-P/L)	10.9	3.2	10.9	$<$5	16.2	12
	Turbidity (NTU)	1.7	1.3	1.1	0.7	5.4	12
15	Conductivity (μS/cm)	222.8	43.9	224.2	161.7	280.8	8
	Discharge (cfs)	1.31	1.76	0.66	0.10	5.38	8
	D. oxygen (mg/L)	9.9	1.6	10.3	7.3	11.7	8
	Fecal coliform (cfu/100mL)	60	67	25	9	170	8
	Ammonia (μg-N/L)	$<$20	22.3	$<$20	$<$20	49.0	8
	Nitrate/nitrite (μg-N/L)	483	382	350	97	1223	8
	pH (units)	7.4	0.2	7.4	7.1	7.6	6
	Temperature (C)	8.8	2.9	8.2	4.6	12.3	8
	Total phosphorus (μg-P/L)	29.6	9.1	28.4	15.8	42.9	8
	Turbidity (NTU)	8.5	3.4	7.7	4.8	14.0	8
16	Conductivity (μS/cm)	182.0	34.1	181.1	123.4	243.0	12
	Discharge (cfs)	1.74	3.09	0.62	0.10	10.82	12
	D. oxygen (mg/L)	10.0	1.6	10.5	6.6	11.9	12
	Fecal coliform (cfu/100mL)	223	368	72	5	1000	12
	Ammonia (μg-N/L)	$<$20	15.4	$<$20	$<$20	24.0	12
	Nitrate/nitrite (μg-N/L)	709	513	695	92	1873	12
	pH (units)	7.6	0.2	7.6	7.3	8.0	11
	Temperature (C)	9.4	2.4	9.1	5.3	13.7	12
	Total phosphorus (μg-P/L)	19.2	8.6	17.0	7.8	34.6	12
	Turbidity (NTU)	4.3	1.5	4.8	1.7	7.3	12

Table 6: Water quality summary, freshwater sites 13–16.

Site	Parameter	Mean	SD	Med	Min	Max	N
17	Conductivity (μS/cm)	471.3	178.4	459.2	251.7	798.7	8
	Discharge	na	na	na	na	na	na
	D. oxygen (mg/L)	10.5	0.8	10.5	9.3	11.8	8
	Fecal coliform (cfu/100mL)	1666	1388	1500	116	3600	8
	Ammonia (μg-N/L)	743.9	1024.9	107.5	<20	2454.9	8
	Nitrate/nitrite (μg-N/L)	1221	626	1068	492	2159	8
	pH (units)	7.9	0.2	7.9	7.7	8.2	6
	Temperature (C)	10.8	3.2	10.3	6.5	15.8	8
	TP (ug/L)	116.8	57.8	90.9	70.9	236.9	8
	Turbidity (NTU)	34.6	55.1	5.1	1.6	153.0	8
18	Conductivity (μS/cm)	307.6	92.9	288.2	207.1	448.3	12
	Discharge (cfs)	1.68	2.14	0.37	<0.05	5.47	10
	D. oxygen (mg/L)	9.5	1.6	9.9	6.1	11.9	12
	Fecal coliform (cfu/100mL)	45	82	10	6	260	9
	Ammonia (μg-N/L)	<20	18	<20	<20	32	12
	Nitrate/nitrite (μg-N/L)	131	174	98	<10	611	11
	pH (units)	7.54	0.24	7.58	7.11	7.92	12
	Temperature (C)	9.6	3.1	10.1	3.5	13.3	12
	Total phosphorus (μg-P/L)	44.8	13.1	45.8	21.8	68.3	12
	Turbidity (NTU)	3.96	2.11	3.30	1.69	9.74	12
19	Conductivity (μS/cm)	210.6	54.3	189.8	165.8	313.0	7
	Discharge (cfs)	4.27	5.60	2.29	0.07	14.87	6
	D. oxygen (mg/L)	5.1	2.6	6.1	1.7	7.6	7
	Fecal coliform (cfu/100mL)	8	11	4	<1	32	7
	Ammonia (μg-N/L)	54	45	46	<20	145	7
	Nitrate/nitrite (μg-N/L)	171	158	144	<10	449	7
	pH (units)	6.88	0.18	6.88	6.56	7.14	7
	Temperature (C)	7.4	2.9	7.0	3.5	11.5	7
	Total phosphorus (μg-P/L)	39.7	19.5	35.0	16.2	67.3	7
	Turbidity (NTU)	2.80	1.81	2.20	1.16	6.69	7
20	Conductivity (μS/cm)	263.7	105.9	230.8	150.7	428.6	8
	Discharge (cfs)	0.58	0.87	0.15	<0.05	2.38	8
	D. oxygen (mg/L)	10.7	1.5	10.3	8.1	12.7	8
	Fecal coliform (cfu/100mL)	60	43	59	9	130	8
	Ammonia (μg-N/L)	25.1	48.5	<20	<20	110.6	8
	Nitrate/nitrite (μg-N/L)	106	118	73	14	385	8
	pH (units)	7.4	0.3	7.3	6.7	7.7	8
	Temperature (C)	7.7	2.8	7.9	4.1	12.4	8
	Total phosphorus (μg-P/L)	65.1	42.1	48.0	23.8	136.6	8
	Turbidity (NTU)	9.4	2.3	10.1	5.3	11.5	8

Table 7: Water quality summary, freshwater sites 17–20.

Site	Parameter	Mean	SD	Med	Min	Max	N
21	Conductivity (μS/cm)	251.8	53.1	244.1	180.3	321.6	8
	Discharge (cfs)	0.57	0.77	0.19	<0.05	1.90	8
	D. oxygen (mg/L)	11.0	1.2	11.1	9.0	12.5	8
	Fecal coliform (cfu/100mL)	38	35	33	<1	88	8
	Ammonia (μg-N/L)	<20	25.1	<20	<20	33.0	8
	Nitrate/nitrite (μg-N/L)	519	495	405	122	1648	8
	pH (units)	7.8	0.2	7.8	7.5	8.1	8
	Temperature (C)	7.9	2.6	8.3	4.3	12.2	8
	Total phosphorus (μg-P/L)	34.9	20.5	30.4	16.3	71.3	8
	Turbidity (NTU)	9.0	4.7	9.8	3.0	17.0	8
22	Conductivity (μS/cm)	298.3	20.3	299.0	274.1	322.0	5
	Discharge (cfs)	0.39	0.59	0.15	<0.05	1.43	5
	D. oxygen (mg/L)	9.8	2.1	9.3	7.4	13.1	5
	Fecal coliform (cfu/100mL)	104	99	93	2	230	4
	Ammonia (μg-N/L)	<20	13.6	<20	<20	20.2	5
	Nitrate/nitrite (μg-N/L)	31	38	21	<10	96	5
	pH (units)	7.9	0.1	7.9	7.8	8.0	4
	Temperature (C)	14.1	4.2	15.8	8.1	18.4	5
	Total phosphorus (μg-P/L)	38.4	12.2	38.3	23.1	54.4	5
	Turbidity (NTU)	11.7	5.4	10.4	5.9	18.2	5
23	Conductivity (μS/cm)	209.7	28.8	210.3	128.3	242.9	12
	Discharge (cfs)	3.81	7.03	0.51	0.07	23.56	12
	D. oxygen (mg/L)	8.3	2.3	7.8	5.5	12.0	12
	Fecal coliform (cfu/100mL)	36	34	25	8	130	12
	Ammonia (μg-N/L)	<20	13.5	<20	<20	<20	12
	Nitrate/nitrite (μg-N/L)	125	184	40	<10	629	12
	pH (units)	7.4	0.1	7.4	7.1	7.6	11
	Temperature (C)	11.4	5.5	10.1	4.6	20.1	12
	Total phosphorus (μg-P/L)	28.1	10.6	25.4	15.5	54.4	12
	Turbidity (NTU)	3.3	2.3	2.8	1.1	9.9	12
24	Conductivity (μS/cm)	272.6	54.1	262.5	214.0	374.6	12
	Discharge (cfs)	4.89	9.07	0.64	0.13	27.76	12
	D. oxygen (mg/L)	7.5	3.4	8.0	1.7	12.5	12
	Fecal coliform (cfu/100mL)	146	181	70	6	500	12
	Ammonia (μg-N/L)	112.4	241.2	<20	<20	822.0	12
	Nitrate/nitrite (μg-N/L)	67	161	<10	<10	552	12
	pH (units)	7.3	0.3	7.3	6.8	7.6	12
	Temperature (C)	12.1	5.7	10.3	5.9	23.6	12
	Total phosphorus (μg-P/L)	122.8	54.7	108.8	64.3	245.5	12
	Turbidity (NTU)	14.7	19.8	9.2	2.0	75.0	12

Table 8: Water quality summary, freshwater sites 21–24.

Site	Parameter	Mean	SD	Med	Min	Max	N
25	Conductivity (μS/cm)	43828	630	43710	43300	44590	4
	D. oxygen (mg/L)	8.2	1.0	8.3	6.9	9.1	4
	Fecal coliforms (cfu/100mL)	2	1	2	<1	2	4
	Nitrate/nitrite (μg-N/L)	170	61	143	132	261	4
	pH (units)	7.92	0.15	8.01	7.75	8.01	3
	Secchi (m)	3.1	0.8	2.7	2.5	4.0	3
	Soluble phosphate (μg-P/L)	37.0	12.1	30.0	30.0	50.9	3
	Temperature (C)	12.4	1.7	13.1	10.0	13.6	4
	Turbidity (NTU)	1.2	0.3	1.3	0.8	1.5	4
26	Conductivity (μS/cm)	43815	581	43790	43200	44480	4
	D. oxygen (mg/L)	7.8	0.8	7.9	6.9	8.6	4
	Fecal coliforms (cfu/100mL)	2	1	2	1	4	4
	Nitrate/nitrite (μg-N/L)	152	71	172	51	214	4
	pH (units)	7.97	0.04	7.97	7.94	7.99	2
	Secchi (m)	2.0	0.5	2.0	1.7	2.4	2
	Soluble phosphate (μg-P/L)	49.9	1.9	51.0	47.7	51.0	3
	Temperature (C)	12.5	1.7	13.1	10.0	13.7	4
	Turbidity (NTU)	2.6	1.8	2.2	1.0	4.9	4
27	Conductivity (μS/cm)	42660	1117	42220	41830	43930	3
	D. oxygen (mg/L)	7.9	1.5	8.3	6.3	9.3	3
	Fecal coliforms (cfu/100mL)	3	3	2	<1	7	3
	Nitrate/nitrite (μg-N/L)	238	73	211	183	320	3
	pH (units)	7.95	0.06	7.95	7.91	7.99	2
	Secchi (m)	6.3	1.1	6.2	5.3	7.5	3
	Soluble phosphate (μg-P/L)	47.2	10.2	47.2	40.0	54.4	2
	Temperature (C)	12.0	1.8	12.5	10.0	13.6	3
	Turbidity (NTU)	0.7	0.0	0.7	0.7	0.8	3
28	Conductivity (μS/cm)	42017	1796	41550	40500	44000	3
	D. oxygen (mg/L)	8.0	1.4	8.5	6.4	9.1	3
	Fecal coliforms (cfu/100mL)	1	0	1	<1	1	3
	Nitrate/nitrite (μg-N/L)	241	85	208	177	337	3
	pH (units)	7.93	0.06	7.93	7.89	7.97	2
	Secchi (m)	7.7	0.8	7.3	7.2	8.6	3
	Soluble phosphate (μg-P/L)	49.0	16.1	49.0	37.6	60.4	2
	Temperature (C)	12.5	2.1	13.2	10.1	14.2	3
	Turbidity (NTU)	0.5	0.3	0.4	0.3	0.9	3

Table 9: Water quality summary, marine sites 25–28.

Site	Parameter	Mean	SD	Med	Min	Max	N
29	Conductivity (μS/cm)	43930	1114	43645	42920	45510	4
	D. oxygen (mg/L)	7.4	1.4	7.8	5.5	8.7	4
	Fecal coliforms (cfu/100mL)	2	1	1	<1	3	4
	Nitrate/nitrite (μg-N/L)	250	66	247	182	326	4
	pH (units)	7.88	0.11	7.90	7.76	7.97	3
	Secchi (m)	6.7	0.7	6.8	6.0	7.3	3
	Soluble phosphate (μg-P/L)	44.2	7.7	39.7	39.7	53.1	3
	Temperature (C)	12.3	1.6	12.6	10.4	13.8	4
	Turbidity (NTU)	0.6	0.3	0.5	0.4	1.1	4
30	Conductivity (μS/cm)	43775	1257	43610	42420	45460	4
	D. oxygen (mg/L)	8.6	2.5	9.1	5.6	10.7	4
	Fecal coliforms (cfu/100mL)	14	24	3	<1	50	4
	Nitrate/nitrite (μg-N/L)	115	142	36	29	278	3
	pH (units)	8.00	0.37	8.00	7.74	8.27	2
	Secchi (m)	4.7	3.9	2.8	2.3	9.2	3
	Soluble phosphate (μg-P/L)	26.4	25.4	11.7	11.7	55.7	3
	Temperature (C)	13.2	2.8	12.8	10.3	16.9	4
	Turbidity (NTU)	1.1	0.9	0.7	0.4	2.2	3
31	Conductivity (μS/cm)	42785	1756	43435	40200	44070	4
	D. oxygen (mg/L)	6.7	1.0	6.9	5.3	7.5	4
	Fecal coliforms (cfu/100mL)	11	16	3	1	35	4
	Nitrate/nitrite (μg-N/L)	271	37	267	230	318	4
	pH (units)	7.82	0.12	7.84	7.65	7.93	4
	Secchi (m)	8.5	1.8	8.6	6.3	10.5	4
	Soluble phosphate (μg-P/L)	51.7	9.8	46.1	46.1	63.0	3
	Temperature (C)	12.4	2.0	12.6	9.7	14.6	4
	Turbidity (NTU)	0.5	0.1	0.5	0.5	0.6	4
32	Conductivity (μS/cm)	43063	1207	43285	41400	44280	4
	D. oxygen (mg/L)	7.0	1.3	7.2	5.3	8.4	4
	Fecal coliforms (cfu/100mL)	2	1	1	1	3	4
	Nitrate/nitrite (μg-N/L)	296	62	300	229	355	4
	pH (units)	7.75	0.24	7.79	7.50	7.97	3
	Secchi (m)	9.0	1.3	8.9	7.6	10.7	4
	Soluble phosphate (μg-P/L)	50.5	10.2	44.6	44.6	62.3	3
	Temperature (C)	12.4	1.8	12.9	9.8	13.9	4
	Turbidity (NTU)	0.6	0.3	0.6	0.3	1.1	4

Table 10: Water quality summary, marine sites 29–32.

Site	Parameter	Mean	SD	Med	Min	Max	N
33	Conductivity (μS/cm)	44150	704	44160	43280	45000	4
	D. oxygen (mg/L)	11.9	0.7	11.9	11.0	12.7	4
	Fecal coliforms (cfu/100mL)	1	0	1	<1	1	4
	Nitrate/nitrite (μg-N/L)	19	7	17	13	29	4
	pH (units)	8.24	0.13	8.24	8.08	8.39	4
	Secchi (m)	1.9	0.2	1.9	1.7	2.1	3
	Soluble phosphate (μg-P/L)	12.8	2.7	14.4	9.7	14.4	3
	Temperature (C)	13.7	2.3	14.4	10.3	15.7	4
	Turbidity (NTU)	2.7	0.8	2.5	2.0	3.7	4

Table 11: Water quality summary, marine site 33.

Positive Correlations	Negative Correlations
Ammonia–Conductivity	Ammonia–Dissolved oxygen
Ammonia–Fecal coliform	Ammonia–pH
Ammonia–Soluble phosphate	Conductivity–Discharge
Ammonia–Total phosphorus	Conductivity–Dissolved oxygen
Ammonia–Turbidity	Discharge–Temperature
Conductivity–Fecal coliform	Discharge–Total phosphorus
Conductivity–pH	Dissolved oxygen–Fecal coliform
Conductivity–Soluble phosphate	Dissolved oxygen–Soluble phosphate
Conductivity–Temperature	Dissolved oxygen–Temperature
Conductivity–Total phosphorus	Dissolved oxygen–Total phosphorus
Conductivity–Turbidity	Fecal coliform–pH
Discharge–Dissolved oxygen	Nitrate/nitrite–Soluble phosphate
Discharge–Nitrate/nitrite	Nitrate/nitrite–Temperature
Dissolved oxygen–Nitrate/nitrite	Nitrate/nitrite–Total phosphorus
Dissolved oxygen–pH	pH–Total phosphorus
Fecal coliform–Temperature	pH–Turbidity
Fecal coliform–Total phosphorus	Temperature–Turbidity
Fecal coliform–Turbidity	
Nitrate/nitrate- pH	
pH–Temperature	
Soluble phosphate–Temperature	
Soluble phosphate–Total phosphorus	
Soluble phosphate–Turbidity	
Total phosphorus- Turbidity	

Table 12: Kendall's τ nonparametric correlations of parameters at freshwater sites (significant at $p \leq 0.05$).

Positive Correlations	Negative Correlations
Conductivity–Turbidity	Conductivity–Secchi depth
Dissolved oxygen–pH	Conductivity–Temperature
Dissolved oxyen–Temperature	Dissolved oxygen–Nitrate/nitrite
Dissolved oxygen–Turbidity	Dissolved oxygen–Secchi depth
Nitrate/nitrite–Secchi depth	Dissolved oxygen–Soluble phosphate
Nitrate/nitrite–Soluble phosphate	Nitrate/nitrite–pH
pH–Temperature	Nitrate/nitrite–Temperature
pH–Turbidity	Nitrate/nitrite–Turbidity
	pH–Secchi depth
	pH–Soluble phosphate
	Secchi depth–Turbidity
	Soluble phosphate–Temperature
	Soluble phosphate–Turbidity

Table 13: Kendall's τ nonparametric correlations of parameters at marine sites (significant at $p \leq 0.05$).

Site	FC	pH	Temp	DO	Site	FC	pH	Temp	DO
1	B	AA	AA	F	18	B	AA	AA	C
2	F	AA	AA	B	19	AA	AA	AA	F
3	F	AA	AA	B	20	A	AA	AA	A
4	F	C	AA	F	21	AA	AA	AA	A
5	B	AA	AA	B	22	B	AA	B	B
6	B	AA	AA	B	23	A	AA	B	C
7	A	AA	AA	A	24	F	AA	F	F
8	AA	AA	AA	A	25	AA	AA	A	A
9	F	AA	AA	C	26	AA	AA	A	A
10	AA	AA	AA	AA	27	AA	AA	A	A
11	F	AA	AA	A	28	AA	AA	A	A
12	AA	AA	AA	B	29	AA	AA	A	A
13	AA	AA	AA	A	30	B	AA	A	A
14	B	AA	AA	A	31	AA	AA	A	B
15	A	AA	AA	B	32	AA	AA	A	B
16	F	AA	AA	B	33	AA	AA	A	AA
17	F	AA	AA	A					

Table 14: Summary of the Washington State Department of Ecology water quality classifications for all sites based on fecal coliform (FC), pH, temperature (temp), and dissolved oxygen (DO); F class denotes values below the lowest defined classification.

Site	Geom. Mean	Max.	Class
1	23	220	B
2	30	430	F
3	67	2600	F
4	29	680	F
5	20	330	B
6	28	264	B
7	10	160	A
8	3	10	AA
9	39	1100	F
10	2	3	AA
11	13	430	F
12	6	48	AA
13	2	8	AA
14	24	230	B
15	26	170	A
16	63	1000	F
17	958	3600	F
18	14	260	B
19	4	32	AA
20	42	130	A
21	17	88	AA
22	43	230	B
23	27	130	A
24	68	500	F
25	1	2	AA
26	2	4	AA
27	2	7	AA
28	1	1	AA
29	1	3	AA
30	4	50	B
31	4	35	AA
32	1	3	AA
33	1	1	AA

Table 15: Washington State Department of Ecology water quality classifications for all sites based on fecal coliform geometric means and maximum coliform counts; F class denotes values below the lowest defined classification.

	1999										2000	
Site	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
1	AA	AA	AA	AA	na	na	na	na	AA	AA	AA	AA
2	AA	AA	AA	AA	na	na	na	na	AA	AA	AA	AA
3	AA	AA	AA	AA	na	na	na	na	AA	AA	AA	AA
4	AA	AA	C	AA	na	na	na	na	AA	AA	AA	AA
5	AA	AA	AA	AA	na	na	na	na	AA	AA	AA	AA
6	AA	AA	AA	AA	na	na	na	na	AA	AA	AA	AA
7	AA	AA	AA	AA	na	na	na	na	AA	AA	AA	AA
8	AA	AA	AA	AA	na	na	na	na	AA	AA	AA	AA
9	AA	AA	AA	AA	na	na	na	na	AA	AA	AA	AA
10	AA	AA	AA	AA	na	na	na	na	AA	AA	AA	AA
11	AA	AA	AA	AA	na	na	na	na	AA	AA	AA	AA
12	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA
13	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA
14	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA
15	AA	AA	AA	AA	na	na	na	na	AA	AA	AA	AA
16	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA
17	AA	AA	AA	AA	na	na	na	na	AA	AA	AA	AA
18	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA
19	AA	AA	AA	AA	na	na	na	na	AA	AA	AA	AA
20	AA	AA	AA	AA	na	na	na	na	AA	AA	AA	AA
21	AA	AA	AA	AA	na	na	na	na	AA	AA	AA	AA
22	AA	AA	AA	AA	AA	na	na	na	na	na	na	na
23	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA
24	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA
25	na	na	na	na	AA	AA	AA	AA	na	na	na	na
26	na	na	na	na	AA	AA	AA	AA	na	na	na	na
27	na	na	na	na	AA	AA	AA	AA	na	na	na	na
28	na	na	na	na	AA	AA	AA	AA	na	na	na	na
29	na	na	na	na	AA	AA	AA	AA	na	na	na	na
30	na	na	na	na	AA	AA	AA	AA	na	na	na	na
31	na	na	na	na	AA	AA	AA	AA	na	na	na	na
32	na	na	na	na	AA	AA	AA	AA	na	na	na	na
33	na	na	na	na	AA	AA	AA	AA	na	na	na	na

Table 16: Washington State Department of Ecology water quality classifications for all sites based on pH; F class denotes values below the lowest defined classification.

	1999										2000	
Site	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
1	AA	AA	AA	AA	na	na	na	na	AA	AA	AA	AA
2	AA	AA	AA	AA	na	na	na	na	AA	AA	AA	AA
3	AA	AA	AA	AA	na	na	na	na	AA	AA	AA	AA
4	AA	AA	AA	AA	na	na	na	na	AA	AA	AA	AA
5	AA	AA	AA	AA	na	na	na	na	AA	AA	AA	AA
6	AA	AA	AA	AA	na	na	na	na	AA	AA	AA	AA
7	AA	AA	AA	AA	na	na	na	na	AA	AA	AA	AA
8	AA	AA	AA	AA	na	na	na	na	AA	AA	AA	AA
9	AA	AA	AA	AA	na	na	na	na	AA	AA	AA	AA
10	AA	AA	AA	AA	na	na	na	na	AA	AA	AA	AA
11	AA	AA	AA	AA	na	na	na	na	AA	AA	AA	AA
12	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA
13	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA
14	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA
15	AA	AA	AA	AA	na	na	na	na	AA	AA	AA	AA
16	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA
17	AA	AA	AA	AA	na	na	na	na	AA	AA	AA	AA
18	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA	AA
19	AA	AA	AA	AA	na	na	na	na	AA	AA	AA	AA
20	AA	AA	AA	AA	na	na	na	na	AA	AA	AA	AA
21	AA	AA	AA	AA	na	na	na	na	AA	AA	AA	AA
22	AA	AA	A	B	AA	na	na	na	na	na	na	na
23	AA	AA	AA	A	B	B	AA	AA	AA	AA	AA	AA
24	AA	AA	F	A	B	AA	AA	AA	AA	AA	AA	AA
25	na	na	na	na	AA	A	A	AA	na	na	na	na
26	na	na	na	na	AA	A	A	AA	na	na	na	na
27	na	na	na	na	A	AA	AA	AA	na	na	na	na
28	na	na	na	na	A	A	AA	AA	na	na	na	na
29	na	na	na	na	A	A	AA	AA	na	na	na	na
30	na	na	na	na	AA	A	AA	AA	na	na	na	na
31	na	na	na	na	AA	AA	A	AA	na	na	na	na
32	na	na	na	na	A	AA	A	AA	na	na	na	na
33	na	na	na	na	A	A	A	AA	na	na	na	na

Table 17: Washington State Department of Ecology water quality classifications for all sites based on temperature; F class denotes values below the lowest defined classification.

	1999										2000	
Site	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
1	F	AA	F	AA	na	na	na	na	F	C	C	C
2	AA	AA	A	AA	na	na	na	na	B	AA	AA	AA
3	AA	AA	AA	AA	na	na	na	na	B	AA	AA	AA
4	AA	A	B	B	na	na	na	na	F	AA	AA	AA
5	AA	AA	A	A	na	na	na	na	B	AA	AA	AA
6	B	AA	AA	AA	na	na	na	na	AA	AA	AA	AA
7	AA	AA	AA	A	na	na	na	na	AA	AA	AA	AA
8	AA	AA	AA	A	na	na	na	na	AA	AA	AA	AA
9	AA	AA	A	C	na	na	na	na	AA	AA	AA	AA
10	AA	AA	AA	AA	na	na	na	na	AA	AA	AA	AA
11	AA	AA	A	A	na	na	na	na	AA	AA	AA	AA
12	AA	AA	AA	A	B	B	A	AA	AA	AA	AA	AA
13	AA	AA	AA	AA	AA	A	A	AA	AA	AA	AA	AA
14	AA	AA	AA	AA	A	A	A	AA	AA	AA	AA	AA
15	AA	AA	A	A	na	na	na	na	B	AA	AA	AA
16	AA	AA	AA	AA	B	B	A	A	AA	AA	AA	AA
17	AA	AA	A	AA	na	na	na	na	AA	AA	AA	AA
18	AA	AA	AA	B	B	C	A	AA	A	AA	AA	AA
19	C	F	F	AA	na	na	na	na	F	B	B	C
20	AA	AA	AA	A	na	na	na	na	AA	AA	AA	AA
21	AA	AA	AA	A	na	na	na	na	AA	AA	AA	AA
22	AA	AA	B	B	A	na	na	na	na	na	na	na
23	C	AA	B	B	B	C	A	B	A	AA	AA	AA
24	A	A	B	B	C	F	C	C	F	AA	AA	AA
25	na	na	na	na	AA	AA	A	A	na	na	na	na
26	na	na	na	na	AA	AA	A	A	na	na	na	na
27	na	na	na	na	AA	AA	A	A	na	na	na	na
28	na	na	na	na	AA	AA	A	A	na	na	na	na
29	na	na	na	na	AA	AA	A	AA	na	na	na	na
30	na	na	na	na	AA	AA	A	AA	na	na	na	na
31	na	na	na	na	A	AA	A	B	na	na	na	na
32	na	na	na	na	AA	AA	A	B	na	na	na	na
33	na	na	na	na	AA	AA	A	AA	na	na	na	na

Table 18: Washington State Department of Ecology water quality classifications for all sites based on dissolved oxygen; F class denotes values below the lowest defined classification.

