Nutrient TMDL for the Nearshore Waters of Lake Pend Oreille, Idaho

TMDL Five-Year Review

Hydrologic Unit Code 17010214

Department of Environmental Quality

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June 2015

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Executive Summary

Lake Pend Oreille is the largest and deepest natural lake in Idaho and the 5th deepest and 8th largest lake in the United States (by volume) (USGS 1996). The lake is also impounded an extra 20 feet for power production by Albeni Falls Dam at the Idaho/Washington border. Lake Pend Oreille is largely surrounded by undeveloped forest due to the steep hillslopes surrounding much of its 111 miles of shoreline. However, the small community of Sandpoint and the surrounding area is home to 10,000 residents at the north end of the lake. This community and the lake itself is the destination of many tourists each year, where people can enjoy fishing, boating, and swimming during the summer and snow skiing, snowboarding, and cross-country skiing in the winter at the nearby Schweitzer resort and surrounding area. Because the local economy is based almost entirely on tourism, maintaining the health and integrity of Lake Pend Oreille is high priority for the people who live in the area (Coombs and Sanyal 2008).

Concern over water quality in the nearshore waters of the lake has been significant for decades. In response to public concerns in the 1990s, the Idaho Department of Health and Welfare, Division of Environmental Quality (now the Idaho Department of Environmental Quality, or DEQ) listed Lake Pend Oreille on Idaho's 1994 §303(d) list as "threatened" with no identified pollutant of concern. This listing status was retained on Idaho's 1996 and 1998 §303(d) lists. Public comments received during Idaho's §303(d) 1998 listing cycle indicated the concerns over water quality in Lake Pend Oreille were due to nuisance algae growth in the nearshore waters of the lake. In 1999, DEQ prepared a problem assessment on the lake, which recommended developing a total maximum daily load (TMDL) for nutrients for the nearshore waters of the lake. In 2002, EPA approved the *Total Maximum Daily Load (TMDL) for Nutrients for the Nearshore Waters of Lake Pend Oreille, Idaho* (DEQ 2002). The TMDL addresses mitigation of increasing anthropogenic eutrophication along the shoreline of Lake Pend Oreille. The beneficial uses of primary contact recreation and aquatic life are addressed in the TMDL.

This document presents a 5-year review of the 2002 TMDL and has been developed to comply with Idaho Code §39-3611(7). The review describes the existing TMDL beneficial use support status, pollutant sources, current water quality data, and recent pollution control actions in the nearshore waters of Lake Pend Oreille, located in the panhandle region of Idaho in hydrologic unit code 17010214.

The results of this review reveal the TMDL targets for total phosphorus of 9 micrograms per liter (μg/L) (average concentration) and 12 μg/L (instantaneous concentration) are reasonable targets and should remain in place. This determination was initially made based on a statistical analysis of the data from the period of record and a baseline study of data collected on other lakes within north Idaho. The statistical analysis suggests the TMDL target has not been met in the northern region of the lake but is being met in the southern end of the lake. The determination that the targets are protective of beneficial use support was validated by evaluating water quality and nearshore productivity in the different regions of the lake.

Funding limitations and changing priorities for annual monitoring stations has created data gaps at individual monitoring stations and made statistical analysis at individual monitoring stations difficult. Therefore, a regional approach was taken to analyze the data by grouping data sets of individual stations together with other stations within the same region of the lake. The lake was

divided into three regions: northern, mid, and southern. The results of this analysis were then compared to an analysis of data from long-term trend sites—two at each of the three regions of the lake. This comparison was necessary to understand whether the regional analysis could be considered representative of individual sites.

Results of the regional analysis showed total phosphorus decreased over time in the northern lake stations, but this decrease was not observed at the long-term trend stations. In the northern region of the lake, total phosphorus concentrations were significantly higher over time than those observed in the mid and southern lake regions. The regional trend analysis in the mid- and southern region of the lake shows total phosphorus concentrations have not changed significantly over time.

A 2014 study of periphyton algae on artificial substrates at 14 nearshore locations around the lake is further evidence that the TMDL targets are appropriate and are protective of beneficial uses in the nearshore waters of Lake Pend Oreille. The study concluded that productivity conditions in the northern lake are higher than the mid and south, and water column nutrients in the northern portion of the lake support higher periphyton productivity than do the nutrients in the southern portion of the lake. Results of a local opinion survey concluded nuisance periphyton growth did occur on the artificial substrates from the northern bays of Lake Pend Oreille. The northern stations in the lake do not currently meet the 9 μg/L TMDL target. The same local opinion survey did not see nuisance periphyton growth on artificial substrates in the mid and southern regions of the lake—the regions of the lake that currently meet the TMDL target.

Results of the regional trend analysis showed a significant decrease in total phosphorus in the month of August in the northern, mid, and southern regions of the lake. This decline could be attributed to periphyton/phytoplankton growth during that month. The periphyton growth study undertaken in 2014 showed periphyton growth rates at their highest during August.

Because the northern region of the lake has the highest human influence, nonpoint sources of excess nutrients from these areas are likely a contributing factor to periphyton growth on the substrates at these stations. If nutrients continue to increase in the nearshore areas, it is likely that nuisance aquatic growths will further impair beneficial uses. The patterns seen in periphyton are likely to exist in epiphyton, plankton, and zooplankton communities as well.

The load capacities put forth in the TMDL for nearshore water in the lake were derived from the TMDL target of 9 μg/L. The TMDL was written to represent average loading limits for the entire nearshore area of the lake, with loading based solely on runoff from nearshore land and septic seepage through ground water immediately adjacent to the lake. Stormwater likely was incorporated as a general nonpoint source. However, the loading calculations did not take into account other loading sources to the lake, including the following:

- The Clark Fork River
- The Pack River
- Other tributaries to the lake
- Specific stormwater from the towns of Kootenai, Ponderay, Hope, and Bayview

The loads from the above sources are significant, particularly in the spring during runoff, when the highest loading of nutrients has been observed (DEQ 2010). Most of the sources listed above are in the northern region of the lake, which has a 1-year hydraulic retention time. Therefore, loading in spring runoff from these sources would remain in the lake during the summer months. The *Montana and Idaho Border Nutrient Load Agreement Technical Guidance* (TSWQC 2001) directly addresses loading from the Clark Fork and addresses load reduction measures that should be taken. The *Pack River Nutrients Total Maximum Daily Load* (DEQ 2007) directly addresses nutrient loading from the Pack River and provides load reduction requirements from identified sources in the watershed.

Stormwater loads from the cities of Kootenai, Ponderay, Hope, and Bayview may have been only partially accounted for in the TMDL. The width of the boundary of the nearshore drainage area used to calculate the load capacity is approximately 0.9 miles immediately adjacent to the shoreline. This band of land would include runoff and nutrient loading from the cities of Kootenai and Pend Oreille. However, it is unclear whether it included the area within the Cities of Kootenai and Ponderay beyond the 0.9-mile distance that deliver stormwater directly to Kootenai Bay.

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1 Introduction

The federal Clean Water Act (CWA) requires that states and tribes restore and maintain the chemical, physical, and biological integrity of the nation's waters. States and tribes, pursuant to §303 of the CWA, are to adopt water quality standards necessary to protect fish, shellfish, and wildlife while providing for recreation in and on the nation's waters whenever possible. Section 303(d) of the CWA establishes requirements for states and tribes to identify and prioritize water bodies that are water quality limited (i.e., water bodies that do not meet water quality standards). States and tribes must periodically publish a priority list (a "§303(d) list") of impaired waters. For waters identified on this list, states and tribes must develop a total maximum daily load (TMDL) for the pollutants, set at a level to achieve water quality standards.

Idaho Code §39-3611(7) requires a 5-year cyclic review process for Idaho TMDLs:

> The director shall review and reevaluate each TMDL, supporting subbasin assessment, implementation plan(s) and all available data periodically at intervals of no greater than five (5) years. Such reviews shall include the assessments required by section 39-3607, Idaho Code, and an evaluation of the water quality criteria, instream targets, pollutant allocations, assumptions and analyses upon which the TMDL and subbasin assessment were based. If the members of the watershed advisory group, with the concurrence of the basin advisory group, advise the director that the water quality standards, the subbasin assessment, or the implementation plan(s) are not attainable or are inappropriate based upon supporting data, the director shall initiate the process or processes to determine whether to make recommended modifications. The director shall report to the legislature annually the results of such reviews.

This report is intended to meet the intent and purpose of Idaho Code §39-3611(7). The report documents the review of an approved Idaho TMDL and implementation plan and considers the most current and applicable information in conformance with Idaho Code §39-3607. The document also evaluates the appropriateness of the TMDL to current watershed conditions and the implementation plan and evaluates the original TMDL recommendations. Final decisions for TMDL modifications are decided by the Idaho Department of Environmental Quality (DEQ) director. Approval of TMDL modifications is made by the US Environmental Protection Agency (EPA), with consultation by DEQ.

1.1 Background

Concern over degradation of water quality in Lake Pend Oreille has been expressed for decades. In 1987, Congress mandated a comprehensive water quality study in the Clark Fork-Pend Oreille Basin. The objectives of the study were to characterize water quality problems, identify pollutant sources, and suggest implementation actions that would improve water quality in the basin. The study primarily focused on nutrients and their effect on anthropogenic eutrophication in the open water and nearshore zones of the lake. Among the number of nutrient-related findings, the study determined water quality in the open waters of the lake has not changed since the 1950s, and approximately 90% of the total surface water inflow and approximately 90% of the nitrogen and phosphorus load to Lake Pend Oreille comes from the Clark Fork River. It also recognized the impact developed areas are having on water quality in the nearshore zone of the lake (Frenzel 1991).

To reverse productivity in the open waters of Lake Pend Oreille, the *Montana and Idaho Border Nutrient Load Agreement Technical Guidance* (TSWQC 2001) was developed. It was an agreement between the states of Montana and Idaho for establishing nutrient targets and apportioning loads to Lake Pend Oreille. The agreement followed the objectives outlined in the *Clark Fork-Pend Oreille Watershed Management Plan* (TSWCC 1993), which were to reduce and manage the nutrient loads in the Clark Fork River Subbasin to achieve and maintain water quality standards. The targets set in the technical guidance aimed at decreasing loading of total phosphorus (TP) to Lake Pend Oreille from the Clark Fork River upstream in Montana and decreasing loading to the lake from the Lake Pend Oreille watershed in Idaho. It also set a target for TP and a target for the total nitrogen (TN) to TP ratio in the lake.

While trophic conditions in the open waters of the lake have not changed since the 1950s, data from as early as the 1990s suggest that the trophic status of the nearshore areas of Lake Pend Oreille may change more rapidly than the open waters, and development may be impacting water quality and productivity in the nearshore waters of the lake (Falter et. al. 1992). In response to public concerns in the 1990s, the Idaho Department of Health and Welfare, Division of Environmental Quality (now DEQ) listed Lake Pend Oreille on Idaho's 1994 §303(d) list as "threatened" without identifying a pollutant of concern. This listing status was retained on Idaho's 1996 and 1998 §303(d) lists. Public comments received during Idaho's §303(d) 1998 listing cycle indicated the concerns over water quality in Lake Pend Oreille were due to nuisance algae growth in the nearshore waters of the lake. In 1999, DEQ prepared a problem assessment on the lake, which recommended developing a TMDL for nutrients for the nearshore waters of the lake. The TMDL addresses mitigation of increasing anthropogenic eutrophication along the shoreline of Lake Pend Oreille. The primary contact recreation and aquatic life beneficial uses are addressed in the TMDL. In 2002, EPA approved the *Total Maximum Daily Load (TMDL) for Nutrients for the Nearshore Waters of Lake Pend Oreille, Idaho* (DEQ 2002).

1.2 TMDL Five-Year Review Approach

This TMDL 5-year review effort is consistent with a larger effort between the states of Idaho and Montana outlined in the *Montana and Idaho Border Nutrient Load Agreement Technical Guidance* (TSWQC 2001), which addresses protection from overall eutrophication of Lake Pend Oreille primarily from the Clark Fork River Basin. The *TMDL for Nutrients for the Nearshore Waters of Lake Pend Oreille, Idaho* (DEQ 2002) addresses shoreline loading, or direct runoff from the land immediately surrounding the lake, and loads from septic seepage through ground water. It does not address loading from tributaries or from other point or nonpoint sources.

The 2002 TMDL has uncertainty associated with selection of numeric targets representative of the desired nearshore lake. Recognizing this inherent uncertainty, the TMDL was developed using available information and data with the expectation that additional monitoring would accompany the TMDL. This approach allowed stakeholders to proceed with source controls while additional monitoring data were collected to provide a basis for reviewing the TMDL. Since the TMDL was written, additional monitoring data have been collected and source controls have been implemented.

This 5-year review of the 2002 TMDL (DEQ 2002) includes a summary of subbasin characteristics and a review of the TMDL, its pollutant targets, load capacity and load allocations, and any other aspects of the TMDL pertinent for this review. This review also includes an update of beneficial use support status, a summary and analysis of current water quality data, and a review of implementation activities. The goals of the 5-year review are to answer the following questions:

1. What is the trend in water quality parameters in the nearshore waters of Lake Pend Oreille?
2. The TMDL states nearshore water of Lake Pend Oreille shall be free of excess nutrients that produce excess slime. Is this objective being met?
3. How do the water quality targets in the TMDL relate to productivity in the nearshore waters of Lake Pend Oreille?
4. The TMDL assumes that the dominant factor affecting nearshore water quality is loading from the immediate nearshore drainage area, not from tributaries. Is this assumption valid?
5. What practices have been implemented to reduce pollutants from entering the lake?

2 Subbasin at a Glance

Lake Pend Oreille is a 329 square kilometer (km^2) (81,297 acre) lake with mean and maximum depths of 164 meters (m) (538 feet) and 357 m (1,171 feet), respectively, making it the largest and deepest natural lake in Idaho and the 8th largest lake in the US (by volume) (USGS 1996). Lake Pend Oreille is in the Pend Oreille Lake subbasin (hydrologic unit code 17010214) in northern Idaho (Figure 1). The Pend Oreille Lake subbasin is located in Bonner and Kootenai Counties. It lies within the Northern Rocky Mountain physiographic region to the west of the Bitterroot Mountains. The Pend Oreille Lake subbasin consists of Lake Pend Oreille and the Pend Oreille River to the Washington border. The subbasin drains 62,700 km^2 of land (Harenberg et al. 1994). Lake Pend Oreille and the Pend Oreille River drain 59,300 km^2 and 34,400 km^2 of land, respectively. Within the subbasin, 68.8% of the land is within the Priest River watershed (Harenberg et al. 1994).

The terms “subbasin” and “watershed” are used throughout this section and the rest of the document to describe specific areas on the land. Subbasin refers to the land area that drains into Lake Pend Oreille and the Pend Oreille River. Subbasins are larger than watersheds, are defined consistently throughout the US using 4th-field hydrologic codes, are identified in Idaho’s water quality standards, and contain many watersheds within them. DEQ uses subbasins for tracking and sorting Idaho’s waters. The term “watershed” is used in this document to refer to the land area that drains into Lake Pend Oreille and includes the lake itself. The Lake Pend Oreille watershed is one of the many watersheds within the Pend Oreille Lake subbasin.

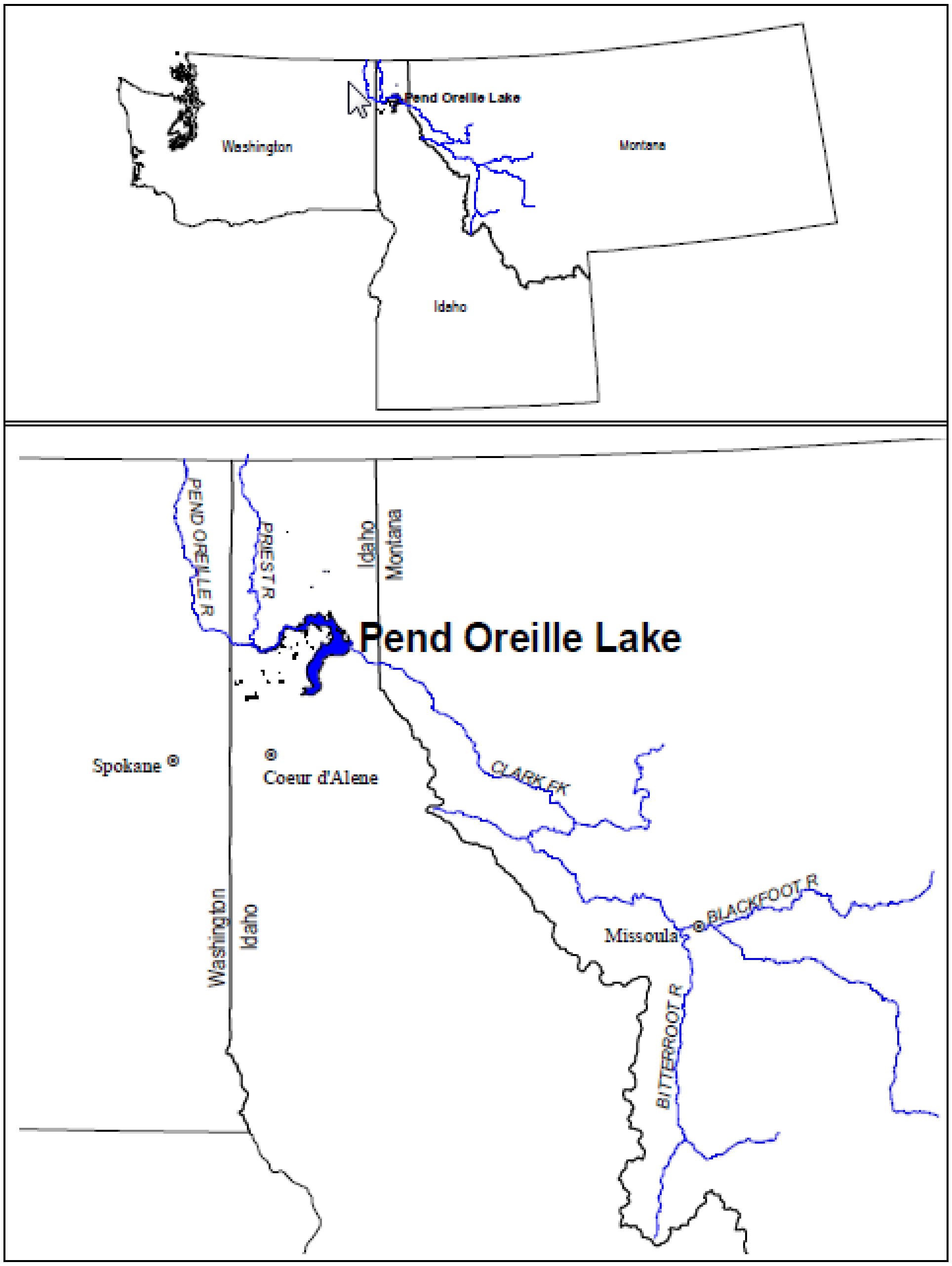


Figure 1. Location of Lake Pend Oreille.