9 Figures

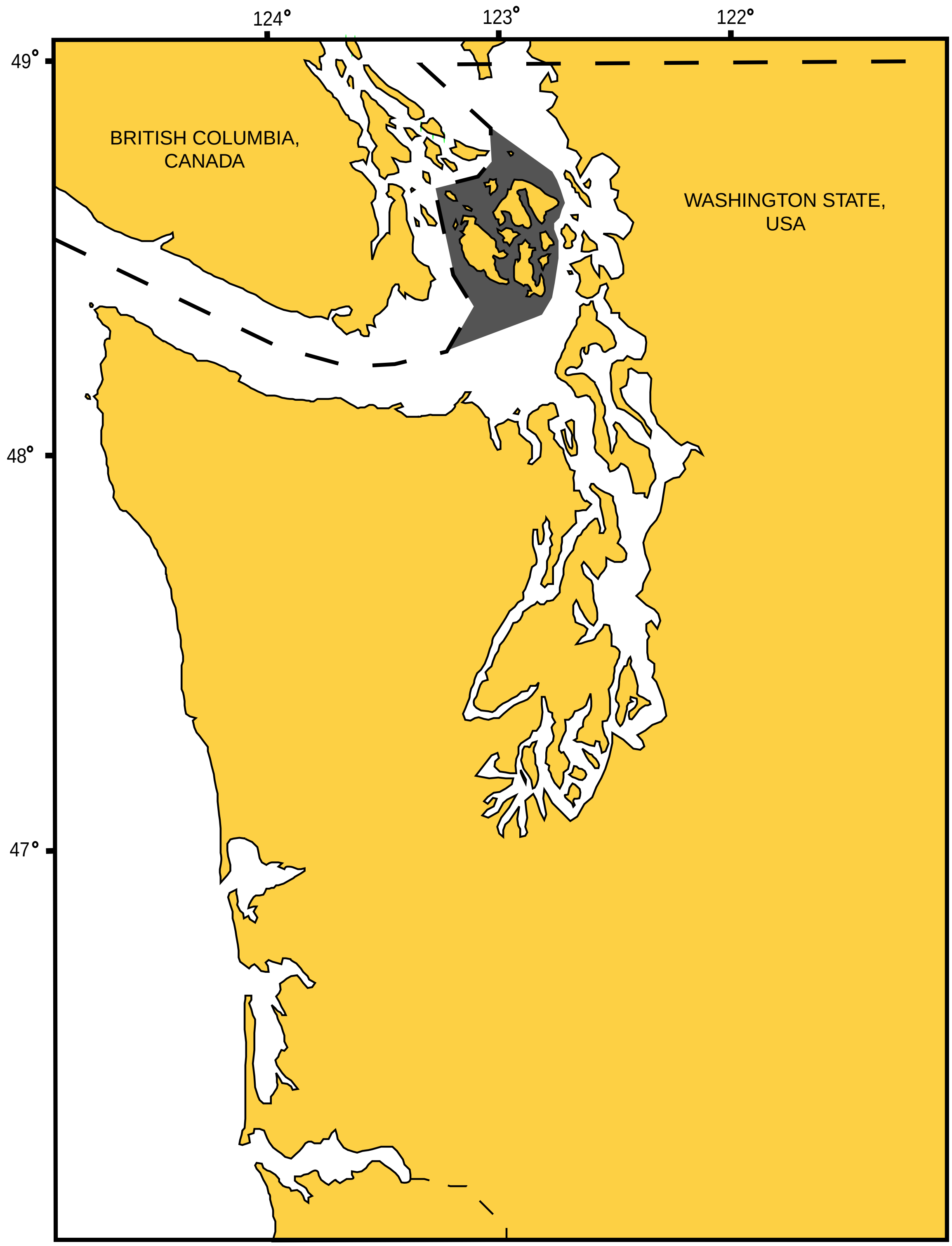

Figure 1: San Juan County and vicinity.

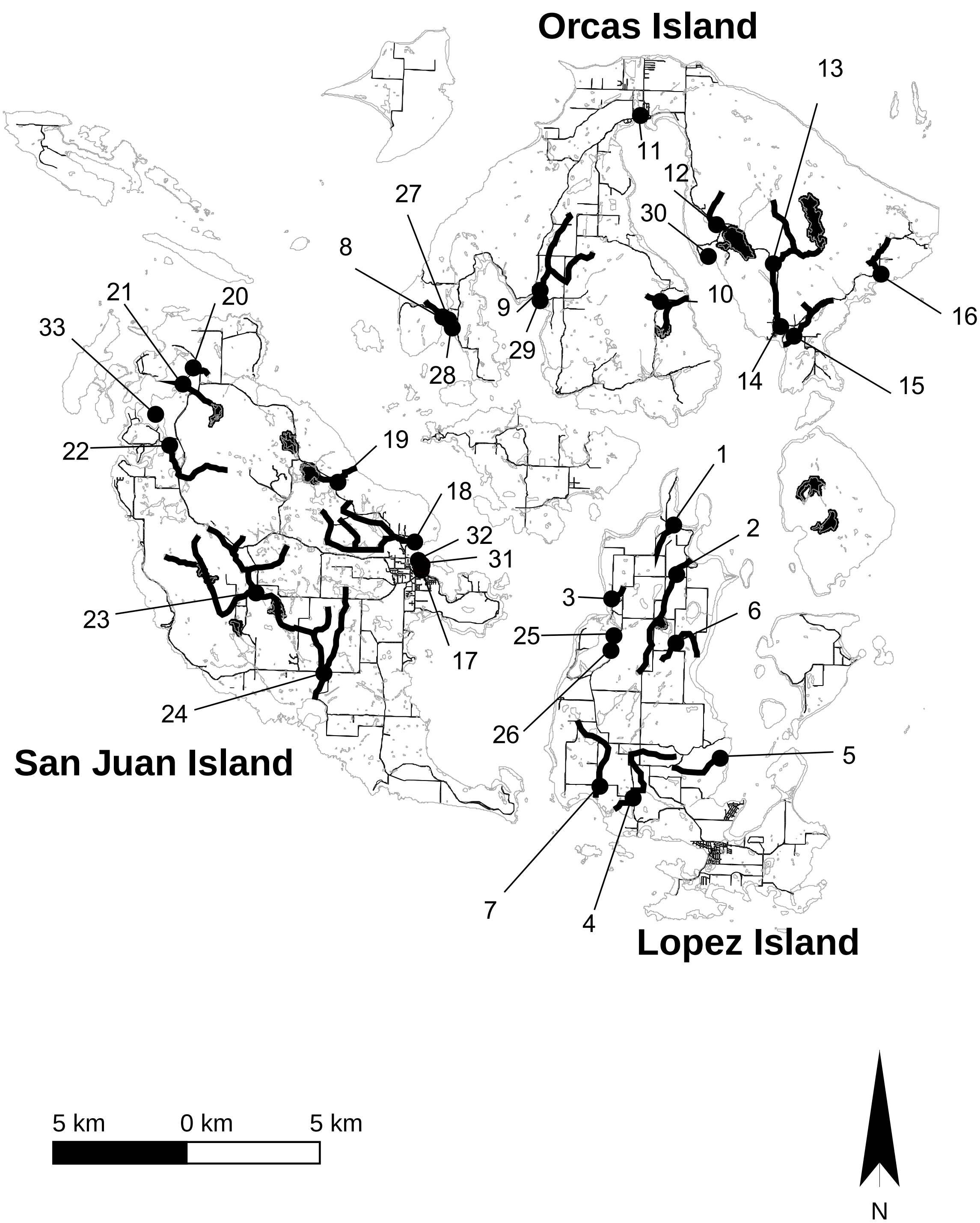

Figure 2: Locations of monitoring sites on in San Juan County.

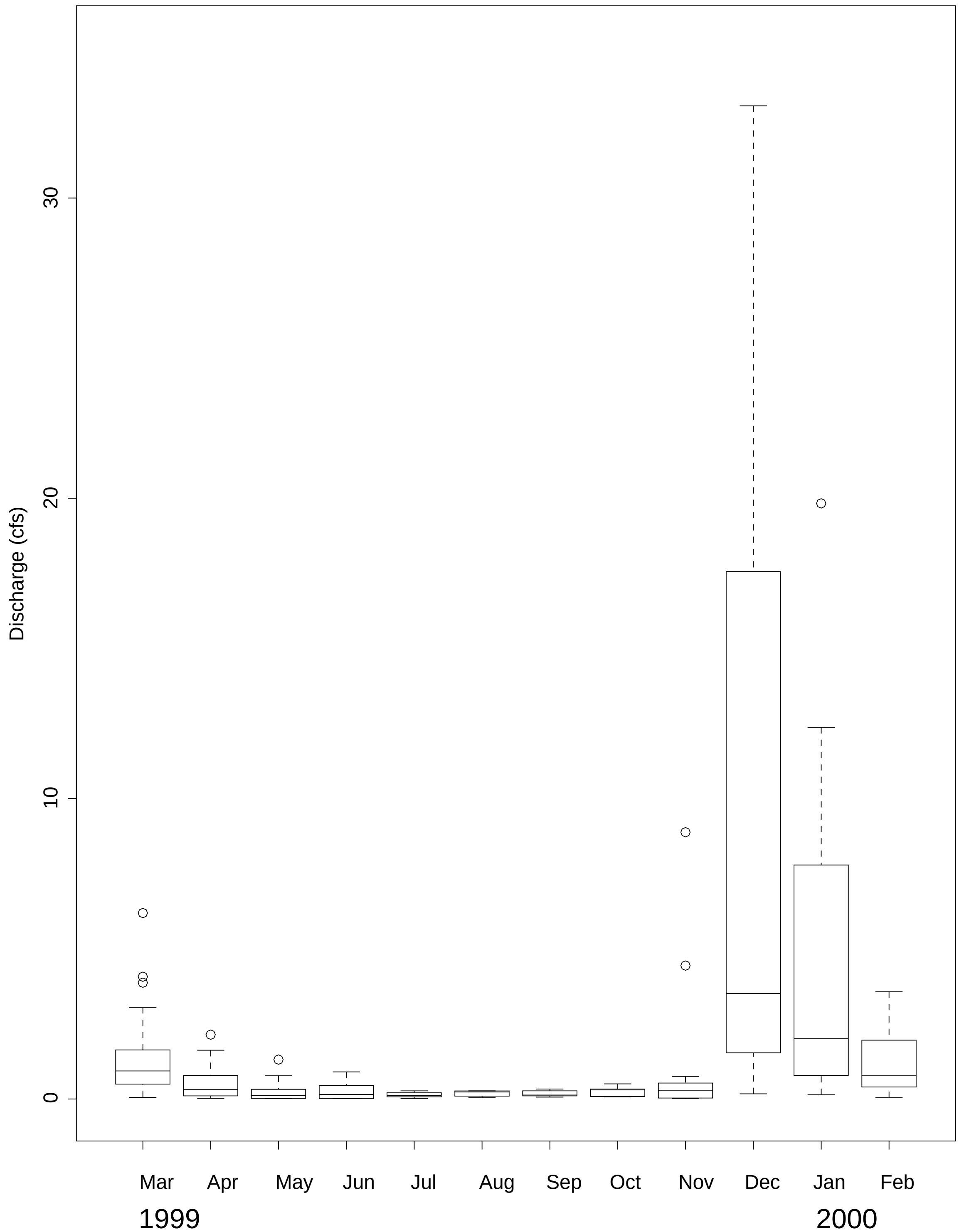

Figure 3: Boxplot of discharge rates at freshwater sites plotted by month. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq 1.5 \times$ interquartile range.

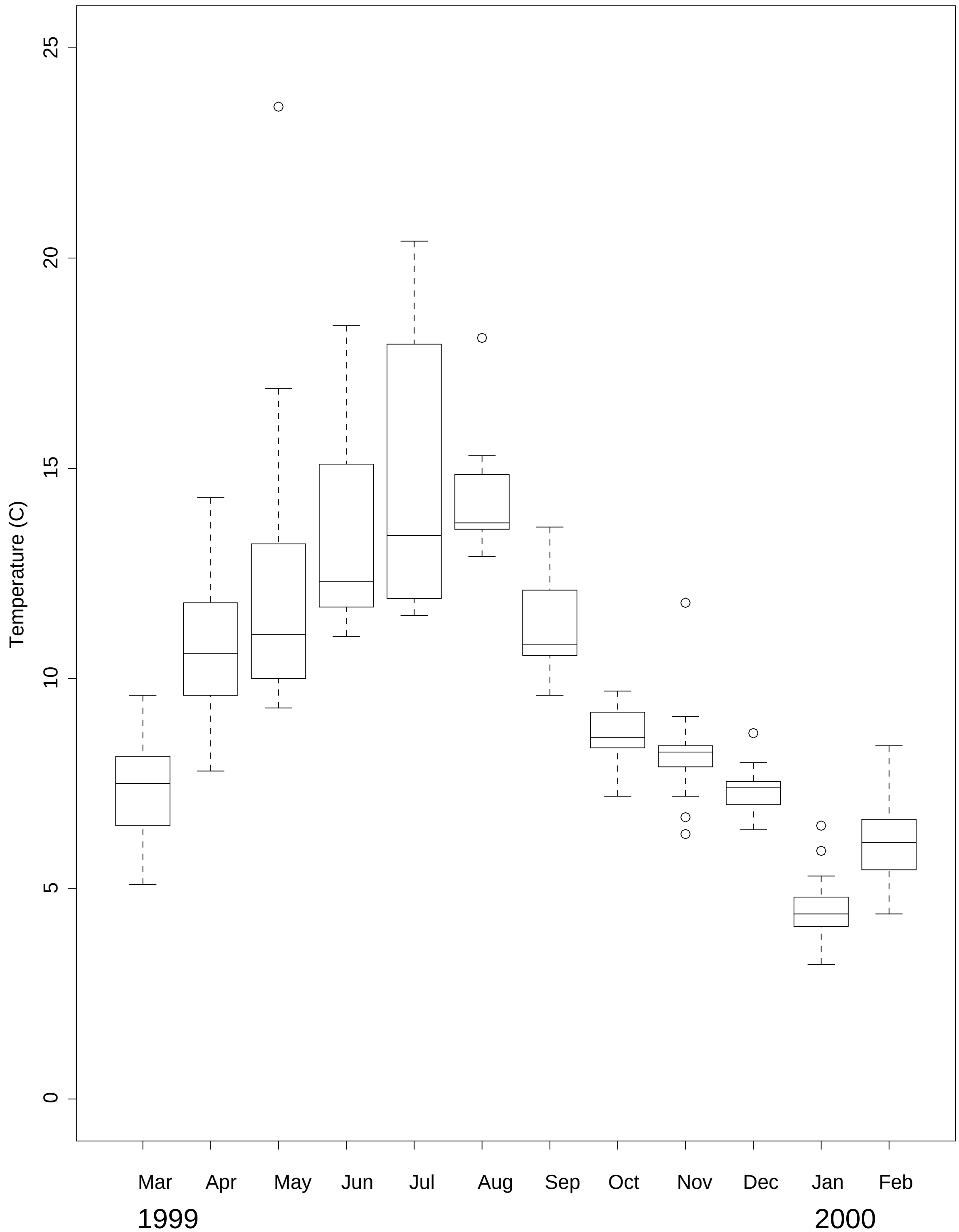

Figure 4: Boxplot of water temperature at freshwater sites plotted by month. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq 1.5 \times$ interquartile range.

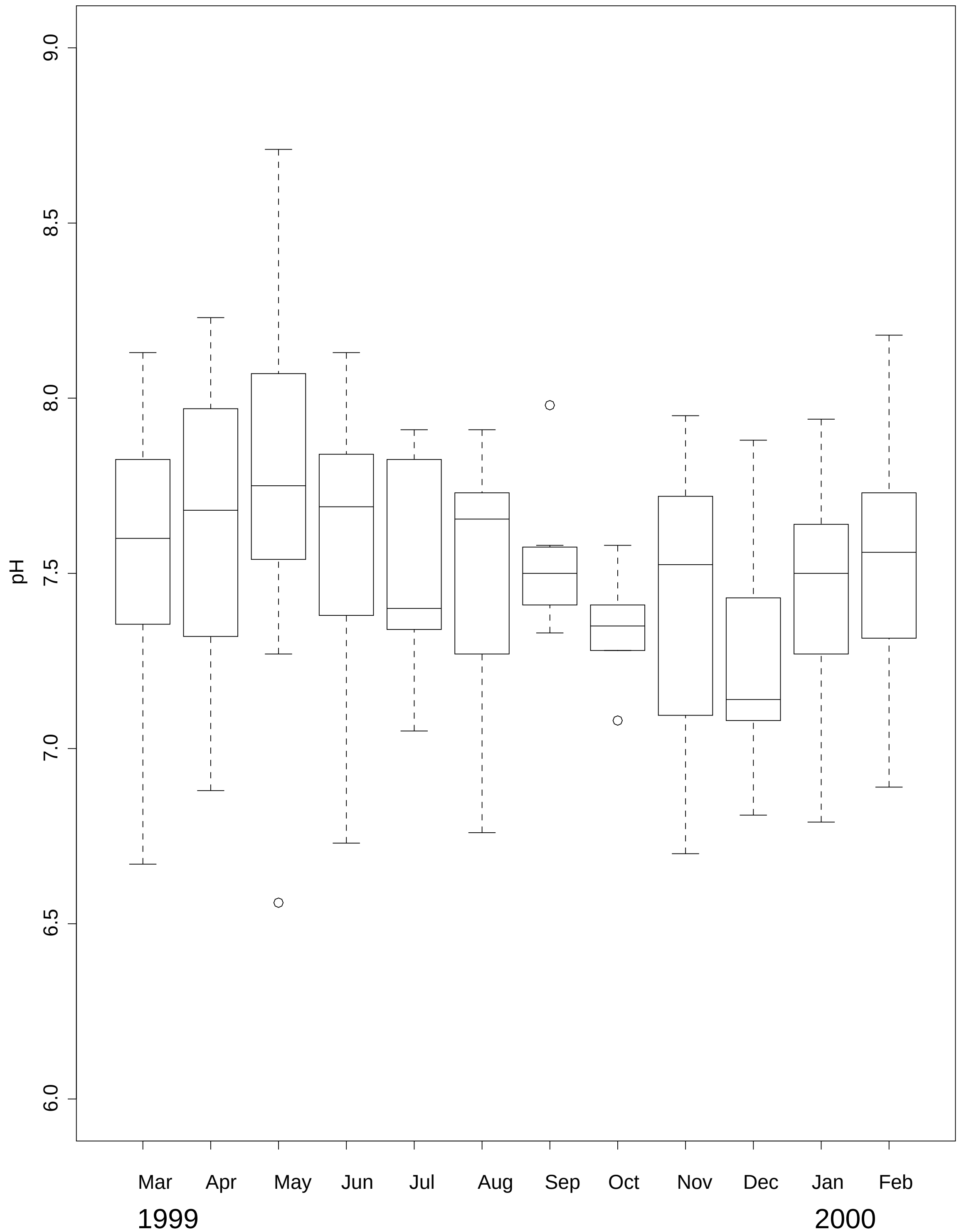

Figure 5: Boxplot of pH at freshwater sites plotted by month. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq$ $1.5 \times$ interquartile range.

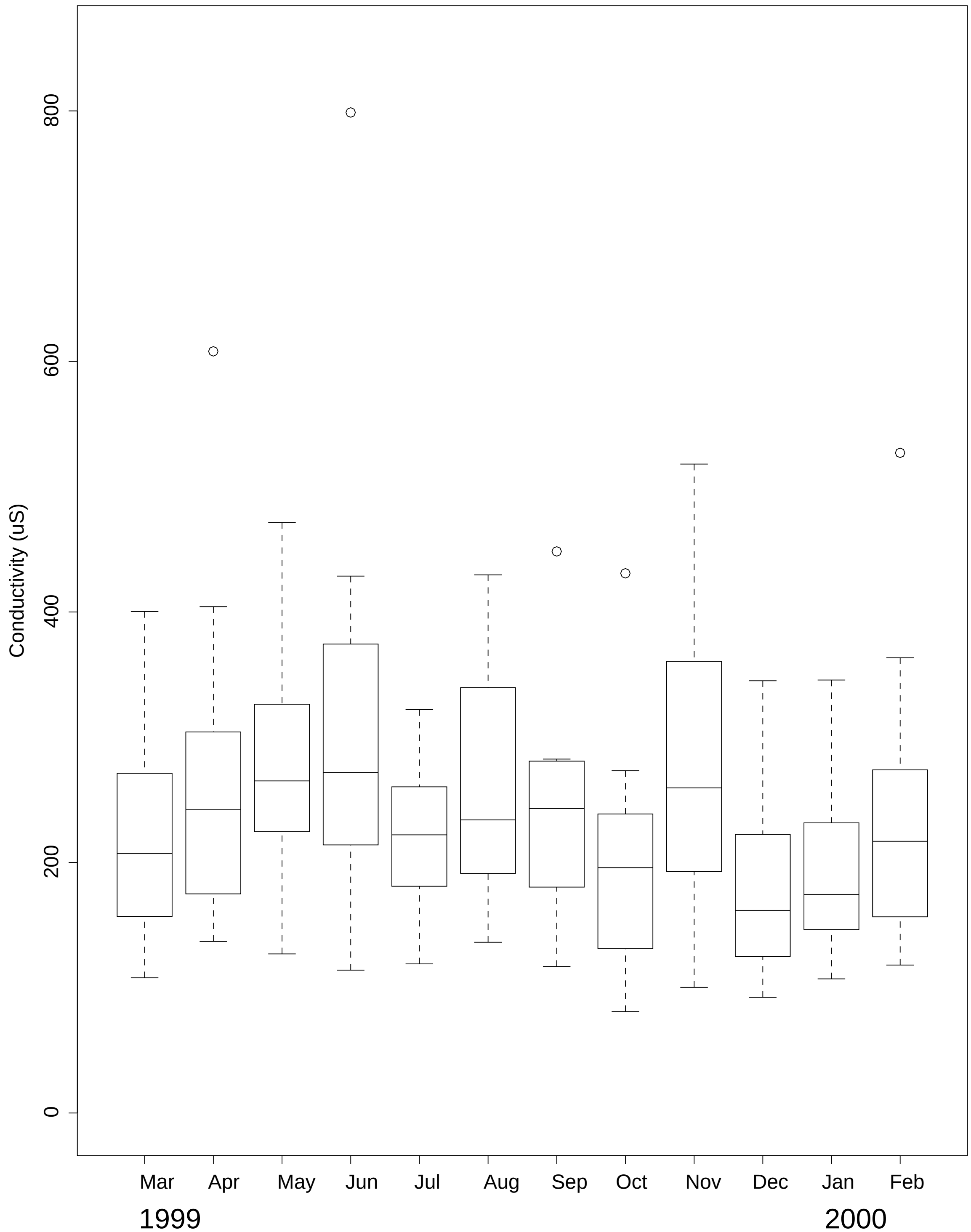

Figure 6: Boxplot of conductivity at freshwater sites plotted by month. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq 1.5 \times$ interquartile range.

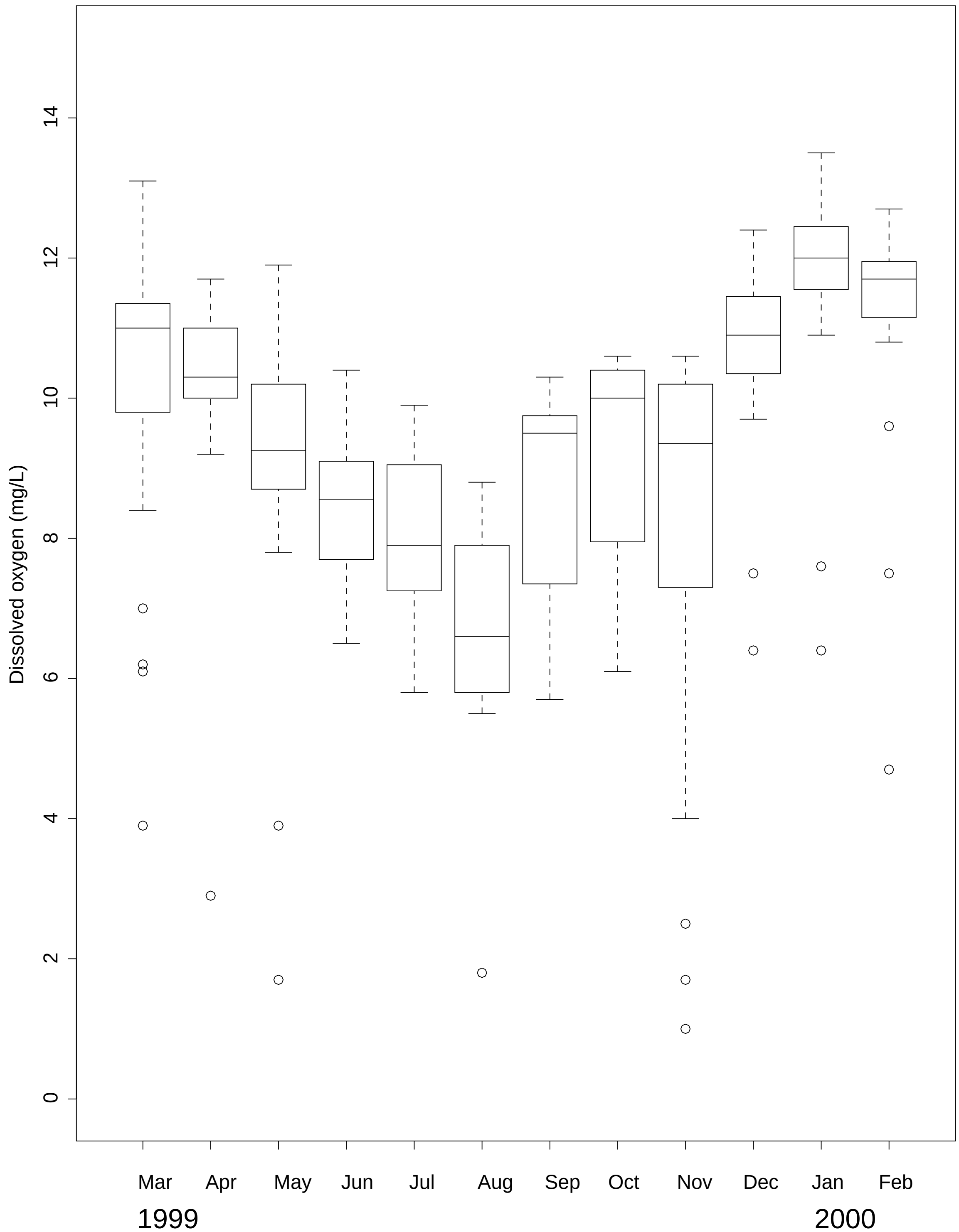

Figure 7: Boxplot of dissolved oxygen at freshwater sites plotted by month. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq 1.5 \times$ interquartile range.

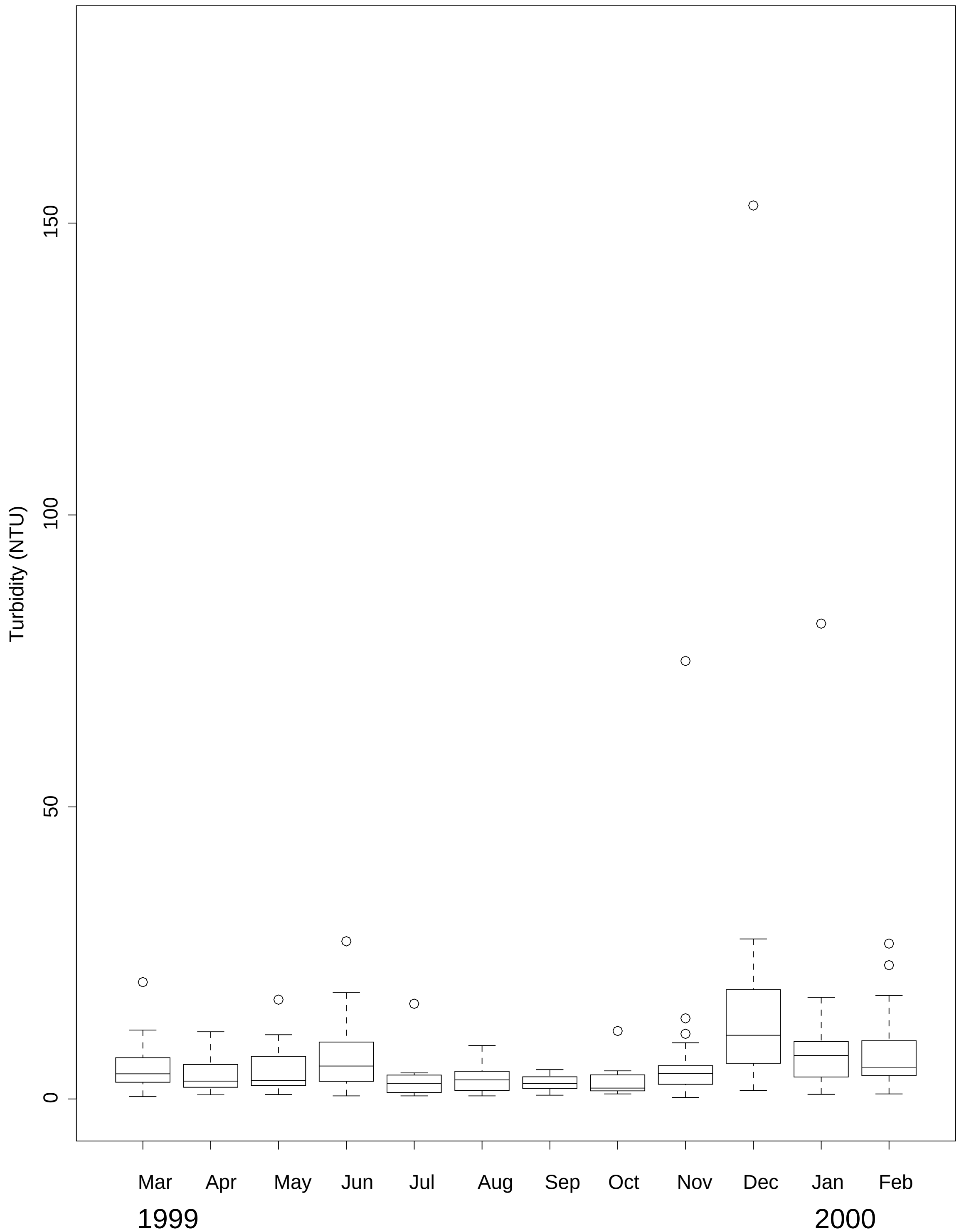

Figure 8: Boxplot of turbidity at freshwater sites plotted by month. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq 1.5 \times$ interquartile range.

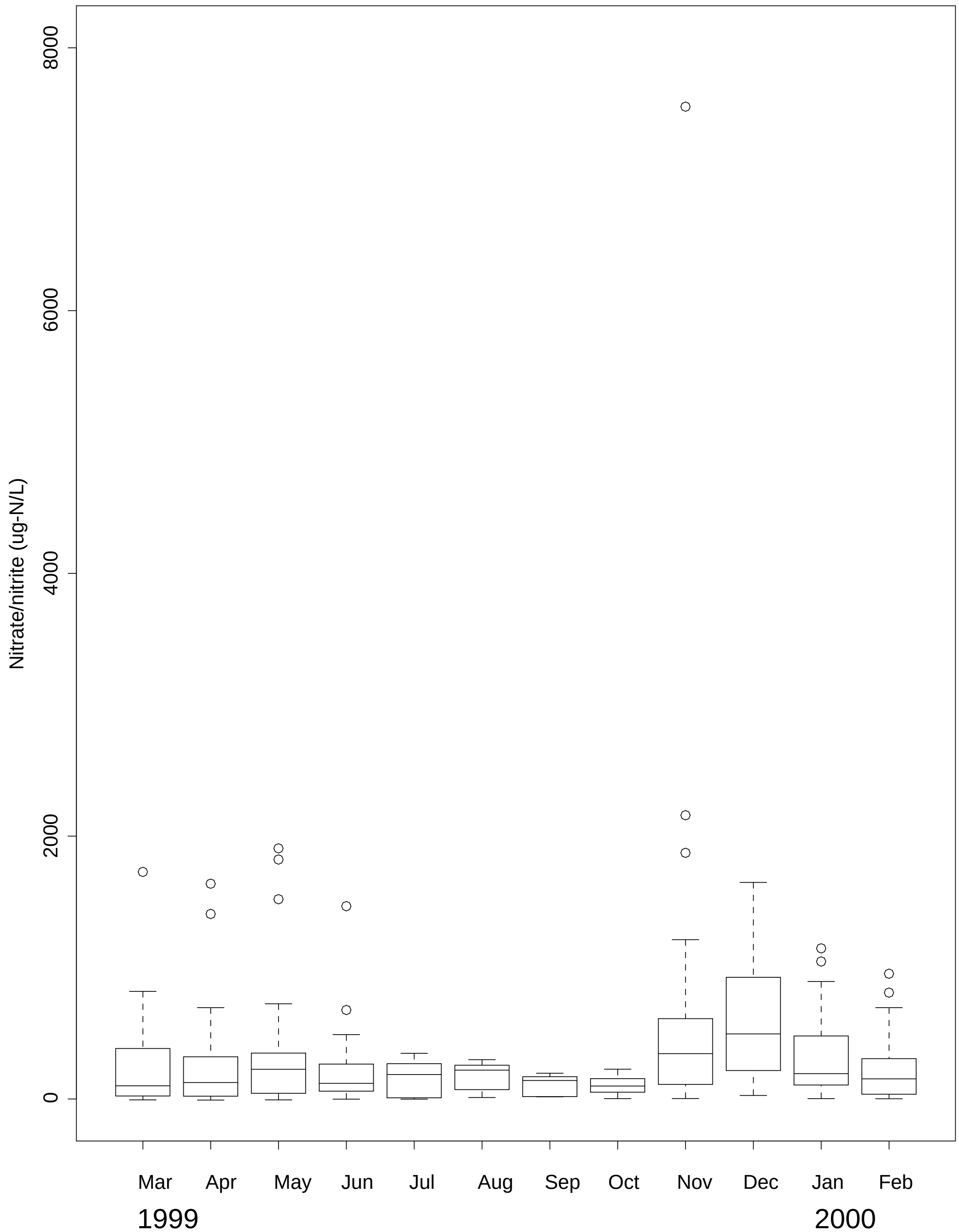

Figure 9: Boxplot of nitrate/nitrite concentrations at freshwater sites plotted by month. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq 1.5 \times$ interquartile range.

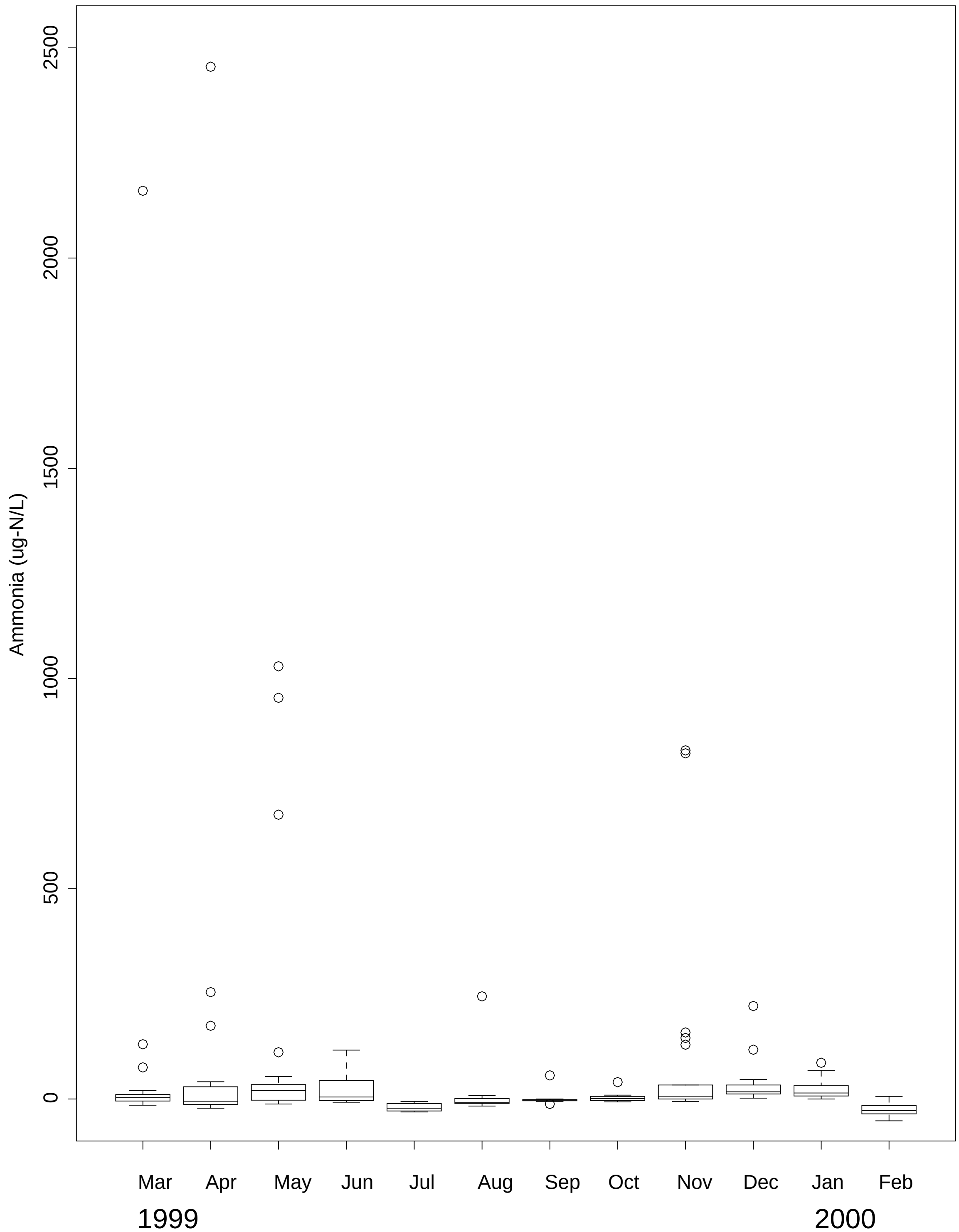

Figure 10: Boxplot of ammonia concentrations at freshwater sites plotted by month. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq 1.5 \times$ interquartile range.

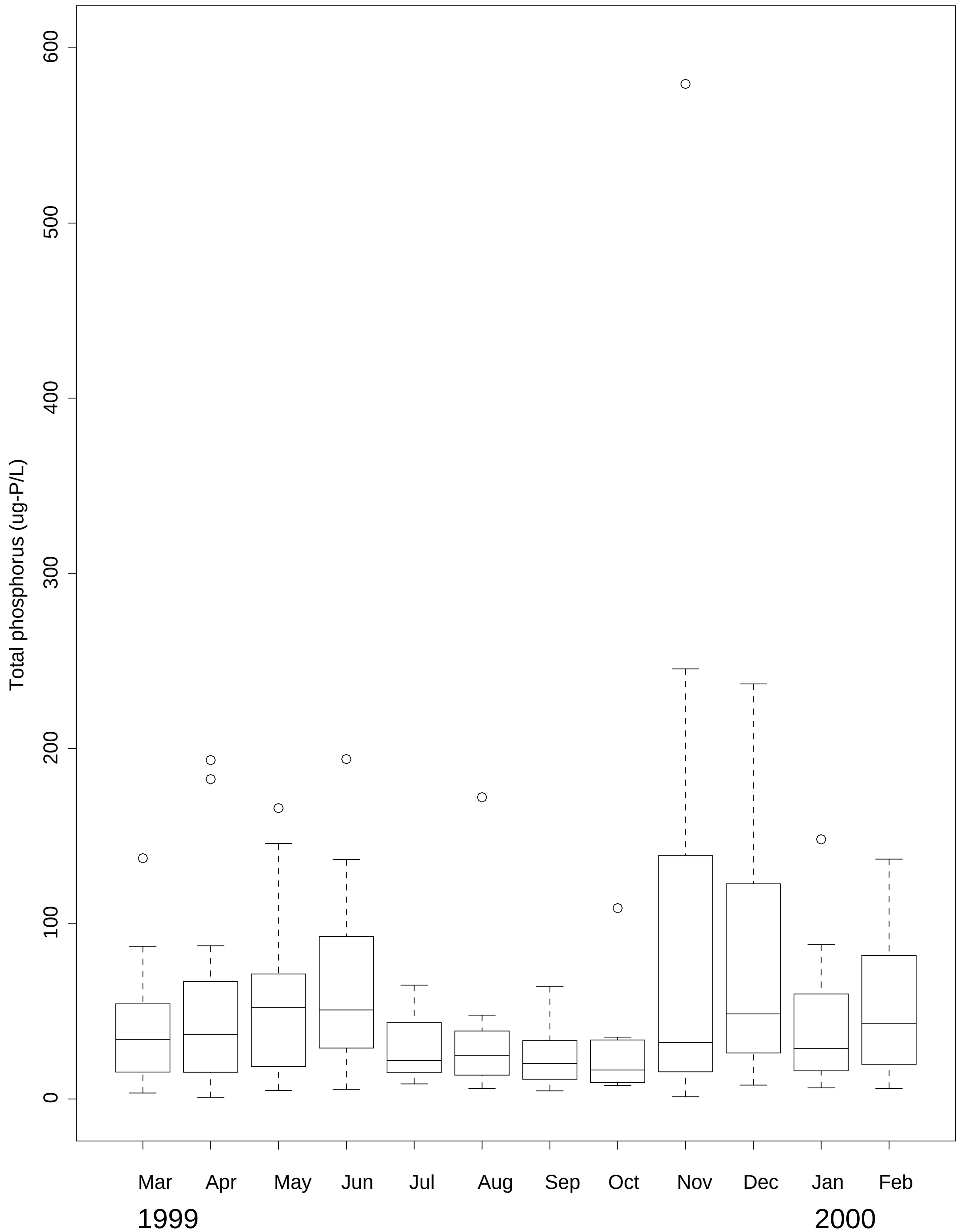

Figure 11: Boxplot of total phosphorus concentrations at freshwater sites plotted by month. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq 1.5 \times$ interquartile range.

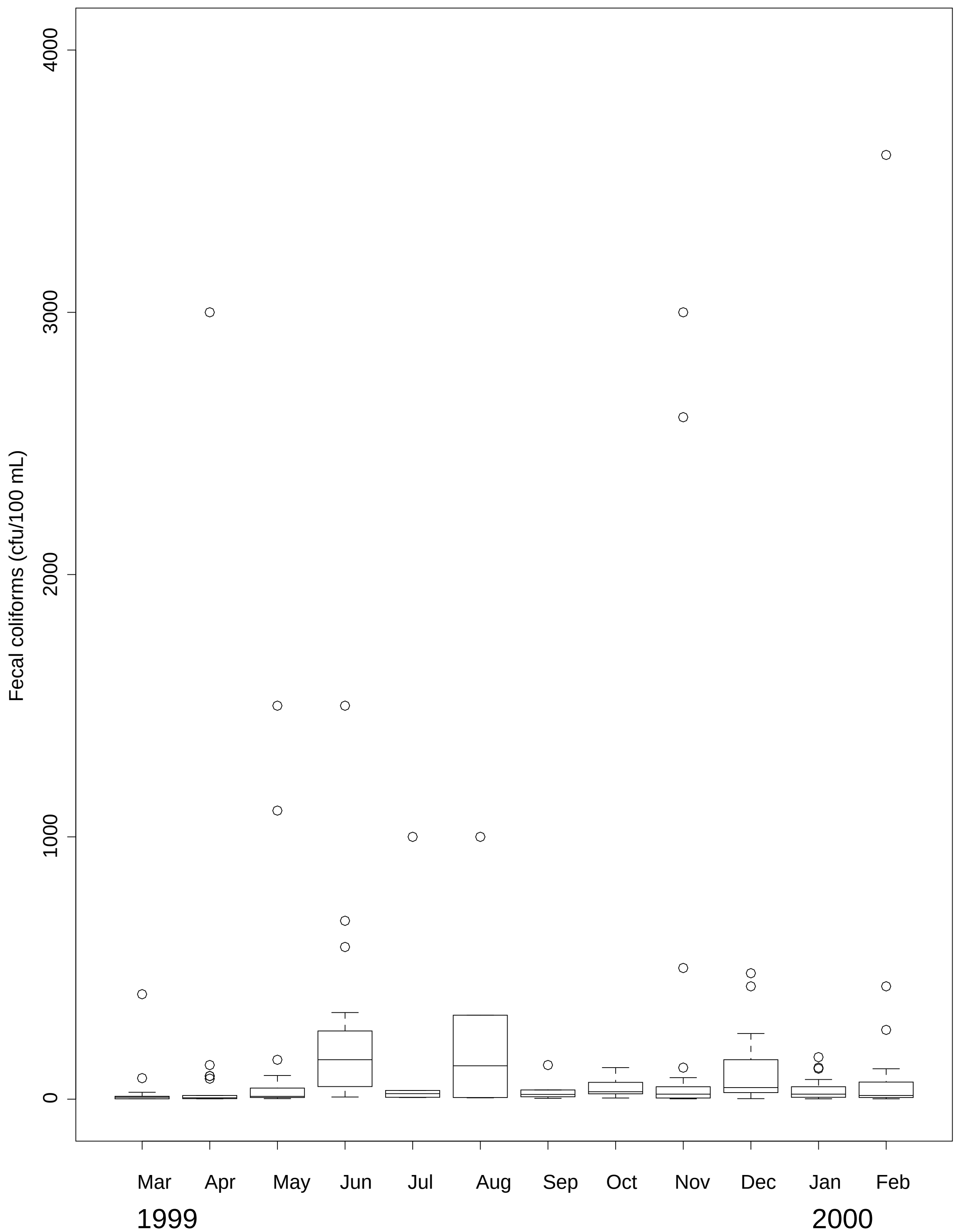

Figure 12: Boxplot of fecal coliform counts at freshwater sites plotted by month. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq 1.5 \times$ interquartile range.

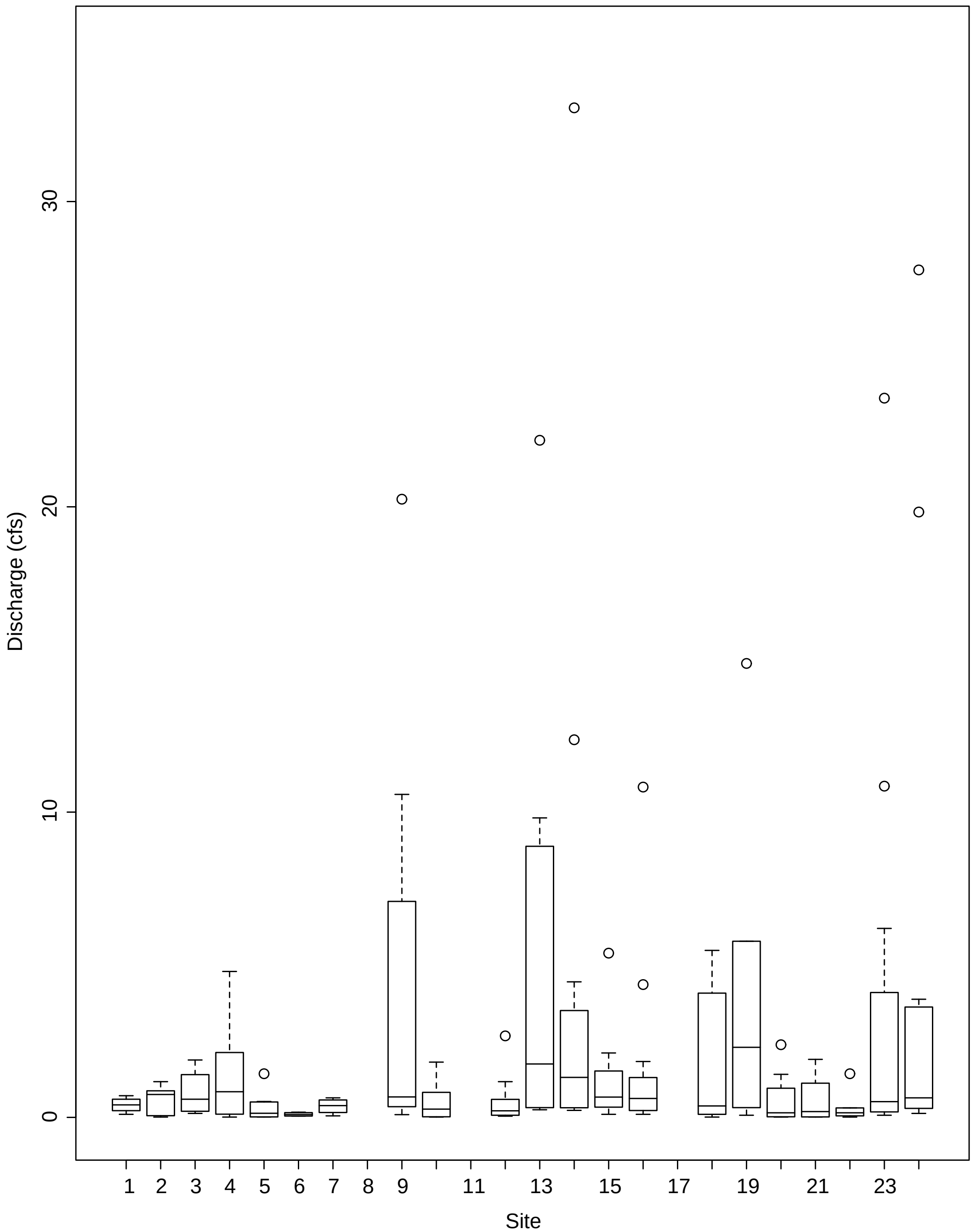

Figure 13: Boxplot of discharge rates at freshwater sites plotted by site. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq 1.5 \times$ interquartile range.