This section presents physical, biological, and cultural characteristics specific to the subbasin. For additional information about the subbasin, see the *Clark Fork/Pend Oreille Sub-Basin Assessment and Total Maximum Daily Loads* (DEQ 2001), the *Pend Oreille Tributaries Sediment Total Maximum Daily Loads* (DEQ and EPA 2007), and the 2002 TMDL (DEQ 2002).

2.1 Physical and Biological Characteristics

Watershed characteristics relevant to pollutants impairing beneficial uses are assessed by describing physical and biological characteristics of the watershed, including a description of the hydrology, climate, and unique characteristics of the individual water bodies in the watershed. To evaluate the Lake Pend Oreille watershed for sensitivity to activities that may impair beneficial uses, many of the subbasin characteristics are identified and described using GIS, census data, biological data, soils, and geologic data.

2.1.1 Hydrology

The headwaters within the subbasin are in the Cabinet, Selkirk, and Bitterroot Mountains, and these tributaries empty into Lake Pend Oreille. The Clark Fork River is the principal tributary to Lake Pend Oreille, contributing about 92% of the annual inflow (Frenzel 1991). The Lower Clark Fork subbasin is comprised of the upper Clark Fork, Flathead, and lower Clark Fork watersheds. Other significant tributaries to Lake Pend Oreille include the Pack River, Sand Creek, and Lightning Creek. Numerous intermittent streams also enter at various points around the lake. The Pend Oreille River is the only surface outflow from the lake; it flows 26 miles west into Washington where it eventually meets the Columbia River.

The Pend Oreille River is impounded by Albeni Falls Dam near the Washington-Idaho border. The dam controls the summer pool level of Lake Pend Oreille between June and September. It is estimated that Lake Pend Oreille contributes 3.8–7% of the total recharge for the Spokane Valley-Rathdrum Prairie aquifer through the poorly consolidated material left by glacial events along its southern boundary (Frenzel 1991).

Annual runoff in the watersheds of the Pend Oreille tributaries is produced primarily by melting snow, with peak flows typically occurring in May or June, but occasionally in April or July. Tributaries to the lake may experience one or more runoff events. Midwinter rain-on-snow events can result in a rapid snow melt, and in some years the peak flow from tributary watersheds occurs during these events. The main body of Lake Pend Oreille seldom freezes due to considerable latent heat content (Corsi et al. 1998).

2.1.2 Lake Characteristics

Lake Pend Oreille is most often divided it into two basins: the deep and relatively poorly flushed southern end and the relatively well-flushed, shallow northern basin. The southern basin contains approximately 95% of the lake’s volume. Lake Pend Oreille is composed of two different depth regimes: the open water zone and the nearshore zone. The deep open water zone represents the open waters of the lake and accounts for about 89% of the lake’s volume. The shallower, nearshore zone is the band of water along the shore where light frequently penetrates to the lake bottom. This nearshore zone accounts for about 11% of the lake’s volume (EPA 1993). According to Hoelscher et al. (1993), the nearshore zone encompasses depths less than 16 m (52.5 feet) and at that time was classified as meso-oligotrophic, meaning it was between nutrient-poor (oligotrophic) and moderately fertile (mesotrophic). Most of the annual inflow moves westward across the northern basin with only limited recharge to the southern basin (Woods 1991a). Mean hydraulic retention time in the northern region of the lake is less than a year, while mean hydraulic retention time in the southern region of the lake is greater than 10 years (Falter et. al. 1992).

In 1996, the US Geological Survey collected data to create a bathymetry map of Lake Pend Oreille and the Pend Oreille River (Appendix A).

2.1.3 Climate

The climate in the region is characterized by relatively dry summers and cold, wet winters. To provide a general representation of the climatic conditions in the subbasin, data from the Western Regional Climate Center, Sandpoint Experiment Station (#108137) near Sandpoint, Idaho, are summarized. These data are based on data collected between 1981 and 2010. Average maximum temperatures range from 21 to 28 °C (70–82 °F) and in winter range from 0 to 8 °C (32–46 °F). Average annual precipitation in the area is 81 centimeters (32 inches) with average seasonal snowfall of 178 centimeters (70 inches) (WRCC 2014).

2.1.4 Fisheries

Diverse fish species are present in Lake Pend Oreille and its tributaries. The larger native fish present are Westslope Cutthroat Trout (*Oncorhynchus clarki lewisi*), Bull Trout (*Salvelinus confluentus*), and Mountain Whitefish (*Prosopium williamsoni*). Non-native sport fish that have been stocked or found their way into the lake over the years include Kokanee Salmon (*Oncorhynchus nerka*), Rainbow Trout (*Oncorhynchus mykiss*), Lake Whitefish (*Coregonus clupeaformis*), Pacific Lamprey (*Entosphenus tridentate*), Brook Trout (*Salvelinus fontinalis*), Brown Trout (*Salmo trutta*), Lake Trout (*Salvelinus namaycush*), Northern Pike (*Esox lucius),* Walleye (*stizosteion vitreum),* Yellow Perch (*Perca flavescens*), Black Crappie (*Pomoxis nigromaculatus*), Largemouth Bass (*Micropterus salmoides*), Smallmouth Bass (*Micropteršu dolomieu),* Brown Bullhead (*Ameiurus nebulosus*), Pumpkinseed Sunfish (*Lepomis gibbosus*), and Northern Pikeminnow (*Ptychocheilus oregonensis*). Other fishes include Large-Scale Sucker (*Catostomus macrocheilus*), Longnose Sucker (*Catostomus catostomus*), Peamouth Chub (*Mylocheilus caurinus*), Redside Shiner (*Richardsonius balteatus*), Slimy Sculpin (*Cottus cognatus*), Torrent Sculpin (*Cottus rhotheus*), Longnose Dace (*Rhinichthys cataractae*), Pygmy Whitefish (*Prosopium coulteri*), and Tench (*Tinca tinca*).

In 2006, the Idaho Department of Fish and Game started a predator control program targeted to Lake Trout that were preying on Kokanee Salmon. Prior to 2006, the mature Kokanee populations were hovering at or near numbers that were not sustainable. Due to an aggressive angler-incentive program ($15/head bounty) and commercial netting to remove the Lake Trout, the Lake Trout population was suppressed to where it no longer depresses the Kokanee population. In 2013, over 1.2 million mature Kokanee survived to spawn in 2013 (IDFG 2013). Also contributing to Kokanee resurgence is the significant drop in the freshwater mysid shrimp population in 2012 and 2013. Mysid shrimp compete with kokanee for the zooplankton food source. In 2012, the mysid shrimp population nearly collapsed and their density was almost 95% lower than the long-term average dating back to 1973. In 2013, the density remained low (IDFG 2013).

In the subbasin, only adfluvial populations of Bull Trout are known to exist; their movements are now limited by Albeni Falls Dam and Cabinet Gorge Dam. Adfluvial Bull Trout spawn in tributary waters where the juveniles rear for 1 to 4 years before migrating to the lake where they grow to maturity. In 1998, the US Fish and Wildlife Service listed the Bull Trout as a threatened species under the Endangered Species Act. Instream habitat requirements make Bull Trout exceptionally sensitive to activities that directly or indirectly affect stream channel integrity and natural flow patterns, including ground water flow (Corsi et al. 1998).

The Lake Pend Oreille watershed is identified as a key watershed in the *State of Idaho Bull Trout Conservation Plan* (Idaho Office of the Governor 1996). In 1998, the Technical Advisory Team for the Pend Oreille Watershed Advisory Group (WAG) prepared the *Lake Pend Oreille Key Subbasin Bull Trout Problem Assessment* report to serve as a technical guide to develop and prioritize conservation and/or recovery actions in the Lake Pend Oreille watershed (Corsi et al. 1998). The Bull Trout conservation plan is a guiding force in all water quality management strategies targeted for the watershed, including TMDL implementation in the watershed. In 2010, the US Fish and Wildlife Service designated critical habitat for Bull Trout throughout their US range, and the Lake Pend Oreille and Pend Oreille River watersheds are listed as critical habitat (USFWS 2010).

2.2 Cultural Characteristics

In the 2010 census, the population of Bonner County was 40,877 people. Its population grew 38% from 1990 to 2000 and 11% from 2000 to 2010; it is still one of the fastest growing counties in Idaho (US Census Bureau 2010). Bonner County has approximately 3,000 waterfront parcels (excluding state and federal lease lots). There are 12,106 acres of private waterfront property with lot/parcel sizes ranging from 505 acres to 522 square feet; the average lot/parcel size is approximately 1/2 acre (Bonner County Assessor's database records 2012).

According to a 2008 University of Idaho survey of 267 nearshore property owners on Lake Pend Oreille, lakeshore residents place a high value on recreation in and around Lake Pend Oreille, noting the following frequent activities: fishing, swimming, motorized watercraft use, and wildlife viewing. According to the same survey, property owners are "quite" to "extremely" interested in water quality issues on the lake and they place "quite" to "extreme" importance on water quality issues. Homeowners "strongly believe" that the lake needs protecting and individuals are responsible for protecting lake water quality; however, they are less than "moderately" knowledgeable about water quality issues (Coombs and Sanyal 2008).