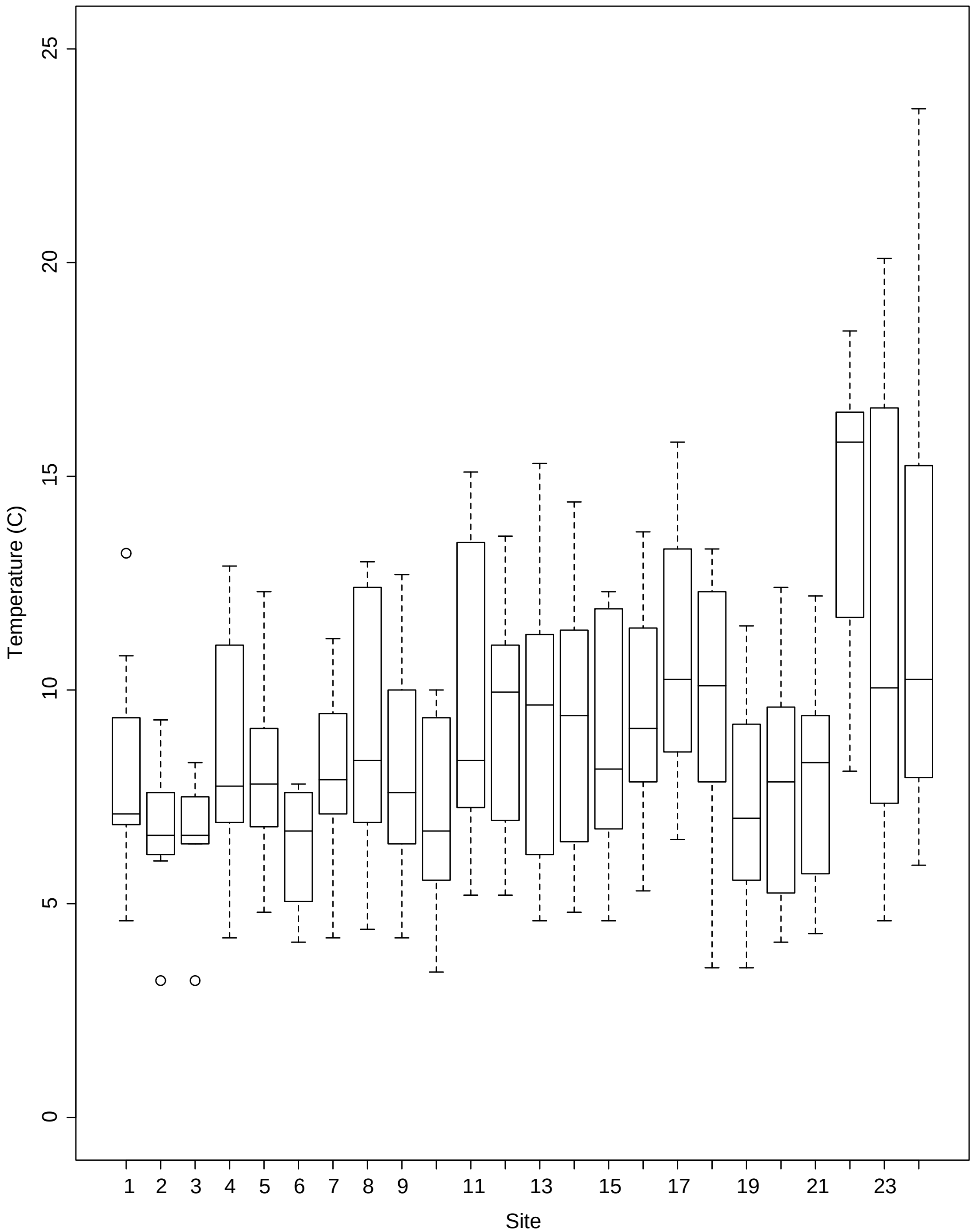

Figure 14: Boxplot of water temperature at freshwater sites plotted by site. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq 1.5 \times$ interquartile range.

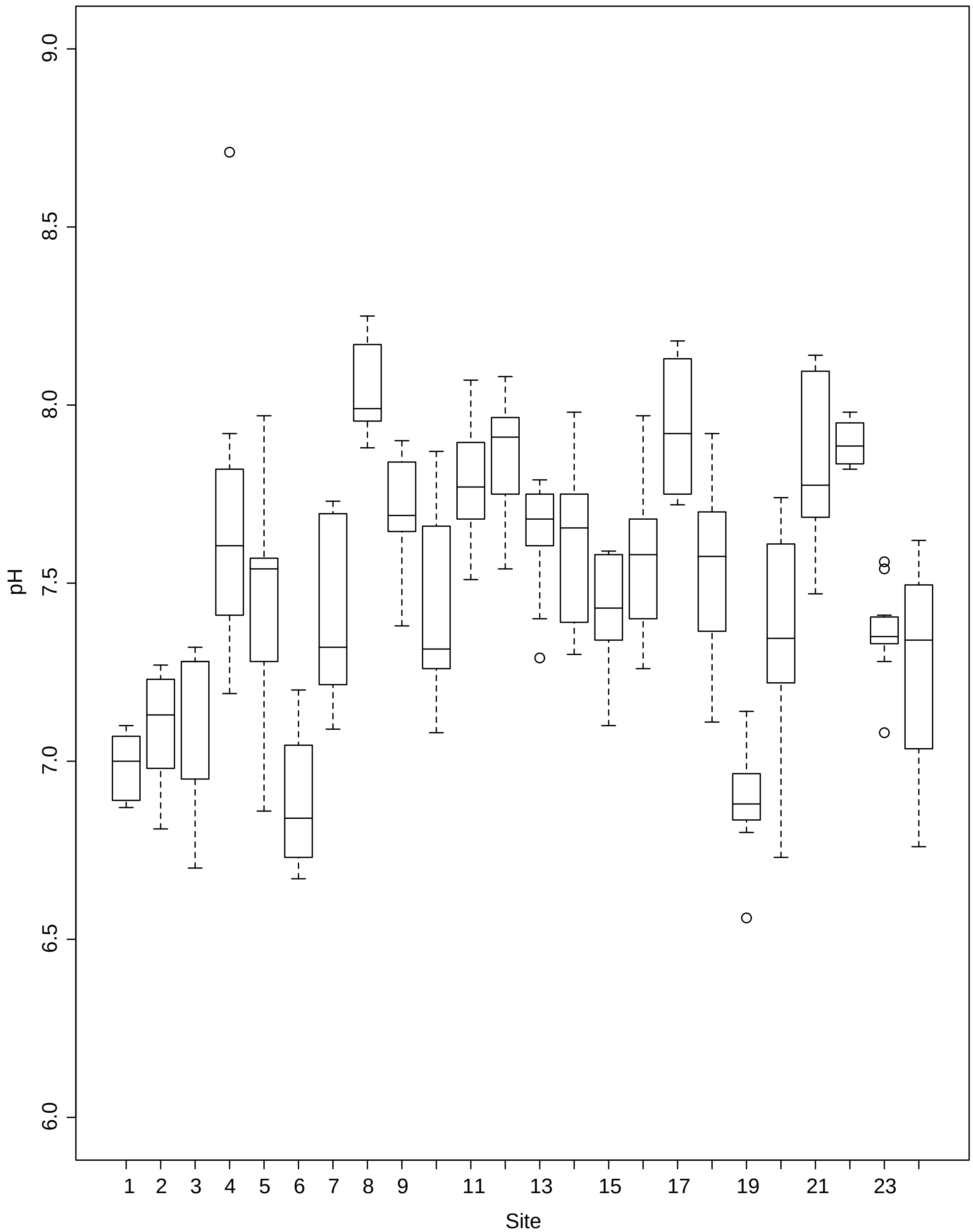

Figure 15: Boxplot of pH at freshwater sites plotted by site. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq 1.5 \times$ interquartile range.

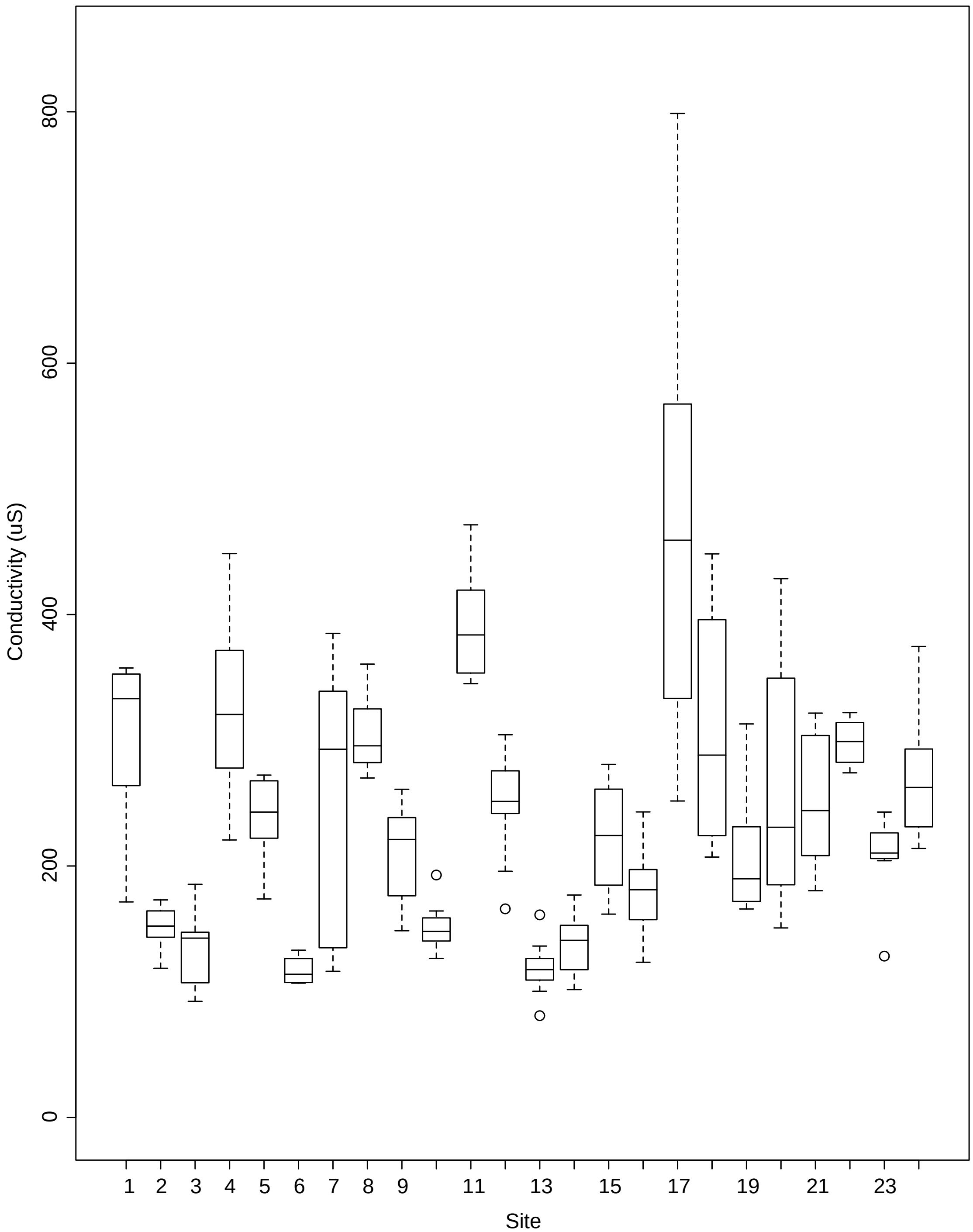

Figure 16: Boxplot of conductivity at freshwater sites plotted by site. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq 1.5 \times$ interquartile range.

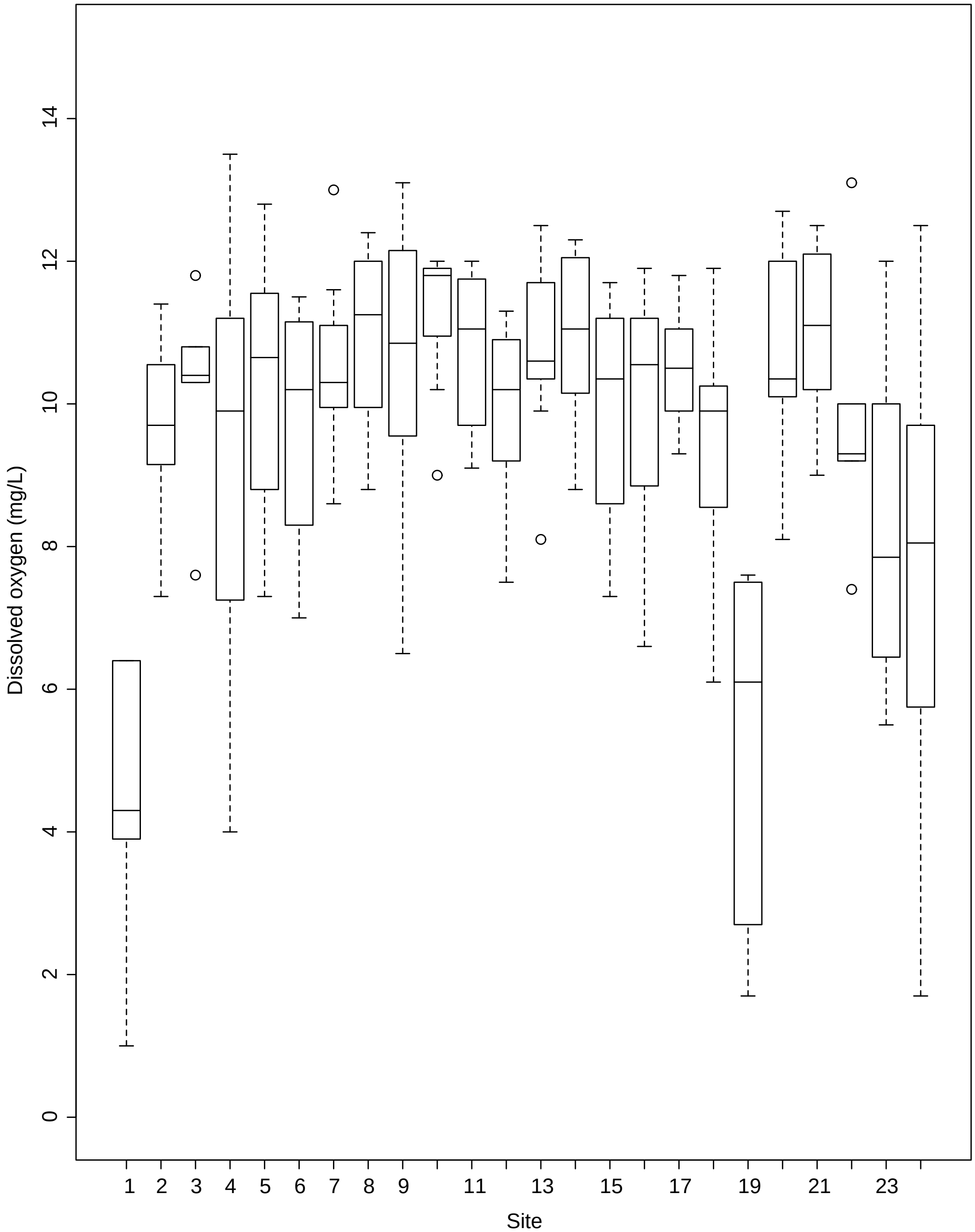

Figure 17: Boxplot of dissolved oxygen at freshwater sites plotted by site. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq 1.5 \times$ interquartile range.

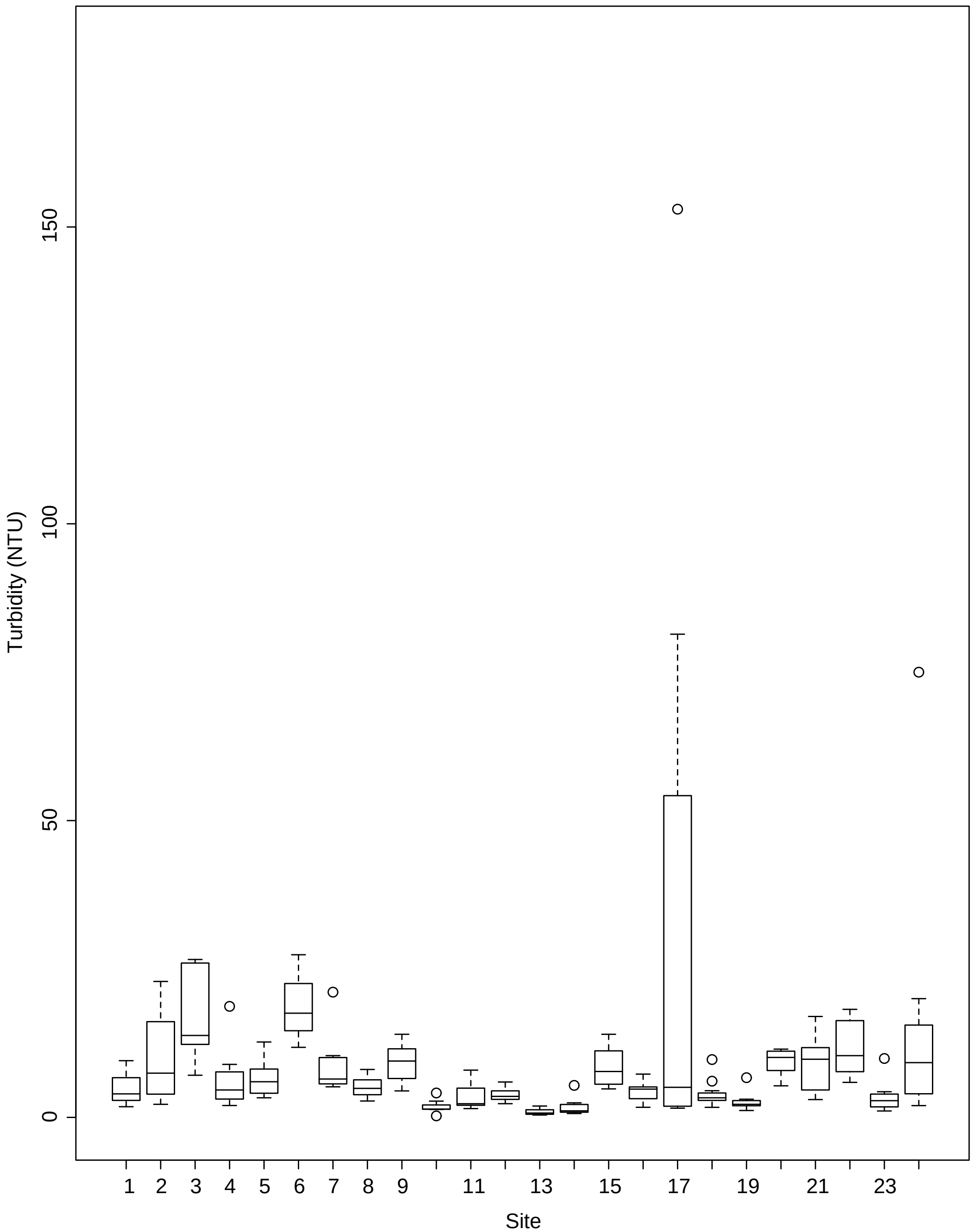

Figure 18: Boxplot of turbidity at freshwater sites plotted by site. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq 1.5 \times$ interquartile range.

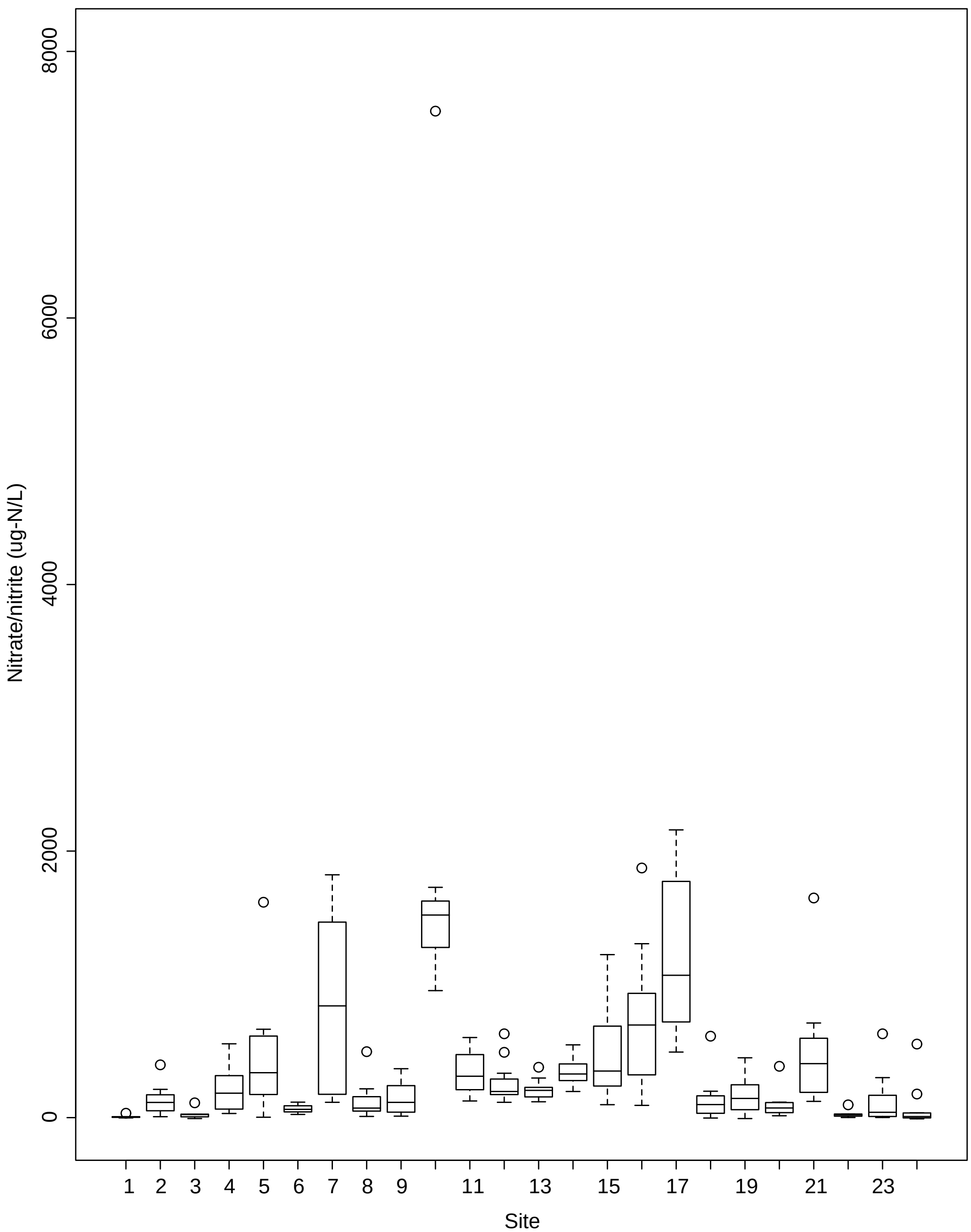

Figure 19: Boxplot of nitrate/nitrite concentrations at freshwater sites plotted by site. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq 1.5 \times$ interquartile range.

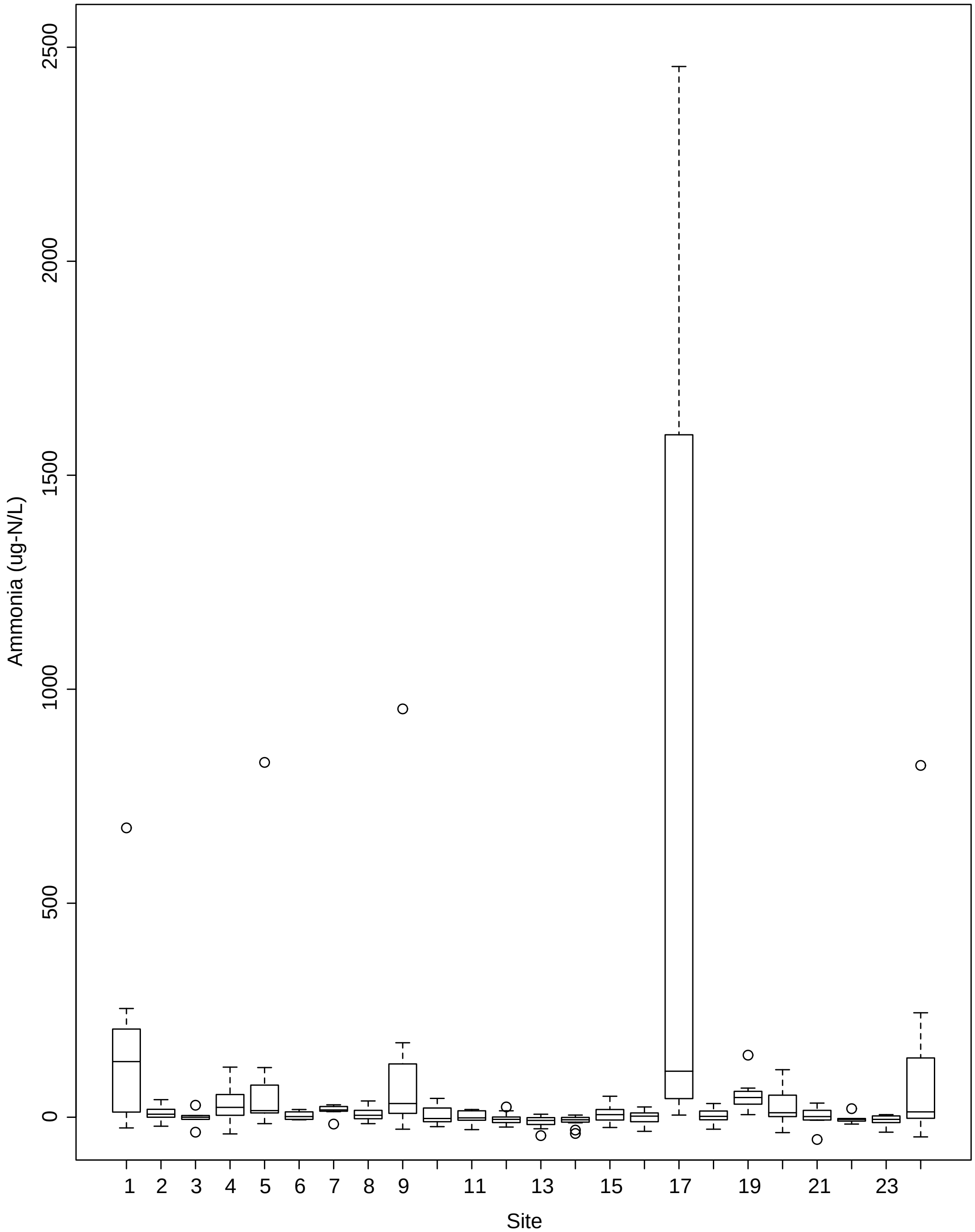

Figure 20: Boxplot of ammonia concentrations at freshwater sites plotted by site. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq 1.5 \times$ interquartile range.