3 TMDL Review and Status

The 2002 TMDL (DEQ 2002) addresses shoreline loading, or direct runoff from the land immediately surrounding the lake, and loads from septic seepage through ground water. It does not address loading from tributaries or from other point or nonpoint sources. However, DEQ pursues implementation to reduce loading from other sources, point and nonpoint.

3.1 Numeric Targets Used in the TMDL

Water quality standards designate the uses of a water body (e.g., aquatic life, recreation) and establish water quality criteria necessary to protect those uses. Standards may be expressed as numeric water quality criteria or as narrative standards for the support of beneficial uses. TMDLs are developed to meet applicable water quality standards, whether numeric or narrative in nature. In Idaho's "Water Quality Standards" (IDAPA 58.01.02), Lake Pend Oreille is designated for cold water aquatic life, salmonid spawning, primary contact recreation, domestic water supply, agricultural water supply, industrial water supply, wildlife habitat, and aesthetics.

The State of Idaho water quality standards applicable to the Lake Pend Oreille nutrient TMDL include the following narrative description for unacceptable levels of nutrients:

> Surface waters of the state shall be free from excess nutrients that can cause visible slime growth or other nuisance aquatic growths impairing designated beneficial uses. (IDAPA 58.01.02.200.06)

Because this applicable water quality standard is narrative, it was necessary to develop a numeric water quality target for the TMDL for specific water bodies. The numeric target represents a measurable endpoint that is equivalent to attaining the narrative standard.

The TMDL set TP targets based on the assumption that the potential impairment to the nearshore waters is as periphyton (attached bottom algae) in the nearshore zone of the lake. Nitrogen and phosphorus contribute to algae growth, and either can be limiting depending on their ratio. Past studies indicate that phosphorus most often limits algae and aquatic plant growth in Lake Pend Oreille, with phosphorus being the primary or exclusive limiting nutrient for algae growth at sites sampled. It is challenging to conclusively identify the threshold concentration of nutrients that causes visible slime growth and other nuisance aquatic growths. An objective of this analysis is to validate the targets set in the TMDL.

The TMDL set a primary target of 9 µg/L to represent an average total phosphorus concentration throughout the nearshore waters of the lake. The TMDL set an action threshold target of 12 µg/L to represent an instantaneous concentration that directs future monitoring to evaluate potential impairment of the monitoring site.

Falter et al. (1992) collected TP and periphyton samples at 17 nearshore locations for critical summer periods in 1989 and 1990. No correlation was found between TP and density of periphyton growth. Because this correlation was not found, phosphorus data were evaluated independently to identify any trends or distributions in the data. The TMDL targets established for the Lake Pend Oreille nearshore TMDL were established using a percentile distribution of existing data from Falter et. al. (1992) and by comparing those values to other values included in literature and to targets used in other nutrient-related TMDLs as representing conditions not impaired by eutrophication. The TMDL set a primary target of 9 micrograms per liter (µg/L) to represent an average TP concentration throughout the nearshore waters of the lake. The TMDL set an action threshold target of 12 µg/L to represent an instantaneous concentration that directs future monitoring to evaluate potential impairment of the monitoring site. The threshold target may also prompt control actions to prevent impairment and restore and maintain water quality standards.

3.2 Control and Monitoring Points

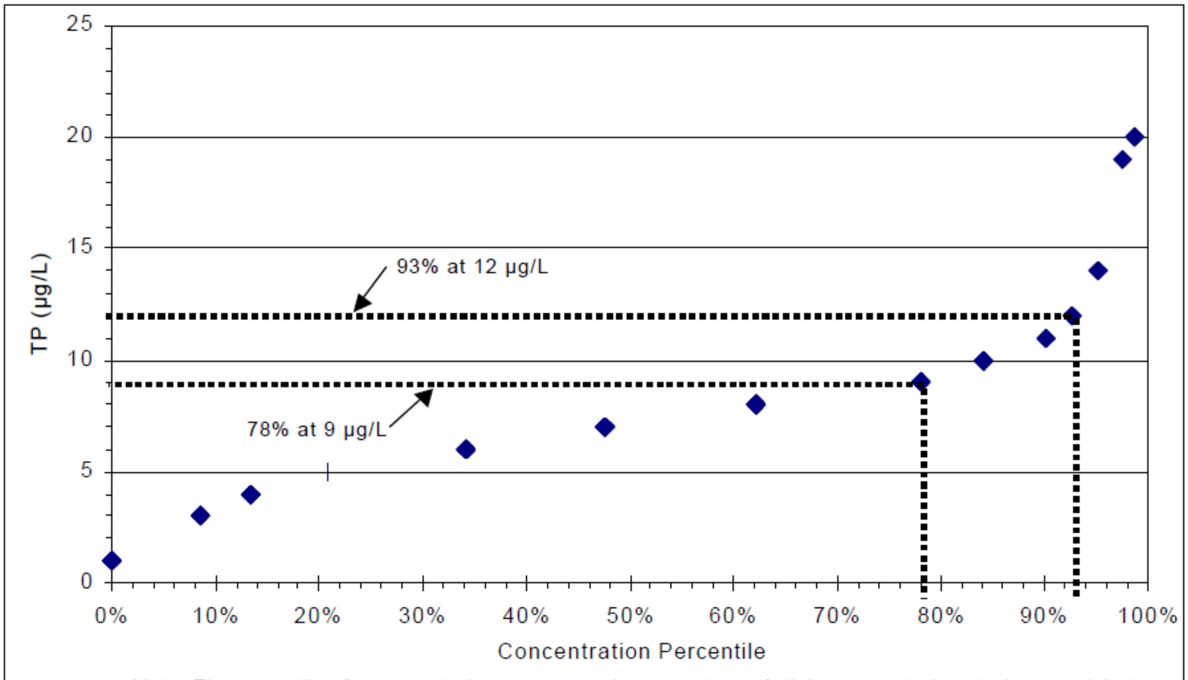
The 9 µg/L target set in the 2002 TMDL (DEQ 2002) is assumed to be a surrogate to the narrative standard for nutrients that is protective of beneficial uses of the entire nearshore waters of the lake. This section of the report will address only whether the TMDL target of 9 µg/L has been met based on a statistical analysis of existing data. The premise that the TMDL target of 9 µg/L, as a surrogate for a narrative nutrient standard, is protective of beneficial use support will be evaluated in later sections of this report when evaluating water quality and productivity data collected from the nearshore waters of the lake.

This section of the report addresses only whether the TMDL target of 9 µg/L has been met based on a statistical analysis of existing data. The premise that the TMDL target of 9 µg/L as a surrogate for a narrative nutrient standard is protective of beneficial use support will be evaluated in later sections of this report.

To determine whether the TMDL target of 9 µg/L is currently being met, a binomial distribution method was used as a statistical approach to evaluate the *probability* of the TMDL target being exceeded based on the number of samples taken. The probability generated by the binomial distribution model is the probability of the nearshore area of the lake meeting the 9 µg/L TMDL target.

3.2.1 Percentile Distribution of Total Phosphorus

In the 2002 TMDL, TP concentrations (from data collected by Falter 2004) were ranked and graphed by the associated percentile of occurrence. Two inflection points were observed at the 78th and 93rd percentiles, which correlated with TP concentrations of 9 µg/L and 12 µg/L, respectively (Figure 2). The inflection points were chosen because there were significant relative increases in the TP concentration beyond these points. Therefore, the values of 9 µg/L and 12 µg/L represented thresholds, beyond which a noticeable change in water quality conditions would occur in the nearshore waters of the lake. As such, the TMDL TP target for the overall nearshore waters of the lake was represented by the first inflection point of 9 µg/L. The second target of 12 µg/L was established as an action threshold to assist in monitoring the nearshore conditions.



Note: The percentile of a concentration represents the percentage of all the concentrations in the record that are equal to or less than that concentration.

Figure 2. Distribution of the occurrence of observed total phosphorus concentrations for all nearshore areas of the lake (using Falter 1992 data) (Source: DEQ 2002).

It is risky to rely solely on the percent of occurrence of samples meeting the TMDL target of 9 µg/L because the raw data have a degree of uncertainty associated with them. Uncertainty is due to the following factors: water quality samples are taken from a variety of water quality conditions; concentrations of the pollutants can vary naturally; errors can be made in the measurements; and occasional violation of a numeric standard may not be an indication of impairment (WDOE 2002). The variability introduced by these factors can result in situations of false positive or false negative errors. A false positive error would be when a water body is supporting its beneficial uses, but a water quality standard or TMDL target is assumed to be exceeded. This occasional exceedance may not be detrimental to the beneficial use. A false negative error would be when the lake is not supporting its beneficial uses, but a numeric standard or TMDL target has not been exceeded.

To minimize the occurrence of false negative and false positive errors, and to better understand whether the TMDL target is being met, a statistical approach using the binomial distribution method was used to analyze the target for this review. The binomial distribution method is a nonparametric analysis that does not rely on a percentile distribution of the raw data; rather, it evaluates the probability of true exceedance of the water quality criteria for a given pollutant based on sample size. The binomial distribution method statistically determines the probability that the water body as a whole is impaired (WDOE 2002). For example, instead of determining impairment based on 10% of the samples exceeding a water quality standard, the binomial distribution method determines the probability of 10% exceedance of the water quality standard in the water body as a whole. It does this by setting an acceptable number of samples that meet the water quality criteria to give relative confidence that the water body is meeting the criteria. Conversely, it sets the minimum number of exceedances of water quality criteria for relative confidence that the water body is not meeting criteria and is thus impaired.