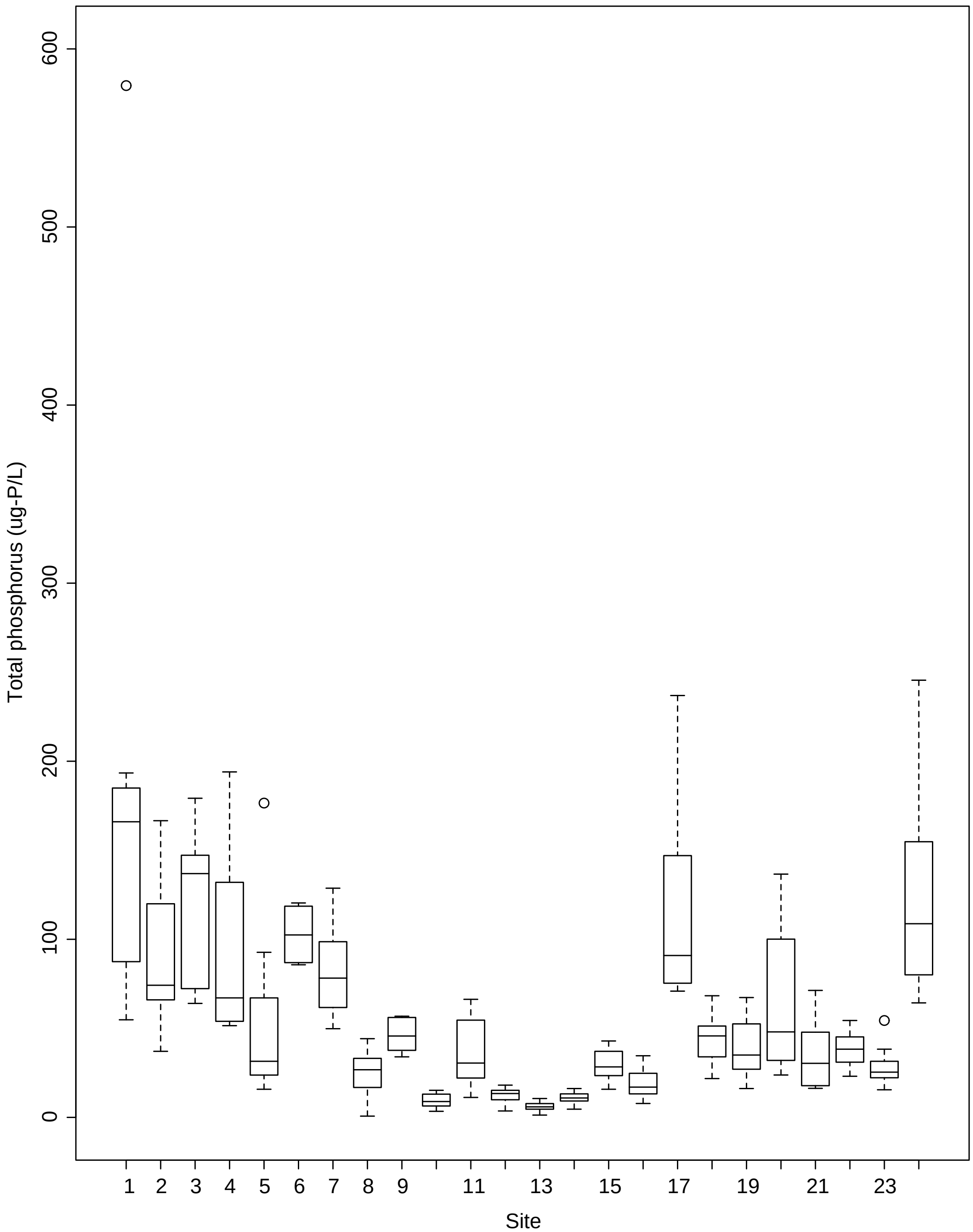

Figure 21: Boxplot of total phosphorus concentrations at freshwater sites plotted by site. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq 1.5 \times$ interquartile range.

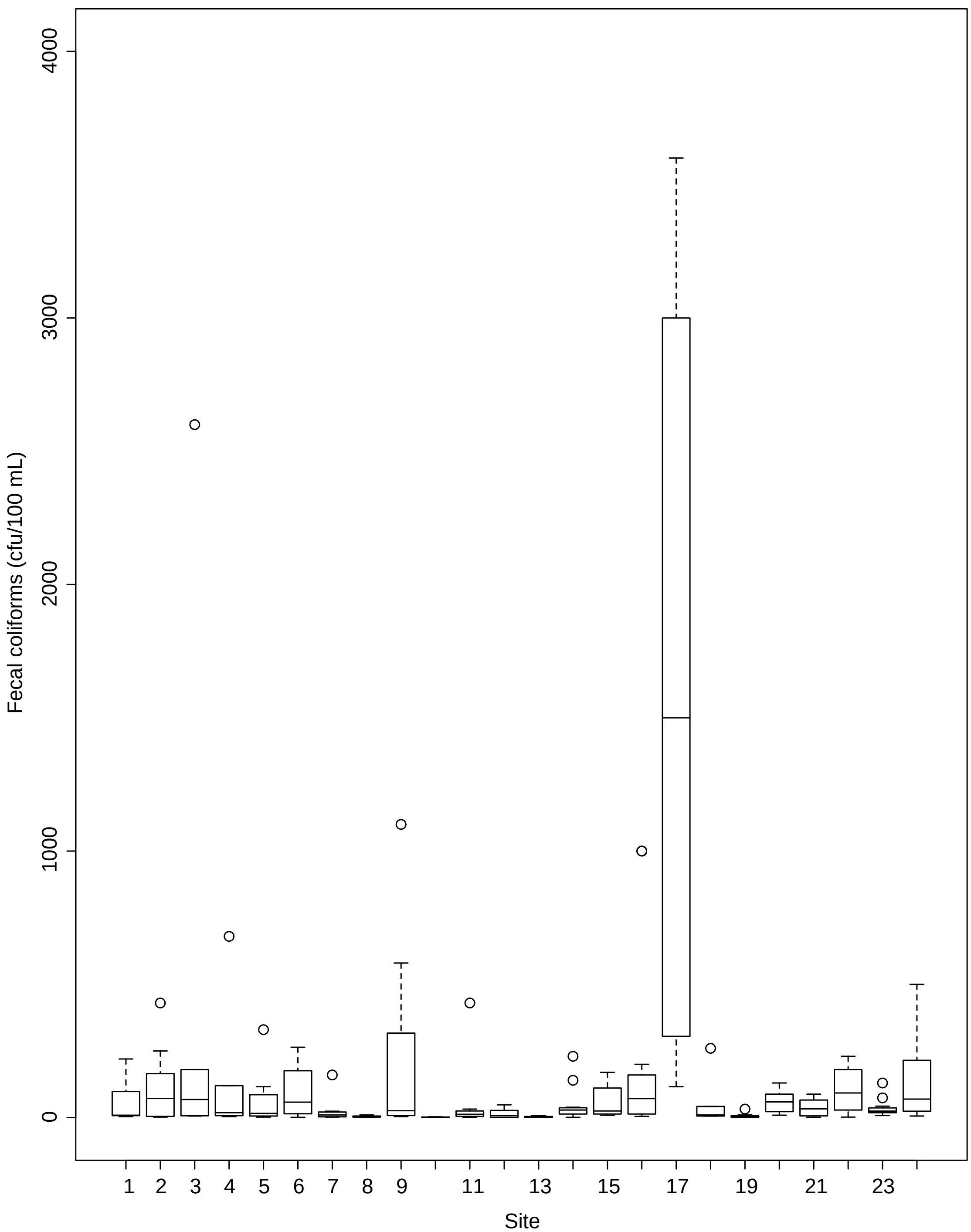

Figure 22: Boxplot of fecal coliform counts at freshwater sites plotted by site. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq 1.5 \times$ interquartile range.

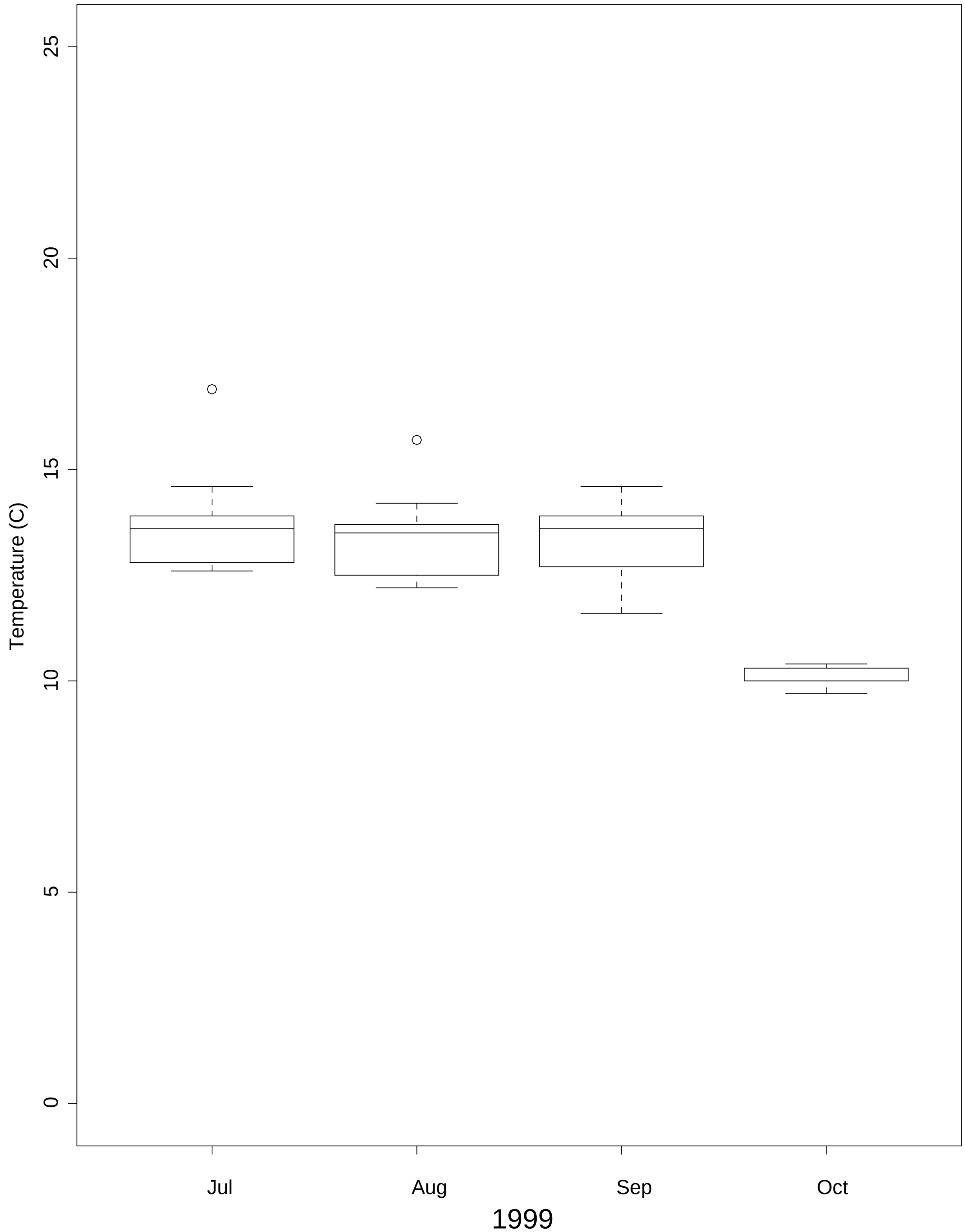

Figure 23: Boxplot of water temperature at marine sites plotted by month. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq 1.5 \times$ interquartile range.

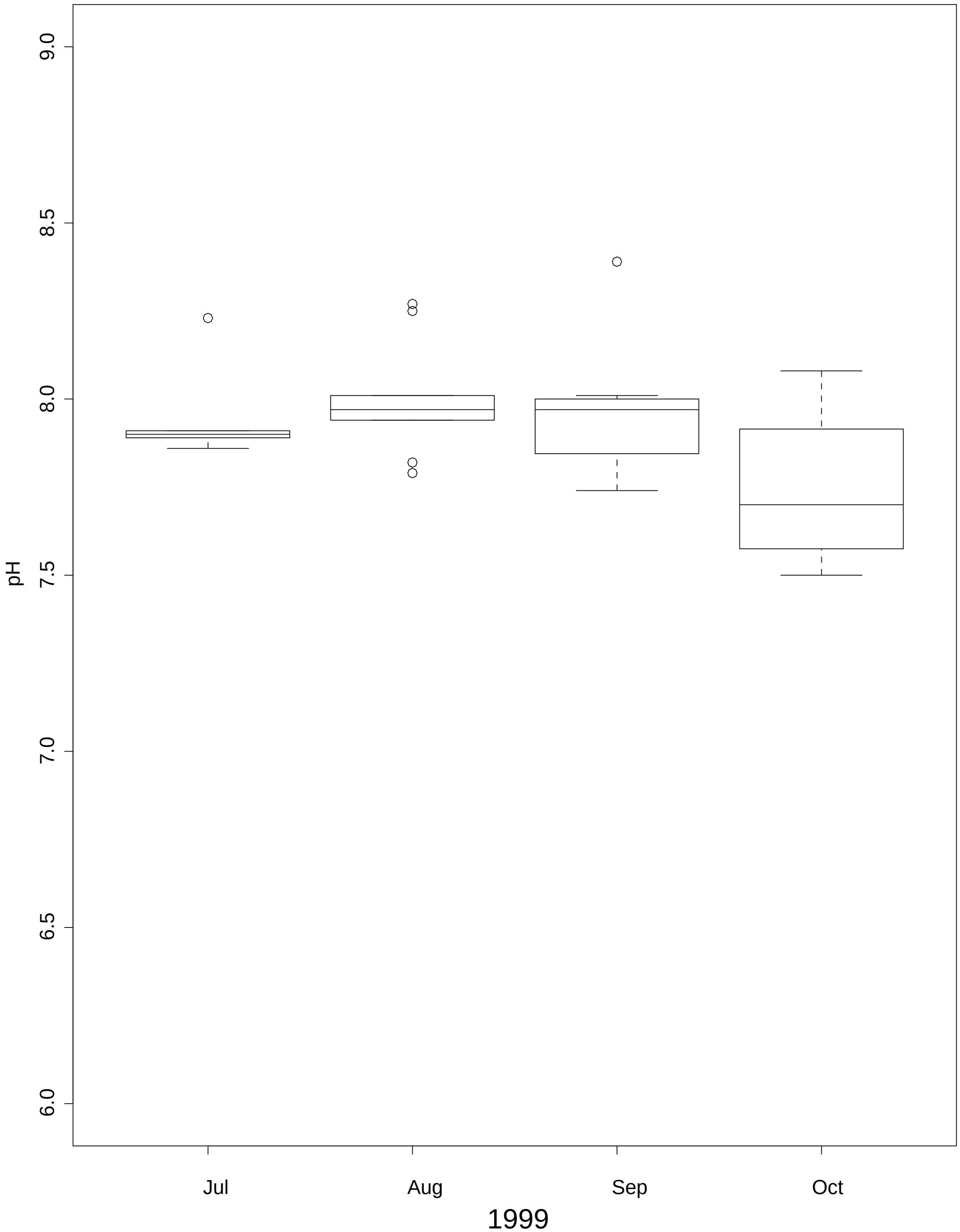

Figure 24: Boxplot of pH at marine sites plotted by month. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq 1.5 \times$ interquartile range.

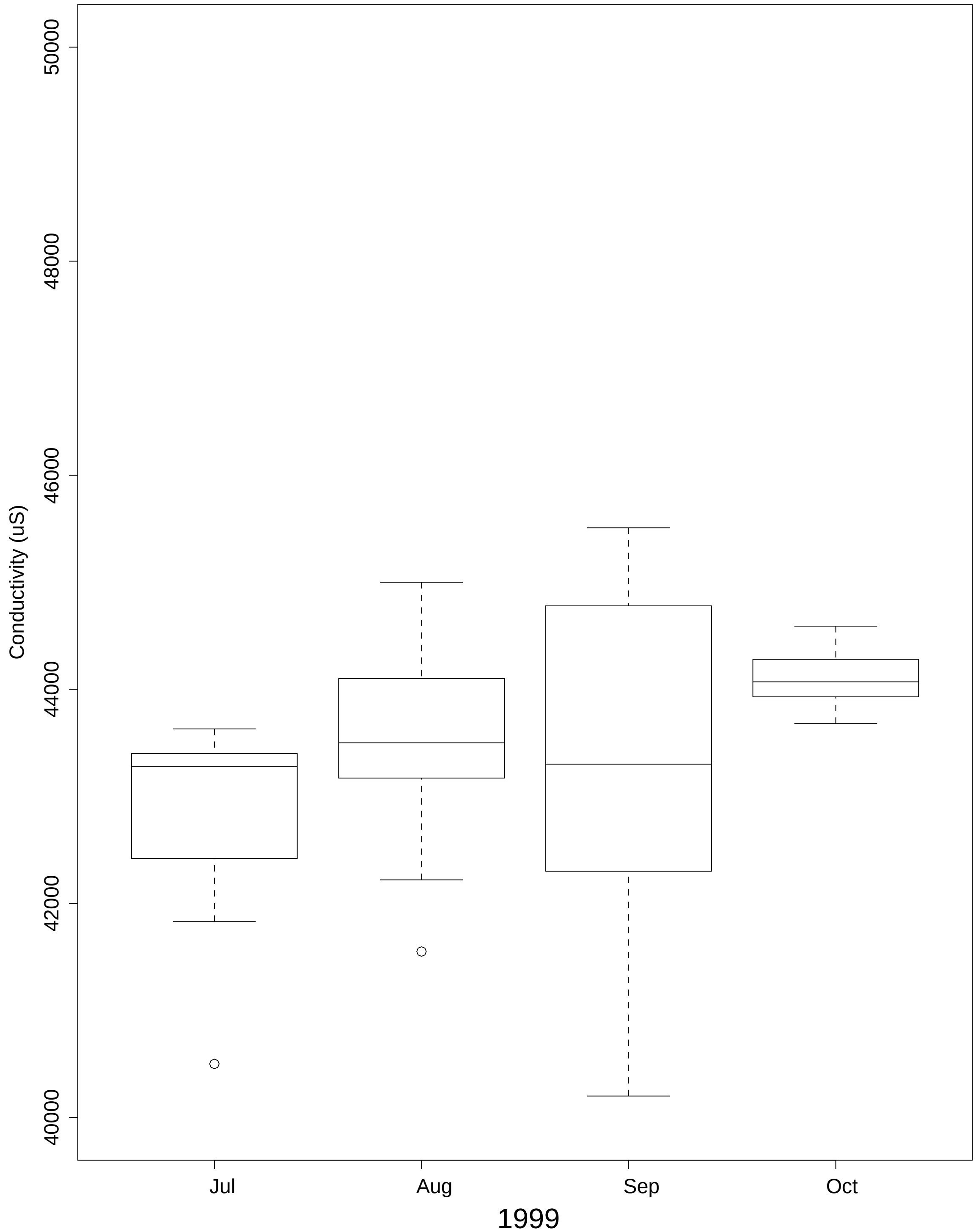

Figure 25: Boxplot of conductivity at marine sites plotted by month. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq 1.5 \times$ interquartile range.

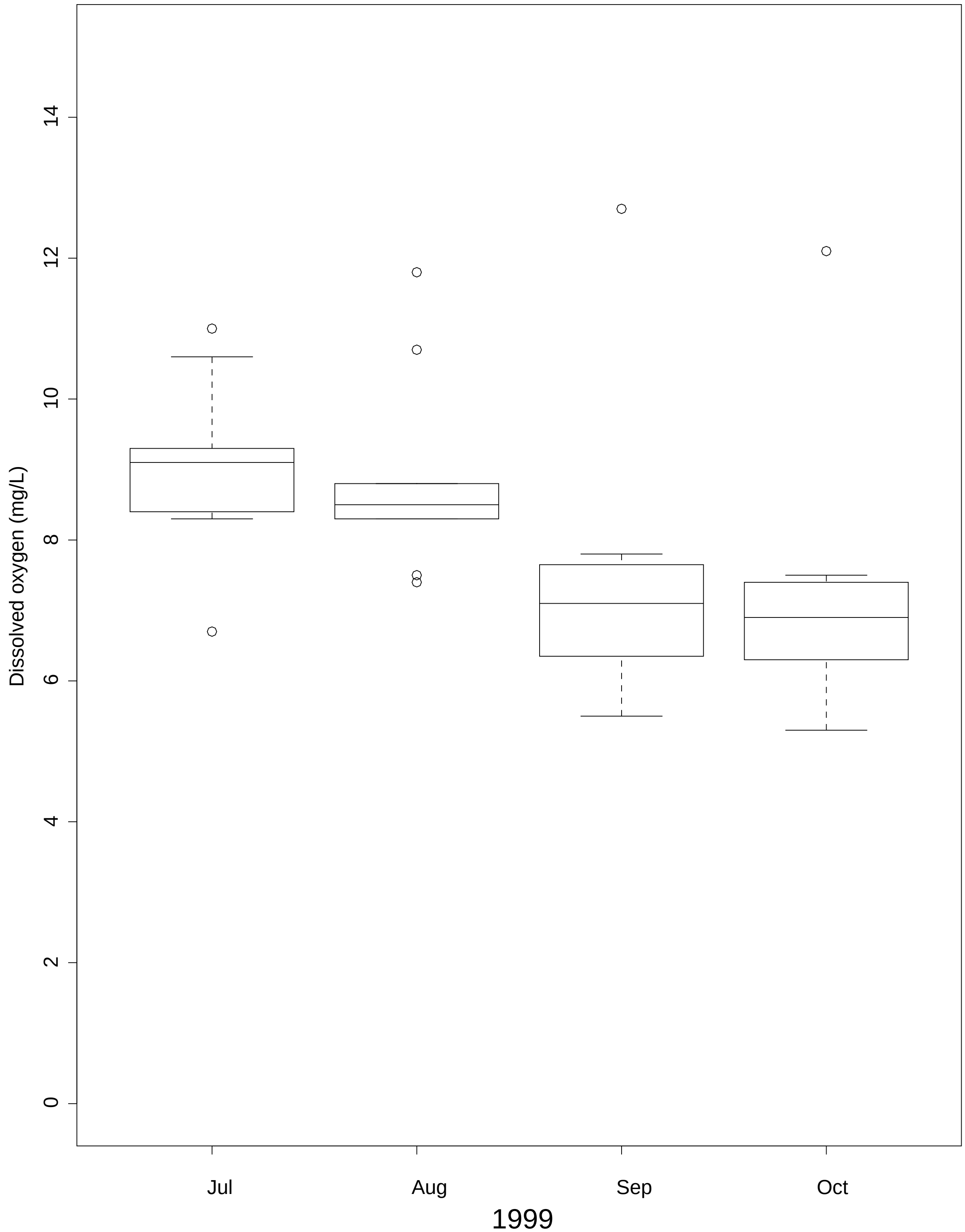

Figure 26: Boxplot of dissolved oxygen at marine sites plotted by month. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq 1.5 \times$ interquartile range.

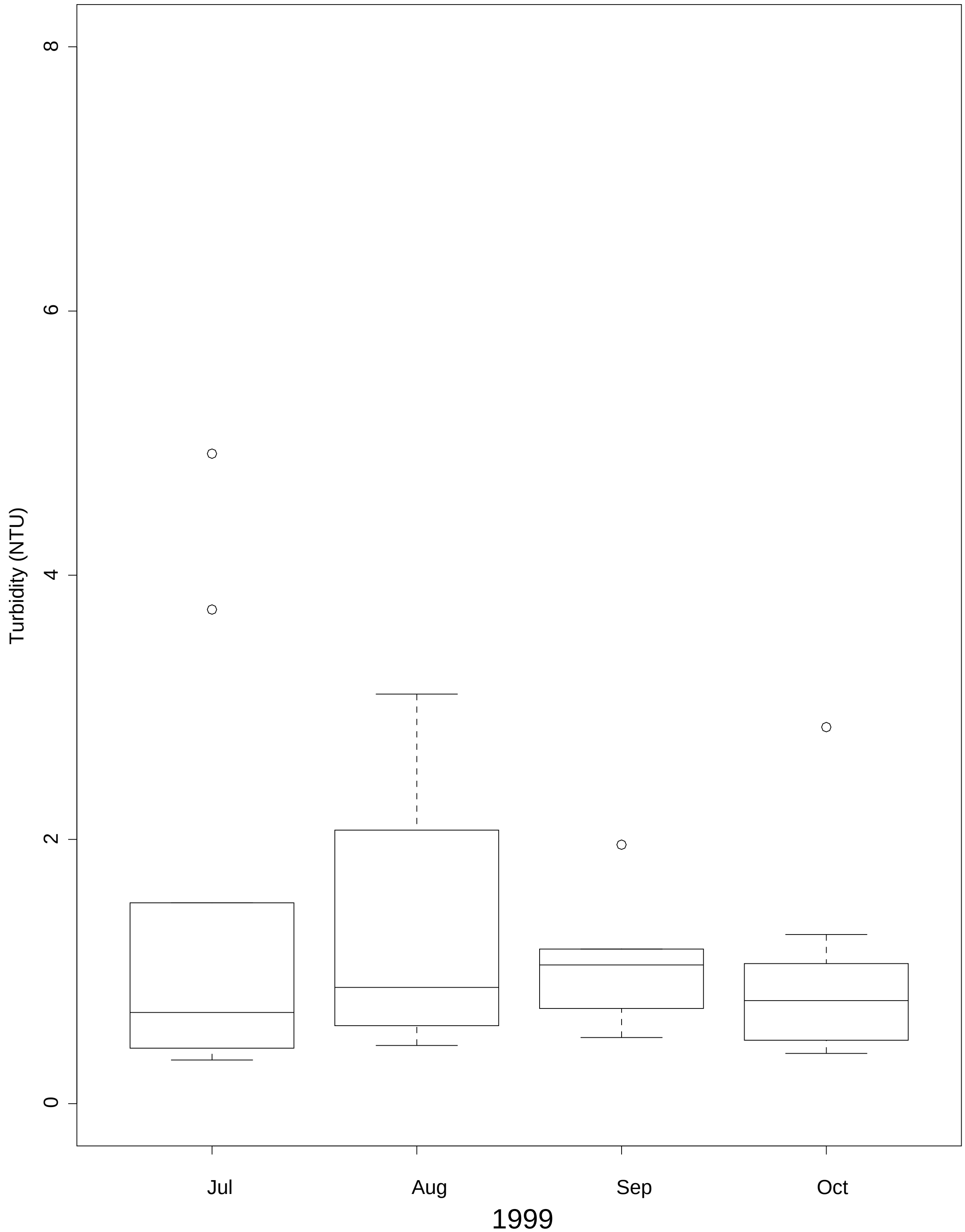

Figure 27: Boxplot of turbidity at marine sites plotted by month. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq$ $1.5 \times$ interquartile range.

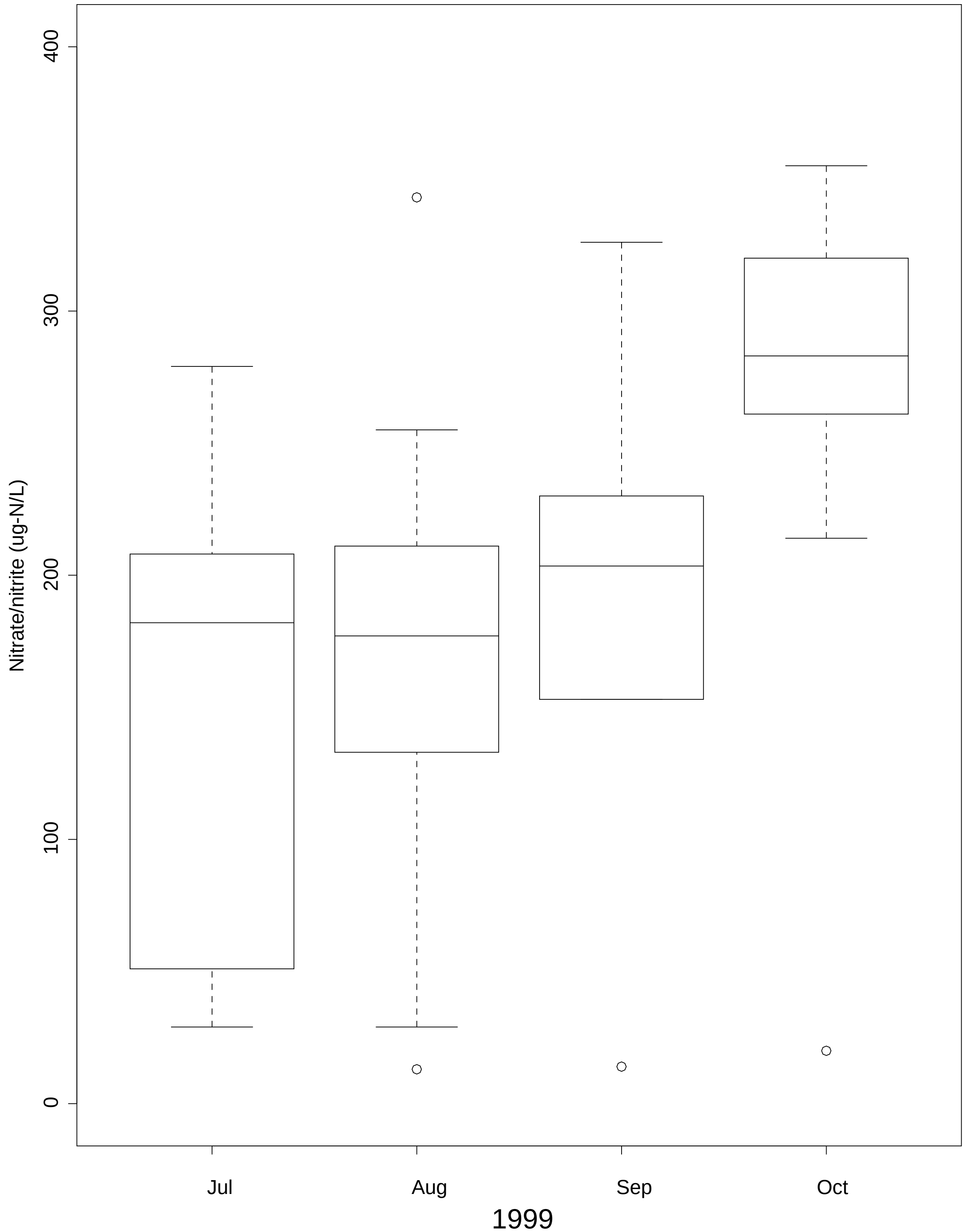

Figure 28: Boxplot of nitrate/nitrite concentrations at marine sites plotted by month. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq 1.5 \times$ interquartile range.

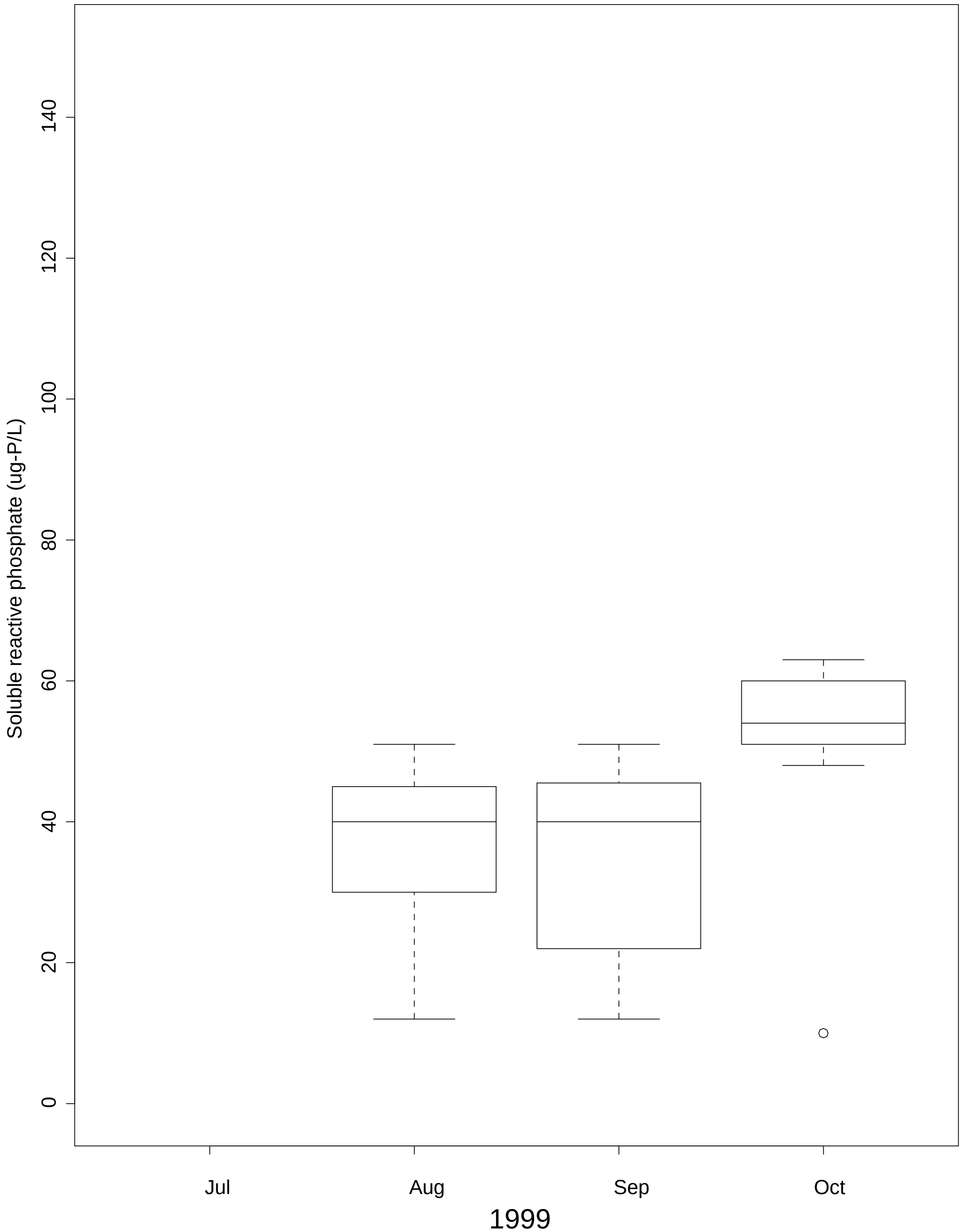

Figure 29: Boxplot of soluble reactive phosphate concentrations at marine sites plotted by month. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq 1.5 \times$ interquartile range.

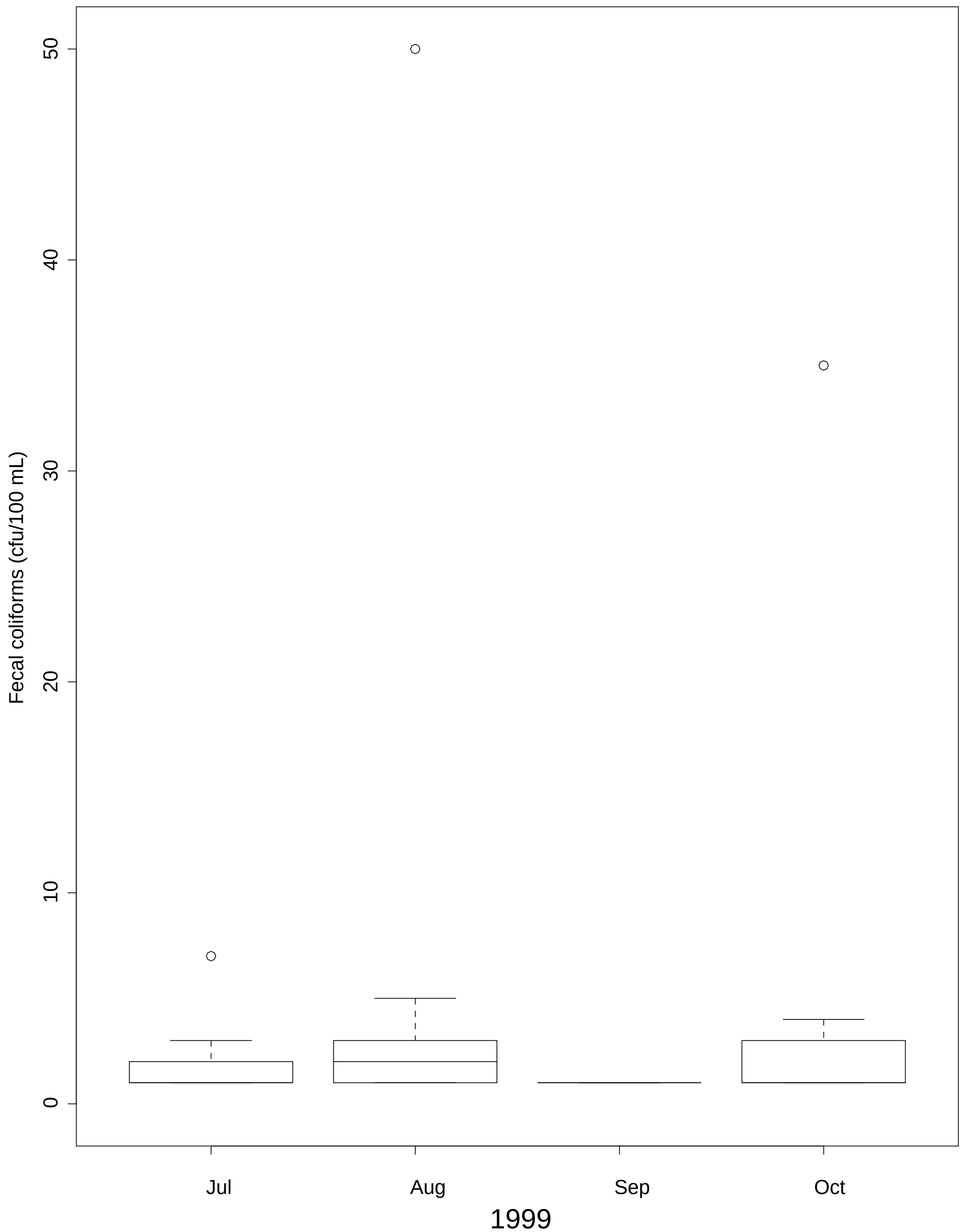

Figure 30: Boxplot of fecal coliform counts at marine sites plotted by month. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq 1.5 \times$ interquartile range.

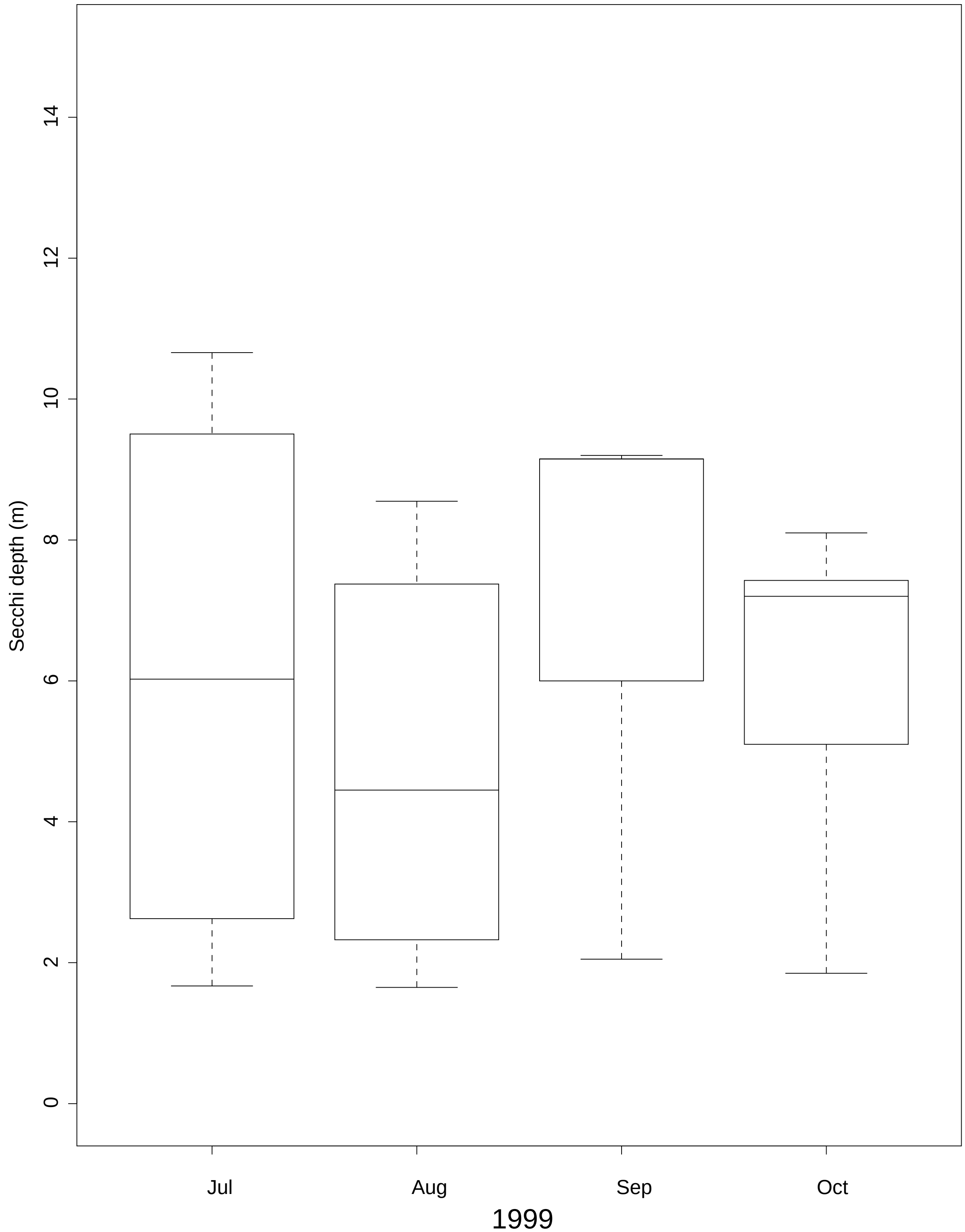

Figure 31: Boxplot of Secchi depths at marine sites plotted by month. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq 1.5 \times$ interquartile range.

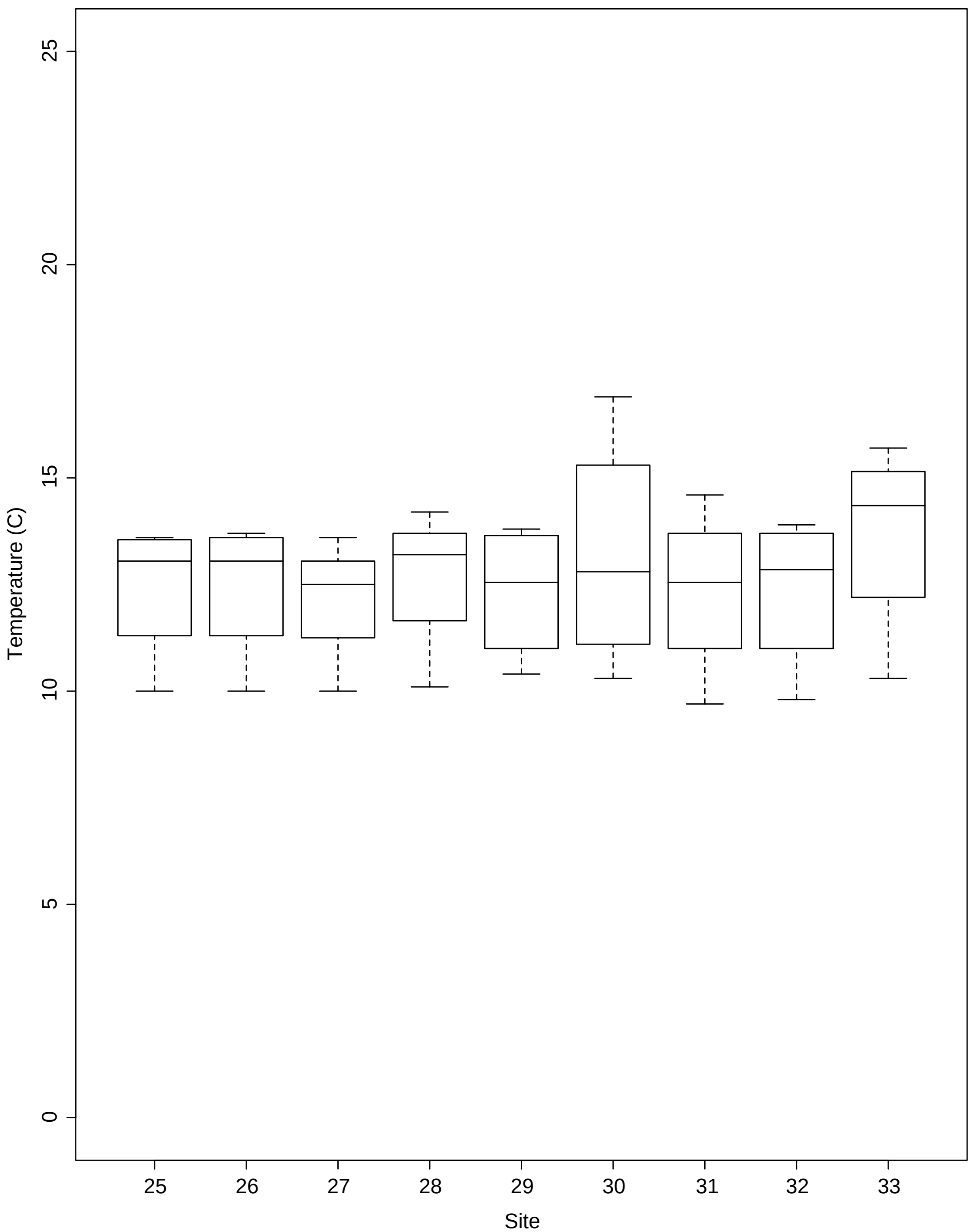

Figure 32: Boxplot of water temperature at marine sites plotted by site. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq 1.5 \times$ interquartile range.

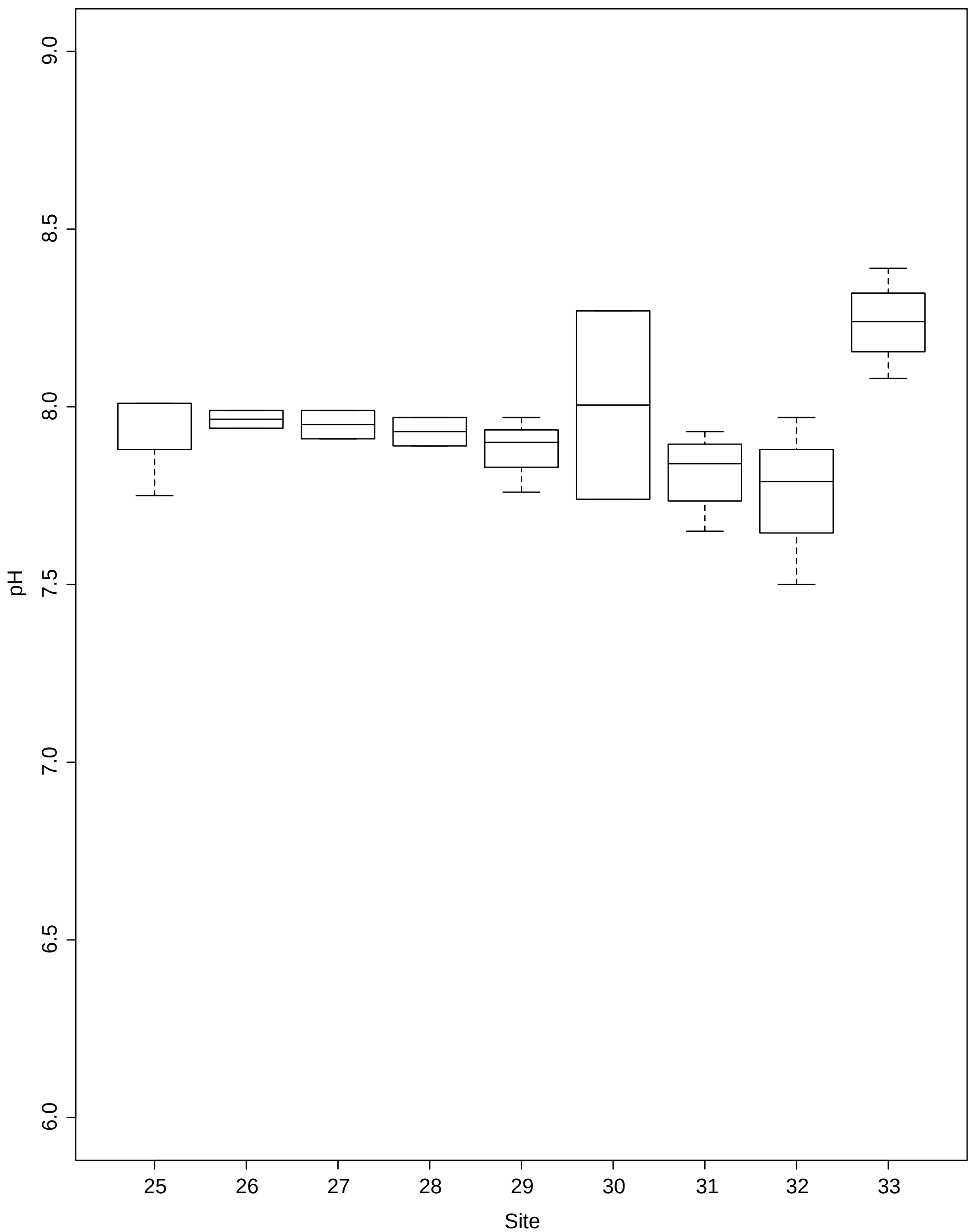

Figure 33: Boxplot of pH at marine sites plotted by site. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq 1.5 \times$ interquartile range.