Using the binomial distribution method, an acceptable number of samples was calculated with a 90% confidence. In this case, the TMDL target is used in place of numeric water quality criteria. If the data set stays within the acceptable number of samples below 9 μg/L, one can conclude with 90% confidence that the TMDL target of 9 μg/L is being met. Conversely, there are a minimum number of exceedances of the 9 μg/L target; if met or exceeded, one can conclude with 90% confidence that the TMDL target is not being met. The minimum number of exceedance was determined using the most recent TP data (2006–2014). Three scenarios were evaluated: (1) data from all nearshore waters of Lake Pend Oreille, (2) data from the nearshore stations in the northern region of the lake; and (3) data from the nearshore stations in the mid/southern region of the lake. The binomial distribution outcomes for the three scenarios are listed in Table 1.

The binomial distribution analysis of the whole nearshore lake data determined the minimum number of TMDL target exceedances was not exceeded; therefore, the TMDL target was met during the 2006–2014 time period. The binomial distribution analysis of data from the north versus mid/south end of the lake concluded the nearshore waters in the northern part of the lake have not met the TMDL target of 9 μg/L; however, the TMDL target was met in the mid/south end of the lake during the 2006–2014 time period.

Table 1. Binomial distribution parameters whether the TMDL target of 9 µg/L has been met (at the 90 percent confidence interval).

Nearshore Areas (2006–2014)	Number of Samples	Minimum Number of Allowable TMDL Target Exceedances	Number of Actual TMDL Target Exceedances	TMDL Target met?
All	164	21	20	Yes
Northern lake	60	9	12	No
Mid/southern lake	104	14	8	Yes

3.3 Comparison with Other North Idaho Lakes

To determine if the the 9 µg/L target may be appropriate for protection of beneficial uses a comparison of median TP concentrations in other north Idaho lakes was made. DEQ compiled baseline study data collected by DEQ and by the Citizen Volunteer Monitoring Program for Upper Priest, Spirit, Hauser, Cocolalla, and Upper Twin Lakes to compare TP ranges and trophic status (DEQ et al. 2011). While differences in limnology and trophic state exist between these lakes and Lake Pend Oreille, this data compilation was useful in demonstrating practical ranges of TP concentrations for consideration when setting a lake-specific water quality target for Lake Pend Oreille.

Twin, Hauser, and Cocolalla Lakes have median TP concentrations well above 9 µg/L; however, these lakes do not support their beneficial uses due to the presence of nuisance algae growth and occasional violations of dissolved oxygen water quality criteria. Upper Priest and Spirit Lakes were on the lower spectrum of TP concentrations in these north Idaho lakes, and they are comparable to the desired condition in Lake Pend Oreille. While Spirit Lake has more human activity around the lake and experiences low dissolved oxygen in the lower 10 m of the lake, it is fully supporting its beneficial uses. Spirit Lake had a median TP concentration of 10 µg/L. Upper Priest Lake, with little human influence, had median TP concentrations of 5 µg/L. Upper Priest Lake is fully supporting its beneficial uses.

3.4 Load Capacity

Through a modeling exercise, a load capacity for the entire nearshore waters of the lake was determined under critical summer conditions in the 2002 TMDL. Load capacities of six individual nearshore water cells were calculated using the water quality target of 9 µg/L and steady-state mass balance equations that considered phosphorus loading from nearshore sources as well as loss across the boundary to the open waters of the lake and to natural decay and growth. The six cells were chosen based on the study by Falter (1992). From his study, water quality data, location, depth of nearshore waters, and land use of watershed draining to the site were used to parameterize the mass-balance equations and determine several of the major input characteristics of the equations. The cells were assumed to appropriately represent typical conditions occurring in the nearshore area. The load capacities of the six cells were then extrapolated to the entire nearshore area to identify an overall loading limit for the nearshore drainage area. Phosphorus export coefficients were part of the calculations to determine the existing load for land uses draining to the nearshore cells. Site-specific export coefficients for the Lake Pend Oreille watershed were based on those derived by Hoelscher et al. (1993). The width of the boundary of the nearshore drainage area used to calculate the load capacity in the TMDL is variable due to topographic variability. However, the TMDL states that width is approximately 0.9 miles immediately adjacent to the shoreline.

No point source discharges to the defined nearshore waters of Lake Pend Oreille were included by this TMDL. Therefore, the wasteload allocation is zero, and the entire TMDL for the nearshore waters of Lake Pend Oreille is available for the load allocation. The load allocation for the nearshore waters is a gross allocation of 4,588 pounds/season, applicable to all nonpoint and background sources in the nearshore drainage of the lake. (The TMDL does not include internal lake loading from the open water waters.)

The load capacities of the nearshore cells were calculated using the TMDL target of 9 μg/L and steady-state mass balance equations based on actual data from the lake. Based on these calculations, the load capacity and load allocations in the TMDL are appropriate for nonpoint and background sources in the nearshore drainage of the lake.

3.5 Margin of Safety

The margin of safety was included in the 2002 TMDL implicitly through a series of conservative assumptions related to estimating the existing load for the TMDL. The conservative assumptions include the following:

- Use of lower phosphorus export coefficients for calculating phosphorus loading from land uses draining to the nearshore cells. Site-specific export coefficients for the Lake Pend Oreille watershed were based on those derived by Hoelscher et al. (1993). These values are lower than other available export coefficients for similar land uses. By using the more conservative land-use coefficients, it is assumed the incoming load to the corresponding conditions is lower, resulting in a lower load capacity.
- Use of conservative assumptions concerning initial mixing within nearshore cells. In this TMDL, the critical conditions established were conservative. The TMDL assumes persistent summer, quiescent conditions with no wind mixing and no lake-to-cell mixing.

3.6 Discussion

A binomial distribution method was used in this 5-year review analysis to determine whether the TMDL target of 9 μg/L was met. The results of the analysis showed the following:

- The overall nearshore waters of Lake Pend Oreille meet the TMDL targets. However, this is not an accurate representation of distinct nearshore regions in the lake.
- To provide a more accurate representation of distinct nearshore regions in the lake, the northern region of the lake was evaluated separate from the mid/southern end of the lake. In this case, the northern nearshore waters of the lake have not met the TMDL target while the mid/southern nearshore regions of the lake have.
- The binomial distribution method evaluates only whether the TMDL target of 9 μg/L is being met. It does not evaluate whether beneficial uses in the nearshore waters of Lake Pend Oreille are supported. Analysis of water quality and productivity data is necessary to determine whether the target is protective of beneficial uses.

Another line of evidence that the 9 μg/L target may be appropriate for protection of beneficial uses lies in a comparison of median TP concentrations in other north Idaho lakes, specifically Upper Priest and Spirit Lakes, which are supporting their beneficial uses and have median TP concentrations close to or below 9 μg/L.

The load capacities put forth in the TMDL for nearshore water in the lake were derived from the TMDL target of 9 μg/L. The TMDL was written to represent average loading limits for the entire nearshore area of the lake, with loading based solely on runoff from nearshore land and septic seepage through ground water immediately adjacent to the lake. However, the loading calculations did not take into account other loading sources to the lake. The following sources were not considered in the TMDL:

- The Clark Fork River
- The Pack River
- Other tributaries to the lake
- Specific stormwater from the cities of Kootenai, Ponderay, Hope, and Bayview

The loads from the above sources are significant, particularly during spring runoff, where the highest loading of nutrients has been observed (DEQ 2010). Most of the sources listed above are in the northern region of the lake. The northern region of the lake has a 1-year hydraulic retention time; therefore, loading in spring runoff from these sources would remain in the lake during the summer months. The *Montana and Idaho Border Nutrient Load Agreement Technical Guidance* (TSWQC 2001) directly addresses loading from the Clark Fork River and addresses load reduction measures that should be taken. The *Pack River Nutrients Total Maximum Daily Load* (DEQ 2007) directly addresses nutrient loading from the Pack River and provides load reduction requirements from identified sources in the watershed.

Stormwater loads from the cities of Kootenai, Ponderay, Hope, and Bayview may have been only partially accounted for in the TMDL. The width of the boundary of the nearshore drainage area used to calculate the load capacity is approximately 0.9 miles immediately adjacent to the shoreline. This band would include runoff and nutrient loading from the cities of Kootenai and Ponderay. However, it is unclear whether it included the cities of Kootenai, Ponderay, Hope, and Bayview beyond the 0.9-mile distance but that deliver stormwater directly to Kootenai Bay. This source of loading should be prioritized for TMDL implementation (section 10).

While the TMDL targets are believed to be protective of beneficial uses in the nearshore waters of Lake Pend Oreille, further evaluation of nearshore productivity and water quality in the different regions of the lake is needed to understand beneficial use support. This effort provides a better understanding of the lake’s true assimilative capacity for nutrients and realistic water quality conditions related beneficial use support. Water quality and productivity data are evaluated in sections 8 and 9 to better determine conditions of beneficial use support in the nearshore waters.

4 Beneficial Use Status

Idaho water quality standards require that surface waters of the state be protected for beneficial uses, wherever attainable (IDAPA 58.01.02.050.02). These beneficial uses are interpreted as existing uses, designated uses, and presumed uses. The *Water Body Assessment Guidance* (Grafe et al. 2002) provides a detailed description of beneficial use identification for use assessment purposes.

Existing uses under the CWA are "those uses actually attained in the water body on or after November 28, 1975, whether or not they are included in the water quality standards." Designated uses are specifically listed for water bodies in Idaho in tables in the Idaho water quality standards (see IDAPA 58.01.02.010.25 and .02.109–160).