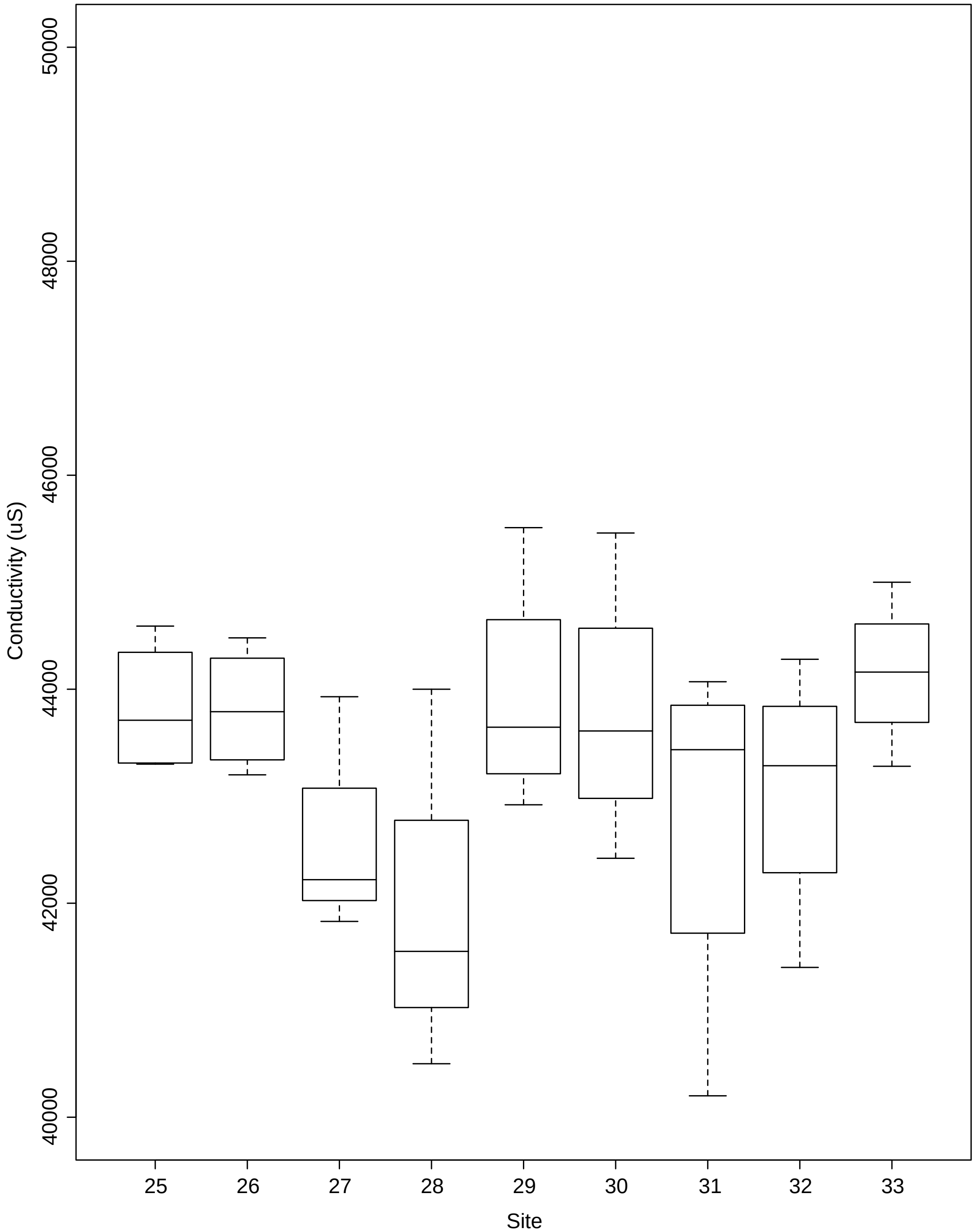

Figure 34: Boxplot of conductivity at marine sites plotted by site. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq 1.5 \times$ interquartile range.

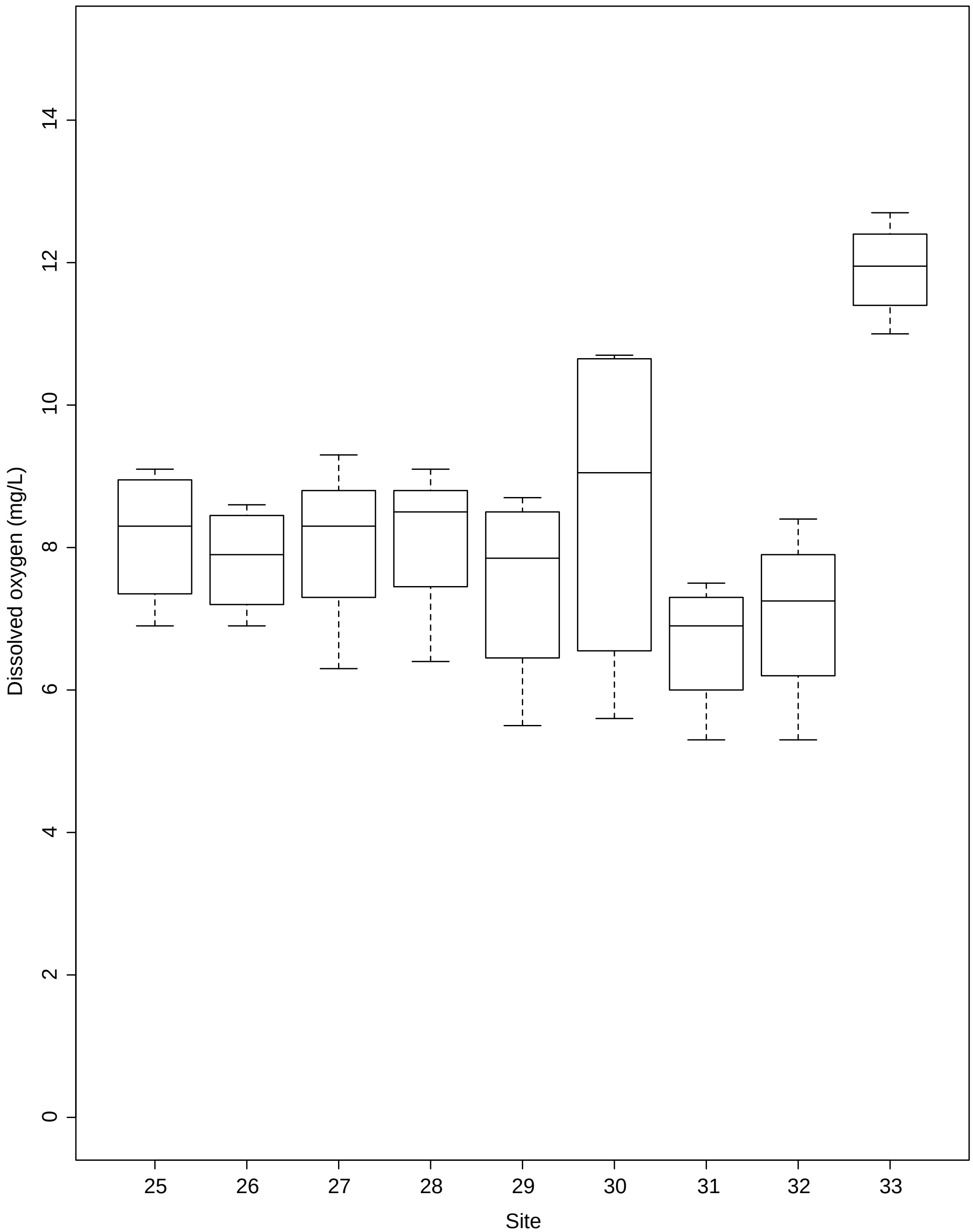

Figure 35: Boxplot of dissolved oxygen at marine sites plotted by site. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq 1.5 \times$ interquartile range.

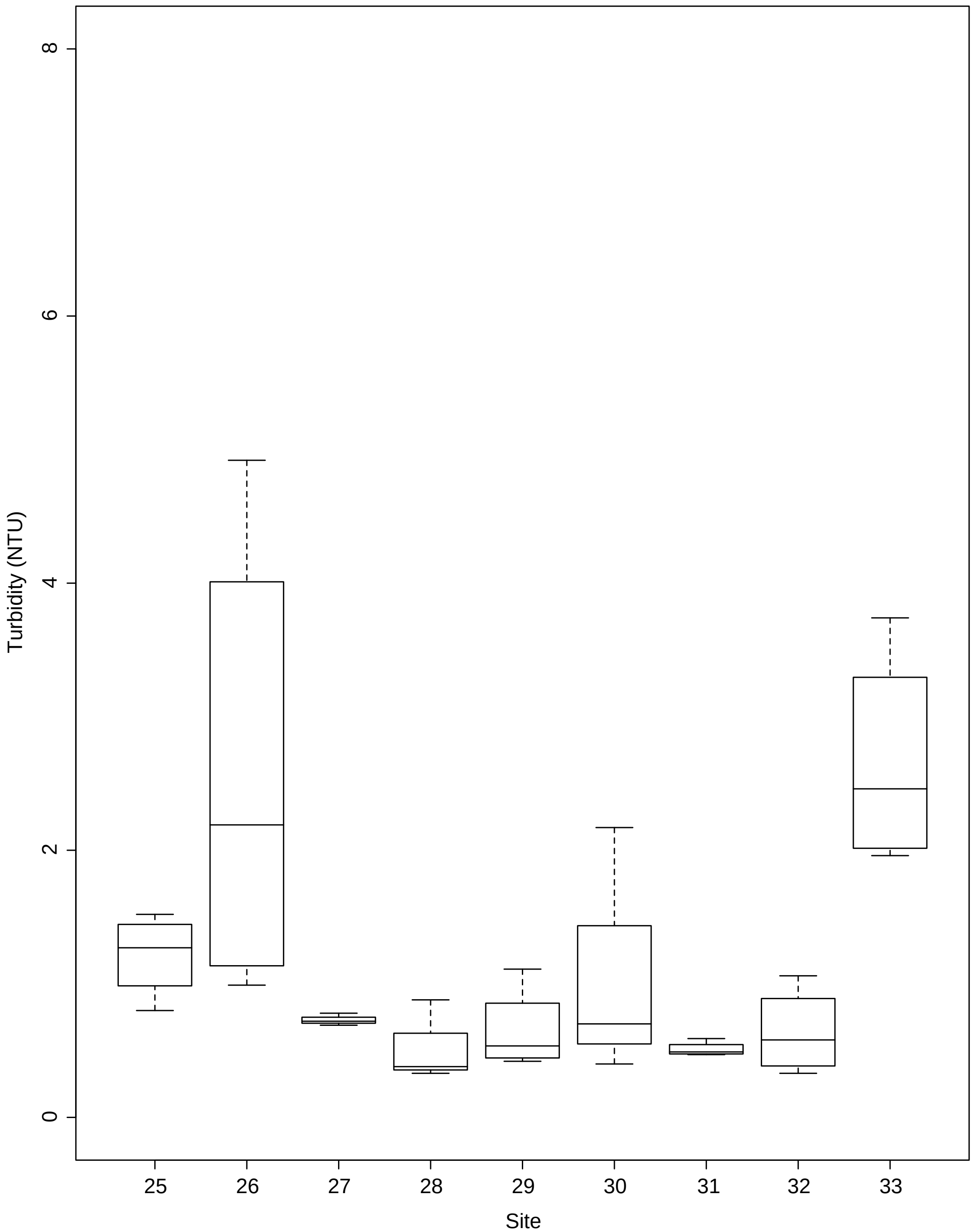

Figure 36: Boxplot of turbidity at marine sites plotted by site. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq$ 1.5 $\times$ interquartile range.

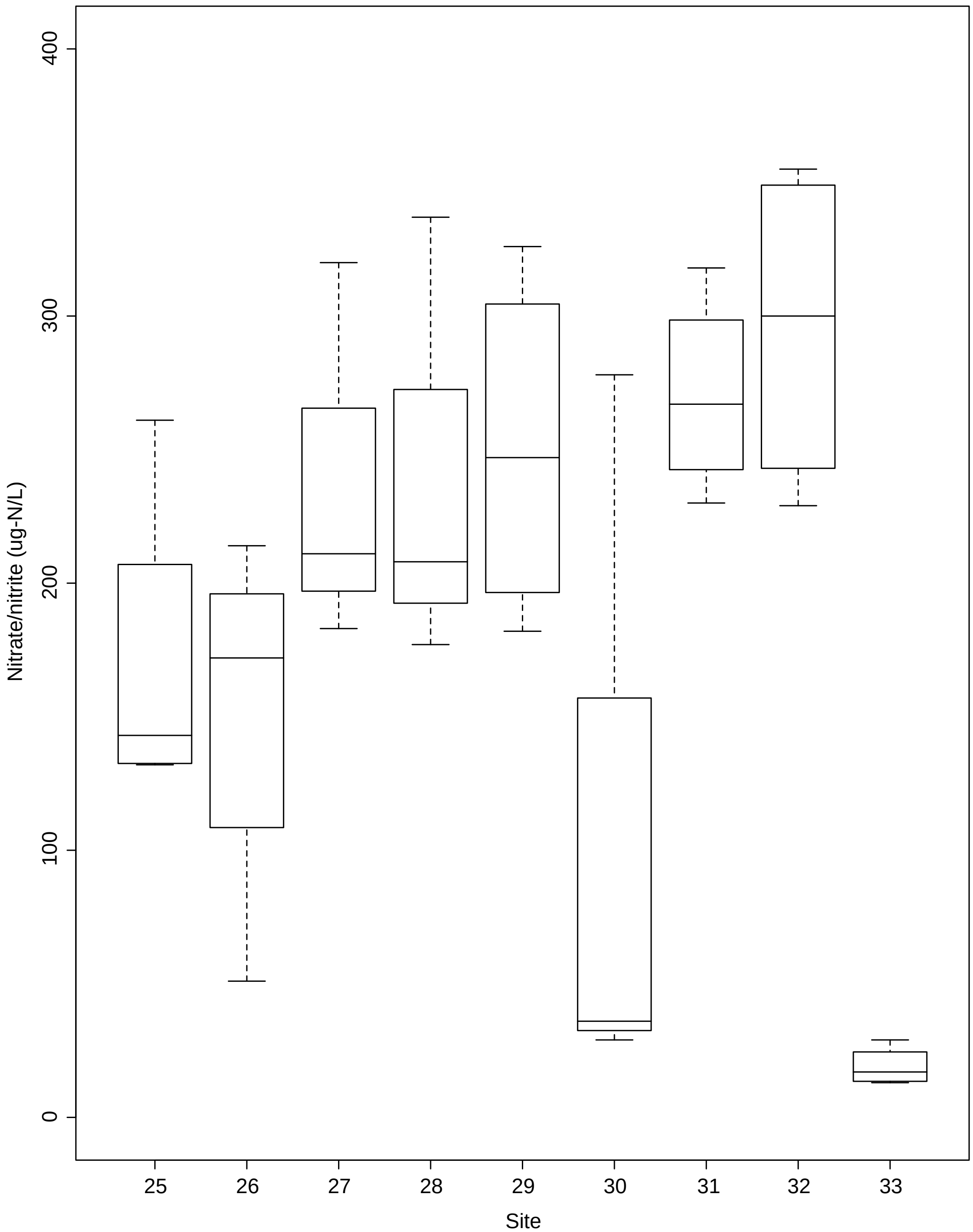

Figure 37: Boxplot of nitrate/nitrite concentrations at marine sites plotted by site. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq 1.5 \times$ interquartile range.

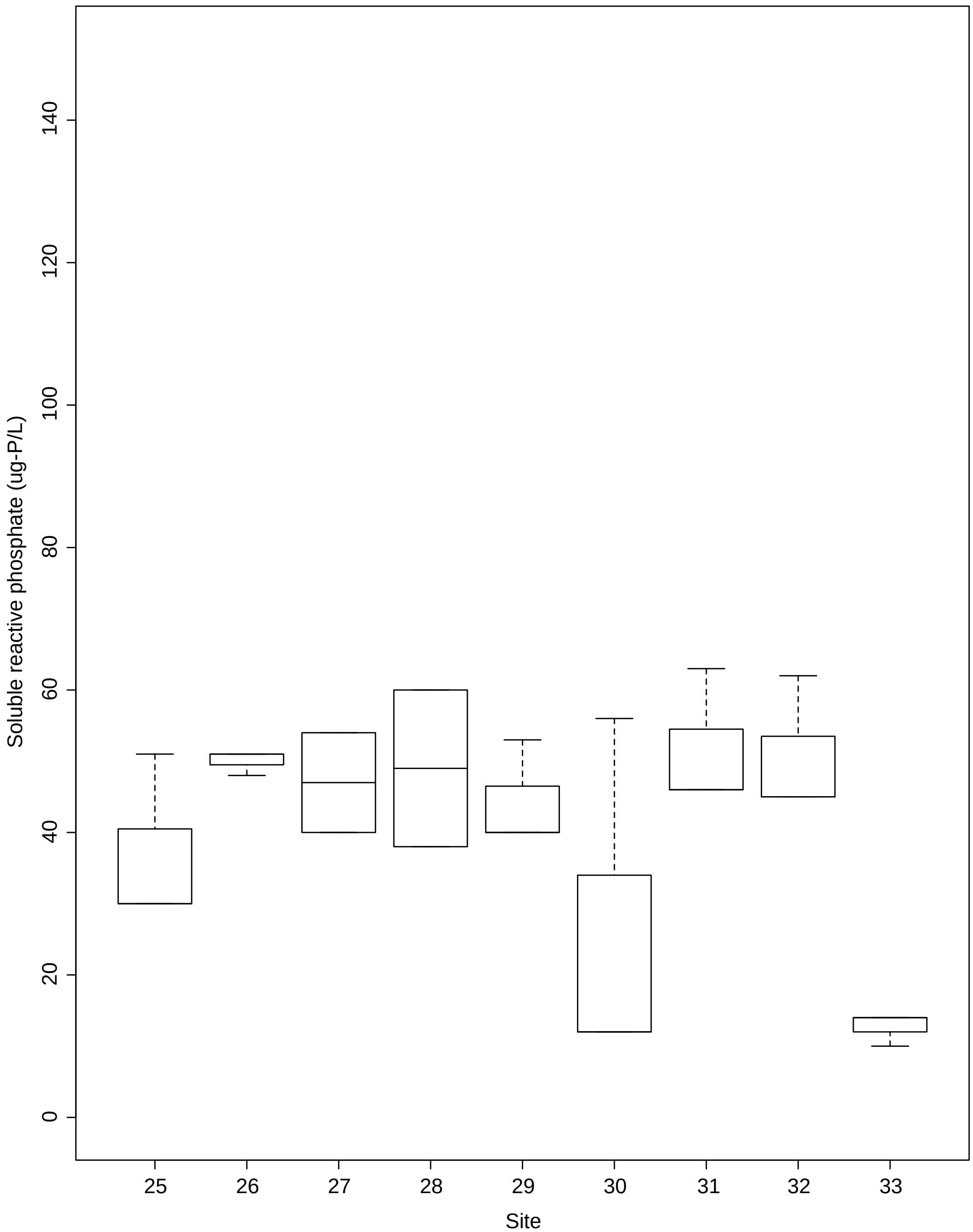

Figure 38: Boxplot of soluble reactive phosphate concentrations at marine sites plotted by site. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq 1.5 \times$ interquartile range.

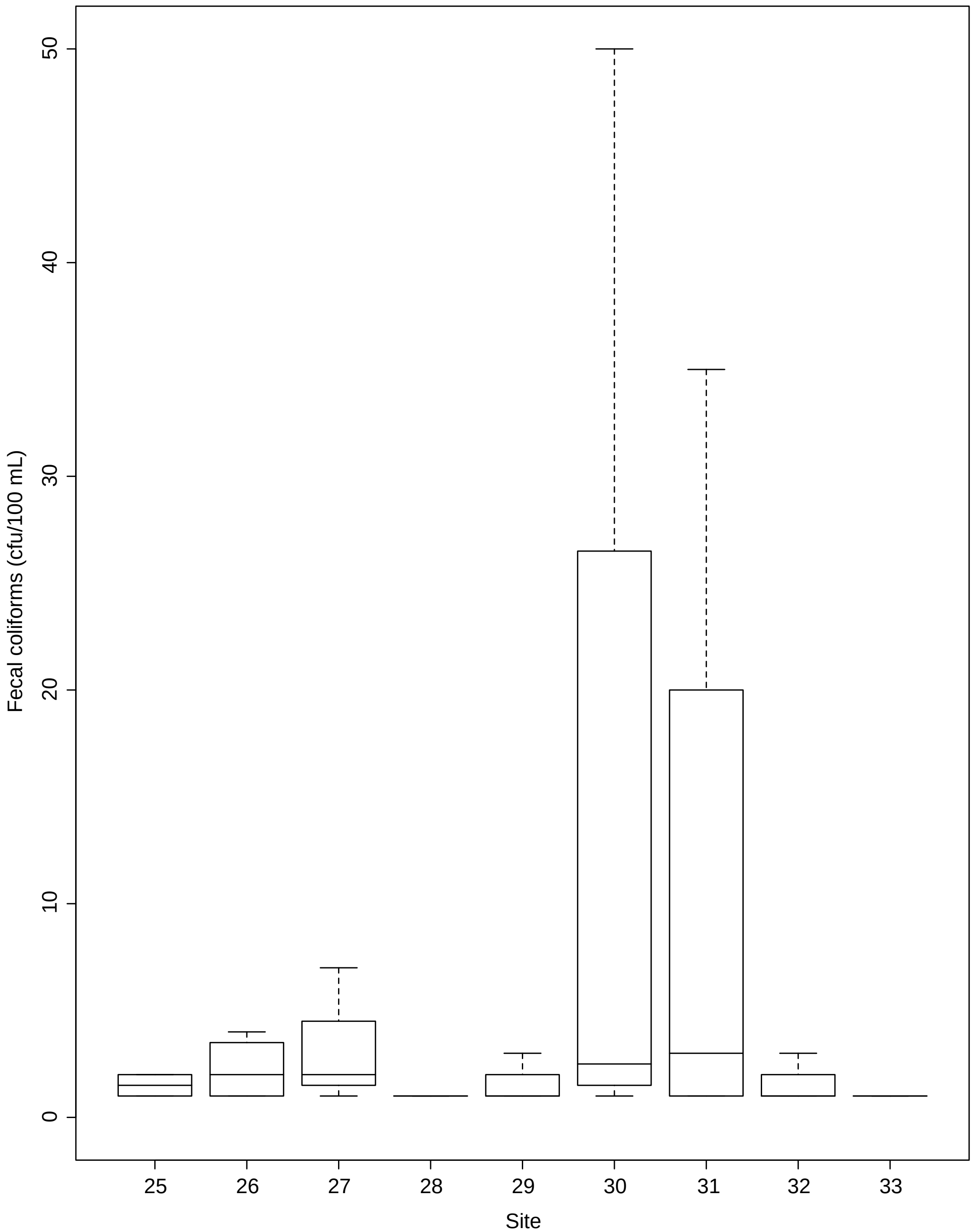

Figure 39: Boxplot of fecal coliform counts at marine sites plotted by site. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq 1.5 \times$ interquartile range.

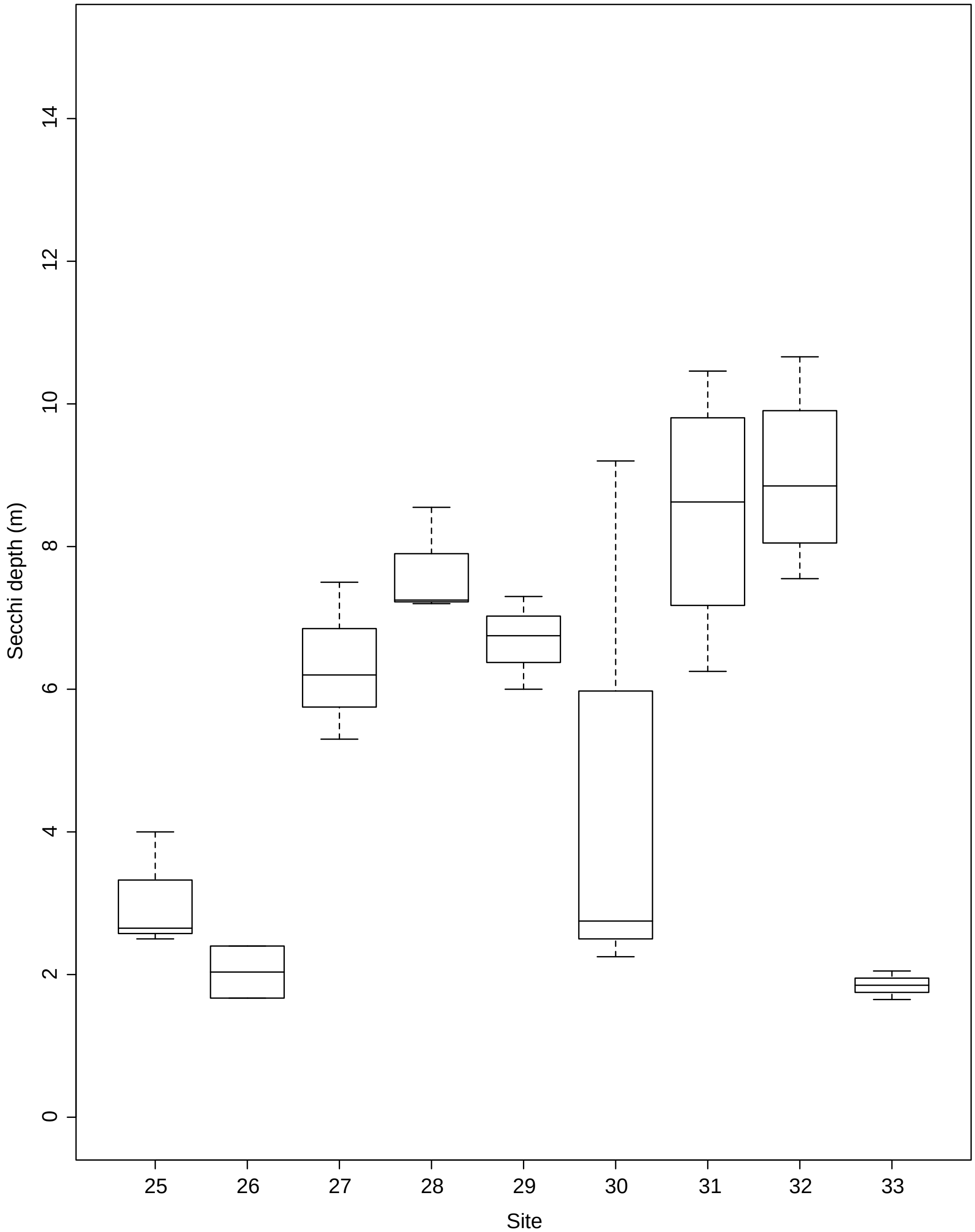

Figure 40: Boxplot of Secchi depths at marine sites plotted by site. Boxes indicate the median and upper/lower 25% quartiles; whiskers show upper/lower 50% quartiles; outliers are $\geq 1.5 \times$ interquartile range.

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A Sampling Site Locations and Descriptions

A.1 Freshwater Sites

SITE 1:
Latitude: 48° 32’12”
Longitude: 122° 53’ 04”
Description: 0.3 km down Port Stanley Rd. coming from Ferry Rd.; north end of the culvert.

SITE 2:
Latitude: 48° 32’09”
Longitude: 122° 52’ 59”
Description: Cross Rd., 0.4 km west of Port Stanley Rd.; north end of the culvert.

SITE 3:
Latitude: 48° 31’38”
Longitude: 122° 54’ 55”
Description: Lopez Rd, 0.3 km north of Lopez Village; west end of the culvert.

SITE 4:
Latitude: 48° 27’36”
Longitude: 122° 54’ 06”
Description: Intersection of Davis Bay Rd. and Richardson Rd.; south end of the culvert.

SITE 5:
Latitude: 48° 28’19”
Longitude: 122° 51’ 29”
Description: 0.1 km down a private drive after turning left off of Elliot Rd.; east end of the culvert.

SITE 6:
Latitude: 48° 30’42”
Longitude: 122° 52’ 57”
Description: 0.1 km north of the intersection of Port Stanley Rd. and Lopez Sound Rd.; east end of the culvert.

SITE 7:
Latitude: 48° 27’49”
Longitude: 122° 55’ 09”
Description: 1.7 km down Davis Bay Rd., west of the intersection between Davis Bay Rd. and Richardson Rd.; south end of the culvert.

SITE 8:
Latitude: 48° 37’24”
Longitude: 123° 00’ 27”
Description: 0.2 km northwest of Cayou Quay marina, Deer Harbor; south end of culvert.

SITE 9:
Latitude: 48° 37’57”
Longitude: 122° 57’ 27”
Description: Deer Harbor Rd.; 1.2 km west of the intersection of Deer harbor Rd. and Horseshoe Highway; next to the residential cement bulkhead.

SITE 10:
Latitude: 48° 37’49”
Longitude: 122° 53’ 43”
Description: Dolphin Bay Rd.; 2.9 km north of the intersection between Dolphin Bay Rd. and White Beach Rd.; east end of culvert.

SITE 11:
Latitude: 48° 41’39”
Longitude: 122° 54’ 29”
Description: Horseshoe Highway; 0.27 km east of the intersection of Horseshoe Highway and Lovers Lane; outfall dumping onto beach, right in front of Indian Is.; south end of culvert.

SITE 12:
Latitude: 48° 39’26”
Longitude: 122° 51’ 58”
Description: Rosario Rd.; 0.1 km south of the intersection of Horseshoe Highway and Rosario Rd.; west end of culvert.

SITE 13:
Latitude: 48° 38’41”
Longitude: 122° 50’ 09”
Description: Horseshoe Highway; 1.2 km east on the highway from Cascade Lake; below the bridge crossing the creek.

SITE 14:
Latitude: 48° 37’21”
Longitude: 122° 49’ 55”
Description: Horseshoe Highway; about 0.32 km east of Olga; Buck Bay; north of the culvert.

SITE 15:
Latitude: 48° 37’12”
Longitude: 122° 49’ 28”
Description: Buoy Bay Rd.; 0.3 km south of the intersection of Buoy Bay Rd. and Horseshoe Highway.

SITE 16:
Latitude: 48° 38’32”
Longitude: 122° 46’ 51”
Description: Doe Bay Rd.; 0.1 km from Doe Bay.

SITE 17:
Latitude: 48° 32’10”
Longitude: 123° 00’ 55”
Description: NE end of Spring St.

SITE 18:
Latitude: 48° 32’42”
Longitude: 123° 01’ 10”
Description: University Rd.; 0.6 km down University Rd. for its intersection with Tucker Av.; SE end of the culverts.

SITE 19:
Latitude: 48° 33’53”
Longitude: 123° 03’ 34”
Description: Roche Harbor Rd.; adjacent to Eureka Dr.

SITE 20:
Latitude: 48° 36’11”
Longitude: 123° 08’ 08”
Description: Westcott Dr.; 0.2 km west of the intersection between Westcott Dr. and Roche Harbor Rd.

SITE 21:
Latitude: 48° 35’53”
Longitude: 123° 08’ 25”
Description: Westcott Dr.; 0.9 km west of the intersection between Westcott Dr. nd Roche Harbor Rd.

SITE 22:
Latitude: 48° 34’37”
Longitude: 123° 08’ 50”
Description: Yacht Haven Rd.; 0.4 km west of the intersection of Yacht Haven Rd. and Mitchell Bay Rd.

SITE 23:
Latitude: 48° 31’34”
Longitude: 123° 05’ 57”
Description: Wold Rd.; 0.3 km south of the intersection of Wold Rd. and San Juan Valley Rd.

SITE 24:
Latitude: 48° 29’59”
Longitude: 123° 03’ 49”
Description: Bailer Hill Rd.; 0.2 km west of the intersection between Bailer Hill Rd. and False Bay Dr.

A.2 Marine Sites

SITE 25:
Latitude: 48° 30’48”
Longitude: 127° 54’ 54”
Description: Fisherman’s Bay; Fisherman Bay Rd.; Lopez Islander Resort-Marina.

SITE 26:
Latitude: 48° 30’26”
Longitude: 122° 55’ 01”
Description: Fisherman’s Bay; Fisherman Bay Rd.; Public dock.

SITE 27:
Latitude: 48° 37’19”
Longitude: 123° 00’ 15”
Description: Deer Harbor; Spring Point Rd.; Cayou Quay Marina.

SITE 28:
Latitude: 48° 37’08”
Longitude: 123° 00’ 08”
Description: Deer Harbor; Deer Harbor Rd.; Deer Harbor Resort and Marina.

SITE 29:
Latitude: 48° 37’45”
Longitude: 122° 57’ 29”
Description: West Sound; Deer Harbor Rd.; West Sound Marina.

SITE 30:
Latitude: 48° 38’47”
Longitude: 123° 52’ 13”
Description: Cascade Bay, East Sound; Rosario Resort; Harbormaster’s dock.

SITE 31:
Latitude: 48° 32’11”
Longitude: 123° 00’ 54”
Description: Friday Harbor; Friday Harbor City Dock, northwest end.

SITE 32:
Latitude: 48° 32’18”
Longitude: 123° 00’ 56”
Description: Friday Harbor; Friday Harbor marina, northwest end.

SITE 33:
Latitude: 48° 35’12”
Longitude: 123° 09’ 13”
Description: Garrison Bay, south end of British Camp boardwalk.

B Quality Assurance/ Quality Control

B.1 Field Duplicates

Field duplicates were used to measure the variability that is inherent in sampling a biological system. The difference between the field duplicates represents the variability associated with sampling, handling, and analysis. Tables 19–23 (pages 88–92) show the field duplicate data and the relative and absolute differences calculated for each parameter and duplicate sample. These data are used solely for reporting variability that occurred during the project. Acceptance or rejection criteria were not assigned to this element of data review.

Most of the field duplicates were within the variability estimated for lab duplicates. However, several field duplicates indicated greater absolute variability than would be expected from lab replicates, and also were greater than 20% different than each other. Table 24 (page 93) contains the duplicate values that were outside of the expected range of repeatability.

B.2 Duplicate Laboratory Analyses

Lab duplicates were analyzed for 10% of all lab samples and the results were used to estimate the amount of precision associated with each method using control charts. Paired duplicate results are included in Appendix C. The summary results shown in Table 25 (page 94) were calculated using 20 sample duplicates to create the control charts. The upper and lower limits for each analysis were determined by multiplying the standard deviation by three. The control charts incorporate the results from projects other than San Juan County for samples that are analyzed in the IWS laboratory. The limit was exceeded two times for samples collected from this project. The duplicate values collected for nitrate on March 26 1999 at Site 4 were 31.0 μg N/L and 35.0 μg N/L, a relative percent difference of 12%, which was outside the control limit of 7.4%. The difference of 4.0 μg N/L was small when considered in absolute. Sample 17 collected on February 25 2000 had a total phosphorus concentration difference of 21.1 μg P/L and the control limit was $\pm$ 15.45 μg P/L. The concentration difference was only slightly outside the range of the limit.

B.3 Check Standards

Two internal check standards were run every month with each analysis at 20% and 80% of the concentration relative to the maximum of the standard curve (Table 26, page 95). The purpose of the check standards was to analyze known standards that were made independently of the standards used to calculate the curve. Control charts were used to determine if the difference between the measured check standard and the true value of the check standard were within 3 standard deviations of the mean. The standard deviation and mean were calculated using 20 measurements from previous analytical runs. Check standards exceeded control limits two times during analytical runs for this project. A 200 μg N/L ammonia check standard was measured as 256 μg N/L, while the control limit was 239 mg N/L. Samples collected during January 2000 were analyzed during this run. A 125 μg P/L check standard was measured to be 111 μg P/L, while the lower control limit was 118 μg P/L. This run included samples collected during February 2000. Samples analyzed on these dates were not rejected. Both runs included an additional check standard that was within control limits.

B.4 Dissolved Oxygen

For 20% of all dissolved oxygen measurements made using the field meter, a sample was collected to measure oxygen using the Winkler technique. Quality control pairs for the oxygen measurements are included in Appendix C.

		Fecal Coliform			
		Value	Value	Rel	Abs
Date	Site	1	2	% Diff	Diff
26 Mar 1999	4	9	13	36%	4
27 Mar 1999	8	2	1	67%	1
28 Mar 1999	19	1	1	0%	0
23 Apr 1999	4	4	1	120%	3
24 Apr 1999	8	1	1	0%	0
25 Apr 1999	20	78	66	17%	12
21 May 1999	21	35	31	12%	4
22 May 1999	9	1100	1000	10%	100
23 May 1999	4	9	6	40%	3
28 Jun 1999	24	110	140	24%	30
29 Jun 1999	12	48	40	18%	8
30 Jun 1999	7	160	160	0%	0
26 Jul 1999	24	6	10	50%	4
27 Jul 1999	16	1000	1000	0%	0
28 Jul 1999	25	2	1	67%	1
24 Aug 1999	24	320	460	36%	140
25 Aug 1999	13	5	2	86%	3
26 Aug 1999	25	2	1	67%	1
19 Sep 1999	23	130	100	26%	30
20 Sep 1999	SJ10*	NA	NA	NA	NA
30 Sep 1999	13	3	1	100%	2
20 Sep 1999	25	1	1	0%	0
22 Oct 1999	23	20	20	0%	0
23 Oct 1999	13	4	1	120%	3
24 Oct 1999	26	4	1	120%	3
19 Nov 1999	28	20	17	16%	3
20 Nov 1999	12	14	10	33%	4
21 Nov 1999	4	120	110	9%	10
17 Dec 1999	19	4	16	120%	12
18 Dec 1999	4	120	110	9%	10
19 Dec 1999	16	53	39	30%	14
21 Jan 2000	20	40	28	35%	12
22 Jan 2000	15	160	140	13%	20
23 Jan 2000	2	72	64	12%	8
25 Feb 2000	19	1	1	0%	0
26 Feb 2000	16	18	24	29%	6
27 Feb 2000	3	68	84	21%	16

Relative % difference not calculated for censored values.
*C. Wiseman thesis site.

Table 19: Fecal coliform field duplicate values, relative percent differences, and absolute differences for the San Juan County monitoring project, 1999-2000.

		Turbidity			
		Value	Value	Rel	Abs
Date	Site	1	2	% Diff	Diff
26 Mar 1999	4	6.4	6.2	3%	0.2
27 Mar 1999	8	4.3	3.1	32%	1.2
28 Mar 1999	19	2.15	2.2	2%	0.1
23 Apr 1999	4	2	2.1	5%	0.1
24 Apr 1999	8	4.7	2.8	51%	1.9
25 Apr 1999	20	11.1	11.5	4%	0.4
21 May 1999	21	17	18.2	7%	1.2
22 May 1999	9	8.78	9.1	4%	0.3
23 May 1999	4	2.97	2.72	9%	0.3
28 Jun 1999	24	2.5	2.35	6%	0.2
29 Jun 1999	12	4.49	4.95	10%	0.5
30 Jun 1999	7	6.46	5.91	9%	0.6
26 Jul 1999	24	2	1.9	5%	0.1
27 Jul 1999	16	3.73	3.26	13%	0.5
28 Jul 1999	25	1.52	1.27	18%	0.3
24 Aug 1999	24	9.14	9.02	1%	0.1
25 Aug 1999	13	0.53	0.23	79%	0.3
26 Aug 1999	25	1.37	1.43	4%	0.1
19 Sep 1999	23	1.87	1.97	5%	0.1
20 Sep 1999	SJ10*	0.67	0.61	9%	0.1
30 Sep 1999	13	4.45	1.72	88%	2.7
20 Sep 1999	25	1.17	1.55	28%	0.4
22 Oct 1999	23	1.08	1.2	11%	0.1
23 Oct 1999	13	1.86	0.89	71%	1.0
24 Oct 1999	26	1.28	1.23	4%	0.1
19 Nov 1999	28	4.49	3.38	28%	1.1
20 Nov 1999	12	2.59	3.68	35%	1.1
21 Nov 1999	4	3.2	2.53	23%	0.7
17 Dec 1999	19	1.88	1.95	4%	0.1
18 Dec 1999	4	18.7	19	2%	0.3
19 Dec 1999	16	4.93	4.5	9%	0.4
21 Jan 2000	20	9.3	9.3	0%	0.0
22 Jan 2000	15	12.6	14.1	11%	1.5
23 Jan 2000	2	7.45	7.02	6%	0.4
25 Feb 2000	19	3.06	2.93	4%	0.1
26 Feb 2000	16	4.71	7.59	47%	2.9
27 Feb 2000	3	26.6	27.5	3%	0.9

Relative % difference not calculated for censored values.
*C. Wiseman thesis site.

Table 20: Turbidity field duplicate values, relative percent differences, and absolute differences for the San Juan County monitoring project, 1999-2000.

		Ammonia			
		Value	Value	Rel	Abs
Date	Site	1	2	% Diff	Diff
26 Mar 1999	4	<20	11	NA	NA
27 Mar 1999	8	<20	<20	NA	NA
28 Mar 1999	19	20	15	29%	5
23 Apr 1999	4	<20	<20	NA	NA
24 Apr 1999	8	<20	<20	NA	NA
25 Apr 1999	20	16	17	4%	1
21 May 1999	21	20	12	50%	8
22 May 1999	9	954	62	176%	892
23 May 1999	4	33	35	6%	2
28 Jun 1999	24	<20	<20	NA	NA
29 Jun 1999	12	<20	<20	NA	NA
30 Jun 1999	7	13	<20	NA	NA
26 Jul 1999	24	<20	<20	NA	NA
27 Jul 1999	16	<20	<20	NA	NA
28 Jul 1999	25	NA	NA	NA	NA
24 Aug 1999	24	244	253	4%	9
25 Aug 1999	13	<20	<20	NA	NA
26 Aug 1999	25	NA	NA	NA	NA
19 Sep 1999	23	NA	NA	NA	NA
20 Sep 1999	SJ10*	<20	<20	NA	NA
30 Sep 1999	13	<20	<20	NA	NA
20 Sep 1999	25	N	NA	NA	NA
22 Oct 1999	23	<20	<20	NA	NA
23 Oct 1999	13	<20	<20	NA	NA
24 Oct 1999	26	NA	NA	NA	NA
19 Nov 1999	28	<20	<20	NA	NA
20 Nov 1999	12	<20	<20	NA	NA
21 Nov 1999	4	13	12	8%	1
17 Dec 1999	19	46	43	7%	3
18 Dec 1999	4	117	109	7%	8
19 Dec 1999	16	<20	<20	NA	NA
21 Jan 2000	20	<20	<20	NA	NA
22 Jan 2000	15	49	<20	NA	NA
23 Jan 2000	2	41	15	93%	26
25 Feb 2000	19	<20	<20	NA	NA
26 Feb 2000	16	<20	<20	NA	NA
27 Feb 2000	3	<20	<20	NA	NA

Relative % difference not calculated for censored values.
*C. Wiseman thesis site.

Table 21: Ammonia field duplicate values, relative percent differences, and absolute differences for the San Juan County monitoring project, 1999-2000.

		Total Phosphorus			
		Value	Value	Rel	Abs
Date	Site	1	2	% Diff	Diff
26 Mar 1999	4	63	66	5%	3
27 Mar 1999	8	24	33	33%	9
28 Mar 1999	19	35	32	9%	3
23 Apr 1999	4	52	50	4%	2
24 Apr 1999	8	<5	27	NA	NA
25 Apr 1999	20	87	64	30%	23
21 May 1999	21	71	84	16%	13
22 May 1999	9	56	65	16%	10
23 May 1999	4	71	74	4%	3
28 Jun 1999	24	99	99	0%	0
29 Jun 1999	12	18	20	10%	2
30 Jun 1999	7	78	78	0%	0
26 Jul 1999	24	65	62	4%	3
27 Jul 1999	16	20	26	27%	6
28 Jul 1999	25	NA	NA	NA	NA
24 Aug 1999	24	172	172	0%	1
25 Aug 1999	13	6	7	16%	1
26 Aug 1999	25	NA	NA	NA	NA
19 Sep 1999	23	20	34	51%	14
20 Sep 1999	SJ10*	19	25	31%	7
30 Sep 1999	13	11	8	26%	2
20 Sep 1999	25	NA	NA	NA	NA
22 Oct 1999	23	17	16	2%	NA
23 Oct 1999	13	8	7	10%	1
24 Oct 1999	26	NA	NA	NA	NA
19 Nov 1999	28	46	43	7%	3
20 Nov 1999	12	4	10	96%	7
21 Nov 1999	4	139	164	16%	25
17 Dec 1999	19	25	22	12%	3
18 Dec 1999	4	125	123	2%	2
19 Dec 1999	16	16	22	35%	7
21 Jan 2000	20	24	28	16%	4
22 Jan 2000	15	40	41	2%	1
23 Jan 2000	2	65	65	0%	0
25 Feb 2000	19	40	39	4%	2
26 Feb 2000	16	13	13	0%	0
27 Feb 2000	3	137	148	8%	11

Relative % difference not calculated for censored values.
*C. Wiseman thesis site.

Table 22: Total phosphorus field duplicate values, relative percent differences, and absolute differences for the San Juan County monitoring project, 1999-2000.

		Nitrate/nitrite			
		Value	Value	Rel	Abs
Date	Site	1	2	% Diff	Diff
26 Mar 1999	4	31	40	25%	9
27 Mar 1999	8	55	54	1%	0
28 Mar 1999	19	99	100	0%	0
23 Apr 1999	4	180	162	11%	19
24 Apr 1999	8	9	9	4%	0
25 Apr 1999	20	45	50	10%	5
21 May 1999	21	420	419	0%	1
22 May 1999	9	70	70	0%	0
23 May 1999	4	292	293	0%	1
28 Jun 1999	24	<10	<10	NA	NA
29 Jun 1999	12	115	117	2%	2
30 Jun 1999	7	1467	1504	2%	37
26 Jul 1999	24	<10	<10	NA	NA
27 Jul 1999	16	347	333	4%	14
28 Jul 1999	25	132	118	11%	14
24 Aug 1999	24	36	38	5%	2
25 Aug 1999	13	219	224	2%	5
26 Aug 1999	25	133	53	86%	80
19 Sep 1999	23	18	7	88%	11
20 Sep 1999	SJ10*	121	137	12%	16
30 Sep 1999	13	147	150	2%	3
20 Sep 1999	25	153	167	9%	14
22 Oct 1999	23	<10	<10	NA	NA
23 Oct 1999	13	145	147	1%	2
24 Oct 1999	26	214	215	0%	1
19 Nov 1999	28	611	620	1%	9
20 Nov 1999	12	490	492	0%	2
21 Nov 1999	4	86	70	21%	16
17 Dec 1999	19	226	227	0%	1
18 Dec 1999	4	554	560	1%	6
19 Dec 1999	16	1305	1413	8%	108
21 Jan 2000	20	70	67	4%	3
22 Jan 2000	15	894	919	3%	25
23 Jan 2000	2	114	113	1%	1
25 Feb 2000	19	267	268	0%	1
26 Feb 2000	16	695	853	20%	158
27 Feb 2000	3	23	22	4%	1

Relative % difference not calculated for censored values.
*C. Wiseman thesis site.

Table 23: Nitrate/nitrite field duplicate values, relative percent differences, and absolute differences for the San Juan County monitoring project, 1999-2000.

Parameter	Site	Date	Value 1	Value 2
Ammonia (μg NH_3-N/L)	25	26 Aug 1999	133	53
Nitrate/nitrite (μg NO_{3+2}-N/L)	20	25 Apr 1999	87	64
Total Phosphorus (μg PO_4-P/L)	23	19 Sep 1999	20	34
Turbidity (NTU)	9	22 May 1999	954	62
Fecal Coliform (cfu/100mL)	24	24 Aug 1999	320	460

Table 24: Field duplicates that were outside the expected range of repeatability for lab duplicates.

Analyte	Standard Deviation	Control Limit 3× SD
Automated Ammonia (μg NH_3-N/L)	4.42	13.27
Nitrate/nitrite (RPD*)	2.46 (RPD)	7.38 (RPD)
Dissolved Oxygen (mg/L)	0.10	0.3
Total Phosphorus (μg PO_4-P/L)	5.15	15.45
Turbidity (NTU)	0.95	2.841

*RPD = Relative percent difference; used because of large concentration range for analyte.

Table 25: Standard deviations for laboratory duplicate analyses.

	20% of Range			80% of Range		
	UCL	value	LCL	UCL	value	LCL
Ammonia (μg NH_3-N/L)	78.9	50	19.5	238.5	200	163.8
Nitrate/nitrite (μg NO_{3+2}-N/L)	140.4	125	112.3	561.0	500	459.2
Total Phosphorus (μg PO_4-P/L)	136.9	125	117.5	549.7	500	470.3

UCL = Upper Control Limit; LCL = Lower Control Limit

Table 26: Control limits for internal check standards.

C Water Quality and Discharge Data

C.1 CD Files

The following is a verbatim copy of the readme.txt file included with the CD:

```
*********************************
README FILE - SAN JUAN 1999-2000
*********************************
The CD included with the 1999/00 San Juan County monitoring report
included the following data files:

FILE NAME  FILE DESCRIPTION
Apr.xls  Original verified excel file for April 1999
Aug.xls  Original verified excel file for August 1999
Dec.xls  Original verified excel file for December 1999
Feb.xls  Original verified excel file for January 2000
Jan.xls  Original verified excel file for February 2000
July.xls  Original verified excel file for July 1999
June.xls  Original verified excel file for June 1999
Mar.xls  Original verified excel file for March 1999
May.xls  Original verified excel file for May 1999
Nov.xls  Original verified excel file for November 1999
Oct.xls  Original verified excel file for October 1999
Sept.xls  Original verified excel file for September 1999

sjc_base.xls  Composite excel file, new site names, sampling time

freshw.dat  Space-delineated ascii file containing only Type I
 freshwater data, times converted to 25 hr fraction

marine.dat  Space-delineated ascii file containing only Type I
 marine data, times converted to 25 hr fraction

sjc_base_fw.txt  Tab-delineated composite ascii file, exact copy of
 first sheet (freshwater) in sjc_base.xls

sjc_base_mar.txt Tab-delineated composite ascii file, exact copy of
 second sheet (marine) in sjc_base.xls

GENERAL INFORMATION:

1) The first row or line in all data files contains the variable list.
```

Variable codes:
Type 1 = regular water quality sample
2 = quality control laboratory duplicates
3 = quality control field duplicates
4 = quality control blanks

Site L1-7 = Sites 1-7 (Lopez Island, freshwater)
O1-9 = Sites 8-16 (Orcas Island, freshwater)
SJ1-8 = Sites 17-24 (San Juan Island, freshwater)
LM1-2 = Sites 25-26 (Lopez Island, marine)
OM1-4 = Sites 27-30 (Orcas Island, marine)
SJM1-3 = Sites 31-33 (San Juan Island, marine)

Island 1 = Lopez
2 = Orcas
3 = San Juan

2) Freshwater sites are 1-24; marine sites are 25-33.

3) All missing values are replaced with -99 (sjc_base*.txt) or NA (*.dat) in the ascii files.

4) All "<" and "<" symbols have been removed from the ascii ".dat" files (e.g. <1 => 1).

5) Text comments have been removed from sjc_base.xls and all ascii files.

OTHER THAN THE ABOVE COMMENTS, THESE DATA ARE NOT CENSORED TO REMOVE NEGATIVE VALUES AND BELOW DETECTION RESULTS. DETECTION LIMITS ARE DISCUSSED IN THE REPORT. IF YOU ARE UNFAMILIAR WITH USING UNCENSORED DATA, PLEASE CONTACT THE INSTITUTE FOR WATERSHED STUDIES AT WESTERN WASHINGTON UNIVERSITY (360-650-3510) FOR ASSISTANCE.

C.2 San Juan County Data

The San Juan County water quality data and quality control data are included on the following pages. The detection limits and analytical methods are summarized below. The detection limits are conservative lower limits that are estimated based on recommended lower detection ranges, instrument limitations, and analyst judgement on the lowest repeatable concentration for each test. The criteria of detection are analytically derived using the laboratory duplicate data according to IWS SOP #14, based on the method developed by the Department of Ecology Laboratory at Manchester, WA.

Parameter	Method	Description	DL	CD
Temperature (°C)	EPA (1979) #170.1	YSI 85 meter	NA	NA
D. oxygen (mg/L)	EPA (1979) # 360.1	YSI 85 meter	0.1	NA
Conductivity (μS/cm)	EPA (1979) #120.1	YSI 85 meter	2	NA
pH	EPA (1979) #150.1	Orion 290A meter	NA	NA
		VWR 8000 meter	NA	NA
Turbidity (NTU)	EPA (1979) #180.1	Hach 2100P meter	0.2	NA
Sol. phosphate (μg-P/L)	EPA (1979) #365.2	Ascorbic acid	5	0.7
T. phosphorus (μg-P/L)	EPA (1979) #365.2	Persulfate digestion, ascorbic acid	5	1.7
Ammonia (μg-N/L)	EPA (1979) #350.1	Auto. phenate	20	12.2
Nitrate/nitrite, freshw (μg-N/L)	EPA (1979) #353.2	Auto. Cd reduction	10	5.8
Nitrate/nitrite, marine (μg-N/L)	Parsons, et al., (1984)	Auto. Cd reduction	10	NA
Fecal coliform (cfu/100 mL)	APHA (1992) #9222	Membrane filter	1–2	NA
Secchi depth (m)	Wetzel and Likens (1990)	Two point average	NA	NA
Discharge (cfs)	Marsh-McBirney (1990)	0.4; 0.9 × Vmax; conduit; or volumetric	0.05	NA

DL = recommended detection limit; CD = analytical criterion of detection.