Undesignated uses are to be designated. In the interim, and absent information on existing uses, DEQ presumes that most waters in the state will support cold water aquatic life and either primary or secondary contact recreation (IDAPA 58.01.02.101.01). To protect these so-called "presumed uses," DEQ applies the numeric cold water aquatic life criteria and primary or secondary contact recreation criteria to undesignated waters.

4.1 Beneficial Uses

The beneficial uses of the water bodies included in the TMDL are provided in Table 2.

Table 2. Beneficial uses of TMDL water bodies.

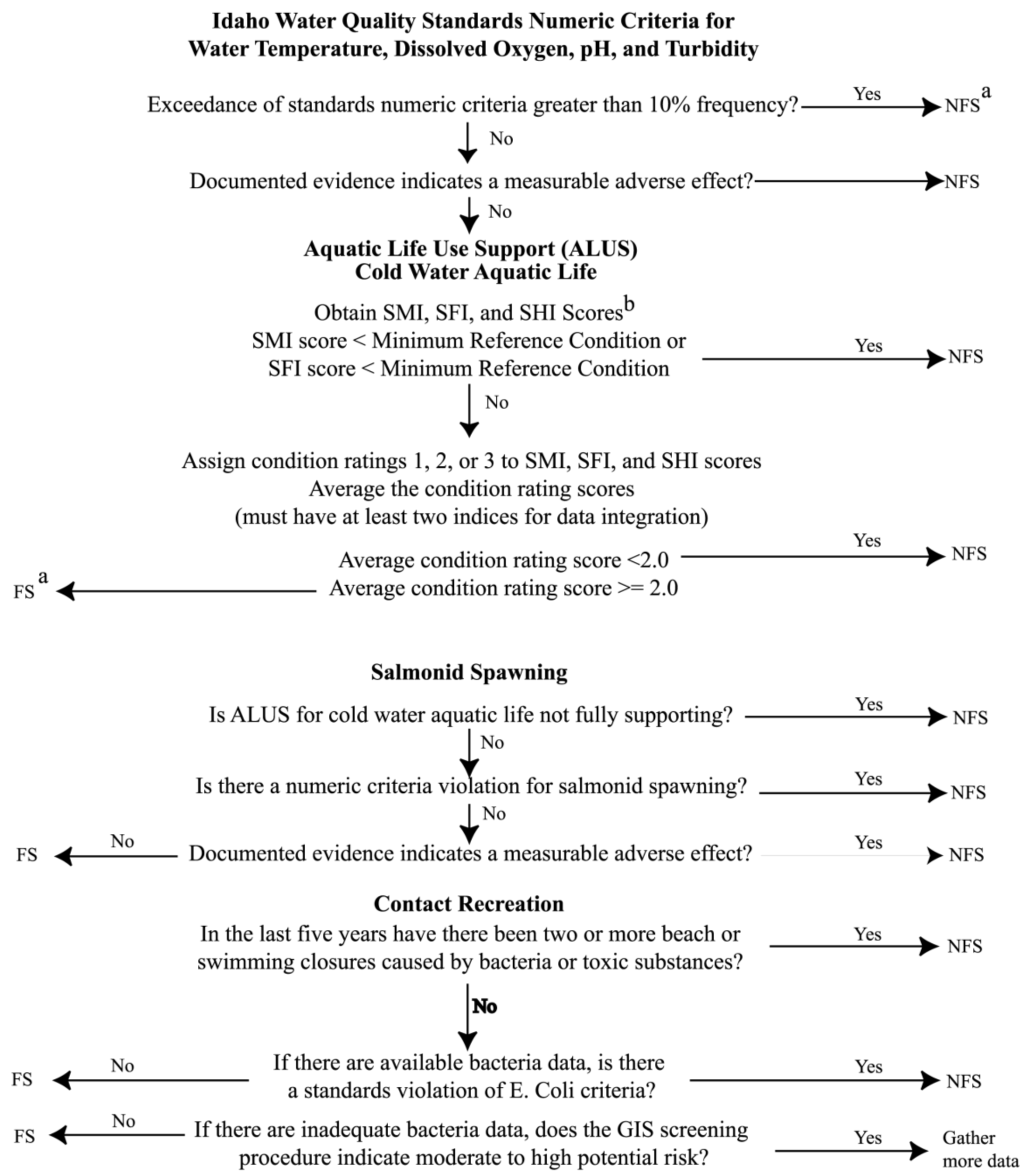
Assessment Unit Name	Assessment Unit Number	Beneficial Uses	Type of Use
Lake Pend Oreille	ID17010214PN018L_0L	Domestic water supply, cold water aquatic life, salmonid spawning, primary contact recreation	Designated

Beneficial uses are protected by a set of criteria, which include *numeric* criteria for pollutants such as bacteria, dissolved oxygen, pH, ammonia, temperature, and turbidity, and *narrative* criteria for pollutants such as sediment and nutrients (IDAPA 58.01.02.250–251). Table 3 includes the most common numeric criteria used in TMDLs; Figure 3 provides an outline of the assessment process for determining support status of the beneficial uses of cold water aquatic life, salmonid spawning, and contact recreation.

Table 3. Common numeric criteria supportive of beneficial uses in Idaho water quality standards.

Parameter	Primary Contact Recreation	Secondary Contact Recreation	Cold Water Aquatic Life	Salmonid Spawning[a]
Water Quality Standards: IDAPA 58.01.02.250–251				
Bacteria				
Geometric mean	<126 *E. coli*/100 mL[b]	<126 *E. coli*/100 mL	—	—
Single sample	≤406 *E. coli*/100 mL	≤576 *E. coli*/100 mL	—	—
pH	—	—	Between 6.5 and 9.0	Between 6.5 and 9.5
Dissolved oxygen (DO)	—	—	DO exceeds 6.0 milligrams/liter (mg/L)	**Water Column DO**: DO exceeds 6.0 mg/L in water column or 90% saturation, whichever is greater **Intergravel DO**: DO exceeds 5.0 mg/L for a 1-day minimum and exceeds 6.0 mg/L for a 7-day average
Temperature[c]	—	—	22 °C or less daily maximum; 19 °C or less daily average **Seasonal Cold Water**: Between summer solstice and autumn equinox: 26 °C or less daily maximum; 23 °C or less daily average	13 °C or less daily maximum; 9 °C or less daily average **Bull Trout**: Not to exceed 13 °C maximum weekly maximum temperature over warmest 7-day period, June–August; not to exceed 9 °C daily average in September and October
Turbidity	—	—	Turbidity shall not exceed background by more than 50 nephelometric turbidity units (NTU) instantaneously or more than 25 NTU for more than 10 consecutive days.	—
Ammonia	—	—	Ammonia not to exceed calculated concentration based on pH and temperature.	—
EPA Bull Trout Temperature Criteria: Water Quality Standards for Idaho, 40 CFR Part 131				
Temperature	—	—	—	7-day moving average of 10 °C or less maximum daily temperature for June–September

[a] During spawning and incubation periods for inhabiting species
[b] *Escherichia coli* per 100 milliliters
[c] Temperature exemption: Exceeding the temperature criteria will not be considered a water quality standard violation when the air temperature exceeds the ninetieth percentile of the 7-day average daily maximum air temperature calculated in yearly series over the historic record measured at the nearest weather reporting station.



[a] FS = fully supporting, NFS = not fully supporting

[b] SMI = Stream Macroinvertebrate Index, SFI = Stream Fish Index, SHI = Stream Habitat Index

Figure 3. Steps and criteria for determining support status of beneficial uses in wadeable streams (Grafe et al. 2002).

4.2 Pollutant/Beneficial Use Support Status Relationships

Most of the pollutants that impair beneficial uses in lakes are due to land/water disturbances caused by humans. The most common pollutants in northern Idaho lakes are dissolved oxygen, sediment, nutrients, and floating, suspended, or submerged matter (nuisance algae).

4.2.1 Dissolved Oxygen

Oxygen is necessary for the survival of most aquatic organisms and essential to stream or lake purification. Dissolved oxygen (DO) is the concentration of free (not chemically combined) molecular oxygen (a gas) dissolved in water, usually expressed in milligrams per liter (mg/L), parts per million, or percent of saturation. Oxygen is considered to be moderately soluble in water. A complex set of physical conditions that include atmospheric and hydrostatic pressure, turbulence, temperature, and salinity affect the solubility.

DO concentrations of 6 mg/L and above are considered optimal for aquatic life. When DO levels fall below 6 mg/L, organisms are stressed, and if levels fall below 3 mg/L for a prolonged period, these organisms may die. Oxygen levels that remain below 1–2 mg/L for a few hours can result in large fish kills. DO levels below 1 mg/L are often referred to as hypoxic, while anoxic refers to conditions with no measurable DO. Juvenile aquatic organisms are particularly susceptible to the effects of low DO due to their high metabolism and low mobility (they are unable to seek more oxygenated water).

DO reflects the health and balance of the aquatic ecosystem. Oxygen is produced during photosynthesis and consumed during plant and animal respiration and decomposition. Oxygen enters water through plant photosynthesis and directly from the atmosphere. Where water is more turbulent (e.g., riffles, cascades), the oxygen exchange is greater due to the greater surface area of water coming into contact with air. The process of oxygen entering water is called aeration.

Water bodies with significant aquatic plant communities can have significant DO fluctuations throughout the day. An oxygen sag will typically occur once photosynthesis stops at night and plant respiration/decomposition processes deplete DO concentrations in the water. Oxygen will start to increase again as photosynthesis resumes with daylight.

Temperature, flow, nutrient loading, and channel alteration all impact DO. Colder waters hold more DO than warmer waters. Oxygen is necessary to help decompose organic matter in the water and on the lakebed. Nutrient-enriched waters have a higher biochemical oxygen demand due to the amount of oxygen required for organic matter decomposition and other chemical reactions. This oxygen demand can result in lower lake DO levels, particularly near the lake bottom.

4.2.2 Sediment

Both suspended (floating in the water column) and lakebed sediment can have negative effects on aquatic life communities. Many fish species can tolerate elevated suspended sediment levels for short periods of time—such as during natural spring runoff—but longer exposures are detrimental. Elevated suspended sediment levels can interfere with feeding behavior (e.g., difficulty finding food due to visual impairment), damage gills, reduce growth rates, and in extreme cases lead to death.

Newcombe and Jensen (1996) reported the effects of suspended sediment on fish, summarizing 80 published reports on streams and estuaries. For Rainbow Trout, physiological stress, which includes reduced feeding rate, is evident at suspended sediment concentrations of 50–100 mg/L when maintained for 14–60 days. Similar effects are observed for other species, although the data sets are less reliable. Adverse effects on habitat, especially spawning and rearing habitat presumably from sediment deposition, were noted at similar concentrations of suspended sediment. Organic suspended materials can also settle to the bottom and, due to their high carbon content, diminish DO through decomposition.

4.2.3 Nutrients

While nutrients are a natural component of the aquatic ecosystem, natural cycles can be disrupted by increased nutrient inputs from anthropogenic activities. Excess nutrients result in accelerated plant growth and can result in a eutrophic or enriched system.

The first step in identifying a water body's response to nutrient flux is to define which of the critical nutrients is limiting. A limiting nutrient is one that normally is in short supply relative to biological needs. The relative quantity of nutrients affects the rate of aquatic biomass production. Either phosphorus or nitrogen may be the limiting factor for algal growth, although phosphorous is most commonly the limiting nutrient in Idaho waters. Ecologically speaking, a resource is considered limiting if the addition of that resource increases growth.

TP is the measurement of all forms of phosphorus in a water sample, including inorganic and organic particulate and soluble forms. In freshwater systems, typically greater than 90% of the TP occurs in organic forms as cellular constituents in the biota or adsorbed (i.e., adhered) to particulate materials, including sediment (Wetzel 1983). The remaining phosphorus is often soluble orthophosphate, a more biologically available form of phosphorus than TP that consequently leads to a more rapid growth of algae. In impaired systems, a larger percentage of the TP is orthophosphate. The relative amount of each form can provide information on the potential for algal growth within the system.

Nitrogen may be a limiting factor at times when a substantial depletion of nitrogen in sediments occurs due to uptake by rooted macrophyte beds. In systems dominated by blue-green algae, nitrogen is not a limiting nutrient since algae can fix nitrogen at the water/air interface. When water nitrogen concentrations are low, this ability gives blue-green algae a competitive advantage over phytoplankton that cannot fix nitrogen.

TN to TP ratios greater than 7 are indicative of a phosphorus-limited system, while those ratios less than 7 are indicative of a nitrogen-limited system. Only biologically available forms of the nutrients are used in the ratios because these are the forms used by the immediate aquatic community.

Nutrients primarily cycle between the water column and sediment through nutrient spiraling. Aquatic plants rapidly assimilate dissolved nutrients, particularly orthophosphate. If sufficient nutrients are available in sediments or the water column, aquatic plants will store an abundance of such nutrients in excess of the plants' actual needs, a chemical phenomenon known as luxury consumption. When a plant dies, the tissue decays in the water column and the nutrients stored within the plant biomass are either restored to the water column or the detritus becomes incorporated into the lakebed sediment. As a result of this process, nutrients (including orthophosphate) that are initially released into the water column in a dissolved form will eventually become incorporated into the lakebed sediment. Once these nutrients are incorporated into the lakebed sediment, they are available once again for uptake by yet another life cycle of rooted aquatic macrophytes and other aquatic plants. This cycle is known as internal nutrient loading and results in the availability of nutrients for later plant growth in higher concentrations downstream.

4.2.4 Sediment–Nutrient Relationship

The linkage between sediment and sediment-bound nutrients is important when dealing with nutrient enrichment problems in aquatic systems. Phosphorus adsorbs to soil through precipitation as calcium carbonate in calcareous soils or through phosphorus sorption by aluminum and iron-oxide minerals. HDR (2007) prepared a thorough literature review of fate and transport of phosphorus in soils, soil sorption isotherms, and fate and transport of phosphorus in ground water. Soil sorption modeling has proven soils have a finite capacity for sorption of phosphorus, with tremendous variability depending on soil type. Soils with a low percentage of calcium carbonate and/or clay particles have a lower affinity to adsorb phosphorus (HDR 2007). Regardless of the soil type, the primary form of phosphorus in soil and runoff is TP, not dissolved phosphorus, because it is bound to soil.

Because phosphorus is primarily bound to particulate matter in aquatic systems, sediment can be a major source of phosphorus to rooted macrophytes and the water column. While most aquatic plants are able to absorb nutrients over the entire plant surface due to a thin cuticle (Denny 1980), bottom sediments serve as the primary nutrient source for most substratum attached macrophytes. The US Department of Agriculture (1999) determined that other than harvesting and chemical treatment, the best and most efficient method of controlling macrophyte growth is by reducing surface erosion and sedimentation.

Sediment acts as a nutrient sink under aerobic conditions because phosphorus adsorbs to soil under aerobic conditions. However, when conditions become anoxic, sediment releases phosphorous into the water column. Nitrogen can also be released, but the mechanism by which it happens is different. The exchange of nitrogen between sediment and the water column is primarily a microbial process controlled by the amount of oxygen in the sediment. When conditions become anaerobic, the oxygenation of ammonia (nitrification) ceases and an abundance of ammonia is produced. This results in a loss of nitrogen oxides to the atmosphere.

Sediment can play an integral role in reducing the frequency and duration of algae blooms in lakes and rivers. In many cases, phytoplankton biomass responds immediately when external sediment sources are reduced. In other cases, the response time is slower, often taking years. Nonetheless, the relationship is important and must be addressed in waters where phytoplankton is in excess.

4.2.5 Floating, Suspended, or Submerged Matter (Nuisance Algae)

Algae are an important part of the aquatic food chain. However, when elevated levels of algae impact beneficial uses, algae are considered a nuisance aquatic growth. The excess growth of phytoplankton (algae is a type of phytoplankton), periphyton, and/or macrophytes can adversely affect aquatic life and recreational water uses. Algal blooms occur where adequate nutrients (nitrogen and/or phosphorus) are available to support growth. In addition to nutrient availability, flow rates, velocities, water temperatures, and penetration of sunlight in the water column all affect algae (and macrophyte) growth. Low-velocity conditions allow algal concentrations to increase because physical removal by transport, scouring, and abrasion does not readily occur.

Increases in temperature and sunlight penetration also result in increased algal growth. When the aforementioned conditions are appropriate and nutrient concentrations exceed the quantities needed to support normal algal growth, excessive blooms may develop.

Water bodies with low nutrient concentrations and a low level of algal growth are said to be oligotrophic. Water bodies with high nutrient concentrations that could potentially lead to a high level of algal growth are said to be eutrophic. The extent of the effect is dependent on both the type of algae present and the size, extent, and timing of the bloom. Nuisance algae blooms appear as extensive layers or algal mats on the surface of the water; they also often create objectionable odors and coloration in water used for domestic drinking water. In extreme cases, algal blooms can also impair recreational water uses due to toxicity.

Cyanobacteria (blue-green algae) blooms appear in summer and fall and can be considered a nuisance in high concentrations. The physical appearance of cyanobacteria blooms can be unsightly, often causing thick green mats along shorelines. In addition, some species can produce toxins (cyanotoxins) that may cause illness and death to animals or humans. The primary target organs for cyanotoxins are the liver and nervous system, but other health effects do occur.

In lakes, algae die and sink slowly through the water column, eventually collecting on the bottom sediments. The biochemical processes that occur as the algae decompose remove oxygen from the surrounding water. Because most of the decomposition occurs within the lower levels of the water column, a large algal bloom can substantially deplete DO concentrations near the lake bottom. Low DO in these areas can lead to decreased fish habitat since fish will not frequent areas with low DO. Both living and dead (decomposing) algae can also affect the pH of the water due to the release of various acid and base compounds during respiration and photosynthesis. Low DO levels caused by decomposing organic matter can also lead to changes in water chemistry and a release of sorbed phosphorus to the water column at the water/sediment interface.

Excess nutrient loading can be a water quality problem due to the direct relationship of high TP concentrations on excess algal growth within the water column, combined with the direct effect of the algal lifecycle on DO and pH within aquatic systems. Therefore, reducing TP inputs to the system can act as a mechanism for water quality improvements, particularly in surface-water systems dominated by blue-green algae. Phosphorus management within these systems can potentially result in improvements in nutrient (phosphorus), nuisance algae, DO, and pH levels.

5 Changes to Subbasin Characteristics

Lake Pend Oreille continues to be an attraction for recreation activities and it is a factor in where people choose to live in north Idaho. Waterfront parcels (excluding state and federal lease lots) are highly valued, and much of the population in Bonner County lives in the greater Sandpoint area.

Growth of the cities of Kootenai and Ponderay on the northern shore of Lake Pend Oreille has necessitated changes to wastewater treatment that is being managed through National Pollutant Discharge Elimination System discharge permit revisions that may also result in water quality improvements in the lake.

As the greater Sandpoint region continues to grow, land use around the rest of the lake has changed only in localized areas. Much of the land around the lake is managed by the US Forest Service and much of the terrain around the rest of the lake is very steep, which precludes development. Since 2009, members of the Lake Pend Oreille Nearshore TMDL Implementation Committee have conducted biennial photo surveys of the nearshore area of the entire lake. Results of the survey have shown development of the nearshore area beyond the greater Sandpoint area has been localized to individual bays and has been slow.

6 Trophic Monitoring Design

Existing data suggest that the trophic status of the nearshore areas of Lake Pend Oreille is changing quicker than the open waters, and development is impacting water quality and productivity in the nearshore waters of the lake (Falter et. al 2001, Falter 2002; DEQ 2002). It also suggests the Pend Oreille River is at risk of water quality degradation. Routine monitoring conducted by DEQ to characterize the biological, chemical, and physical condition of Lake Pend Oreille has been consistent with the goals of the *Montana and Idaho Border Nutrient Load Agreement* (TSWQC 2001). All monitoring conducted by DEQ has followed directives outlined in the *Quality Assurance Project Plan, Lake Pend Oreille and River Trophic Monitoring* (QAPP) (DEQ 2014). Routine monitoring is conducted for the following reasons:

1. To understand trends in water quality and trophic status in the nearshore and open waters of the lake and Pend Oreille River
2. To understand any correlations with water quality and productivity on the lake
3. To assist in determining beneficial use support status of Lake Pend Oreille and the Pend Oreille River
4. To support the 5-year review process for the 2002 TMDL (DEQ 2002)
5. To guide lake management decisions for water quality, including improvement projects on Lake Pend Oreille and the Pend Oreille River

Common in limnological investigations is the determination of status and trends in trophic conditions in a lake. DEQ collects water quality data necessary for evaluating the status and trend in trophic conditions in Lake Pend Oreille using the TN:TP ratio, the Carlson's Trophic Index (Carlson 1977). The TN:TP ratio is an indicator of nitrogen or phosphorus limitation in a lake and it drives the phytoplankton composition in the lake (Smith 1983; Schindler 1977). The trophic indices are based on concentrations of nutrients, chlorophyll *a*, and water clarity.

DEQ conducts routine water quality monitoring on a monthly basis from June through September at a minimum of the 6 locations (out of 17) on Lake Pend Oreille. The locations remain the same throughout the monitoring season. The following is a list of water quality data collected under the routine trophic monitoring program:

- Secchi depth and profiles through the water column of chemical and physical parameters including water temperature, pH, dissolved oxygen, and electrical conductivity.
- A composite of 5 samples taken from equal-depth intervals from the lake surface to a depth as directed by stratification of the site and the depth of the photic zone. Samples are taken to the analytical laboratory for analysis of TN, TP, and chlorophyll *a*.

- If the site is stratified, a grab sample is taken at half the depth between the hypolimnion knee and the lake bottom. Samples are taken to the analytical laboratory for analysis of TN and TP.

Monitoring locations on Lake Pend Oreille have been somewhat consistent since they were first established by Falter (1992). They were established to analyze trends in trophic status and productivity over time. There are 14 nearshore monitoring sites from which annual monitoring sites are selected. These locations provide distributed spatial coverage throughout the lake. They also provide good representation of the northern, mid, and southern lake (Table 4, Figure 4). Monitoring sites are rotated on an annual basis as monitoring needs dictate. Results of trophic and other water quality monitoring are presented in section 8.

Table 4. DEQ water quality monitoring locations on Lake Pend Oreille.

Site Name	Lake Area	Character	Latitude (WGS 1984)	Longitude (WGS 1984)
Bayview North	South	Nearshore	116.543333	47.981389
Bottle Bay	North	Nearshore	116.454167	48.248056
Camp Bay	Mid	Nearshore	116.382712	48.19779
Ellisport Bay	North	Nearshore	116.290278	48.233333
Garfield Bay	Mid	Nearshore	116.430833	48.179722
Glengary Bay	North	Nearshore	116.369444	48.223611
Granite Point	Mid	Nearshore	116.427667	48.085974
Idlewilde Bay	South	Nearshore	116.572738	47.950697
Kootenai Bay	North	Nearshore	116.512668	48.303182
Lakeview	South	Nearshore	116.458633	47.9723
Oden Bay	North	Nearshore	116.463611	48.305833
Sunnyside	North	Nearshore	116.416111	48.286389
Talache Landing	Mid	Nearshore	116.478194	48.127528
Trestle Creek	North	Nearshore	116.354722	48.283611

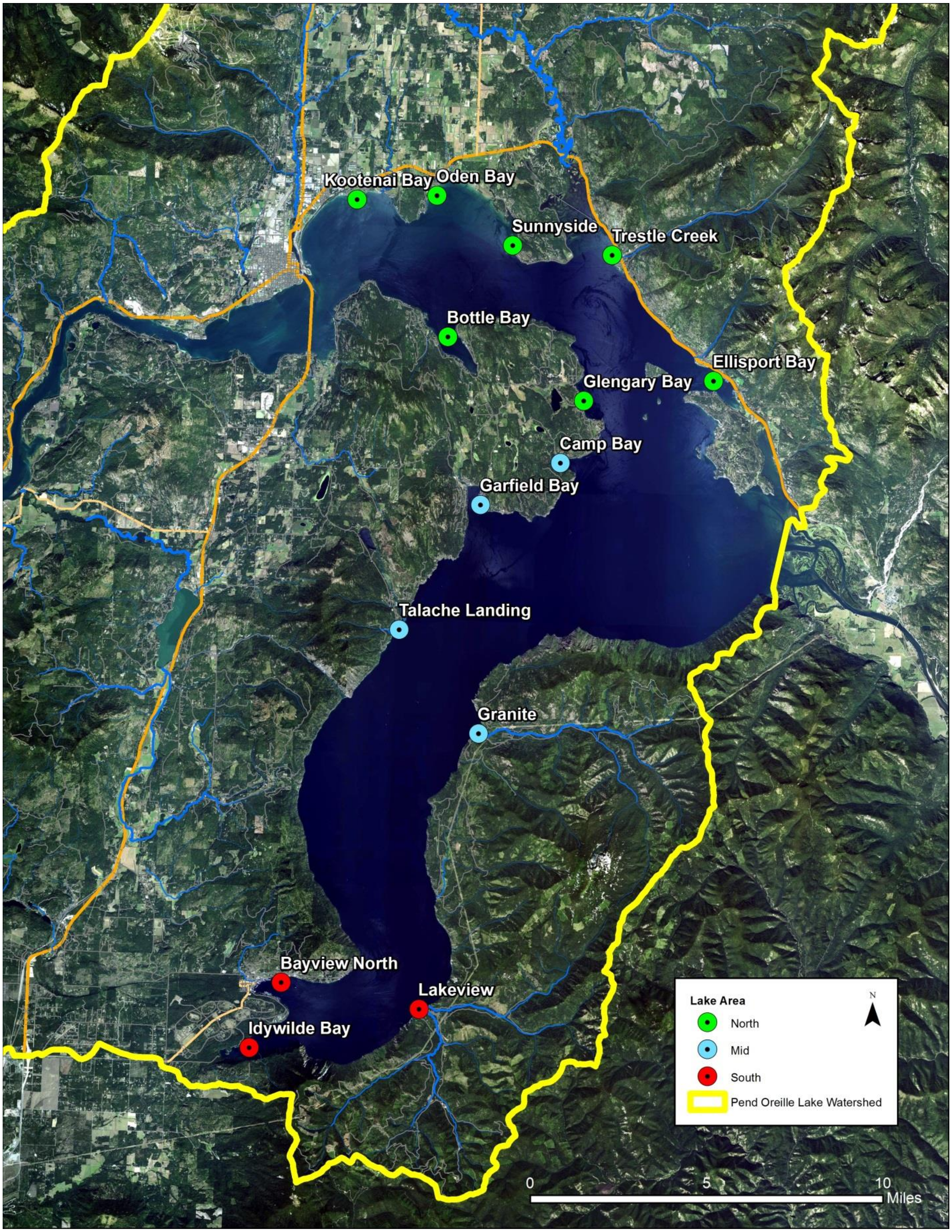


Figure 4. Location of monitoring sites on Lake Pend Oreille.

7 Productivity Monitoring Design

Another aspect of limnological investigations is the evaluation of benthic algae or periphyton, which is the assemblage of algae, cyanobacteria, and micro-invertebrates attached to bottom substrate. In addition to being the primary food source for aquatic insects, periphyton are considered early indicators for change in chemical and physical environmental factors within a lake. Periphyton growth can be light-limited, nutrient-limited, or both, and growth is influenced by temperature. It is also an important water-quality indicator because it can quickly consume water-column nutrients, and periphyton community composition will vary with nutrient concentrations (Shilling 2008). Phytoplankton are also considered basic indicators of the health of a lake due to their ability to quickly react to environmental conditions.

In November 2013, a technical group of professionals from state and federal agencies, the private sector, and the University of Idaho met to discuss the 2002 TMDL (DEQ 2002), the TMDL targets, monitoring results, and ways to evaluate the link between TP and macrophyte/algae growth and visible aesthetic/recreation impairment. It was agreed that data gaps exist in understanding the relationship between productivity and water column chemistry in Lake Pend Oreille. The group voiced concern that the low values of water column chlorophyll *a* along with low values of TP may not accurately represent the actual productivity in the nearshore waters of the lake. It was hypothesized that consumption of TP by periphyton and other phytoplankton may not translate to higher chlorophyll *a* values in the water column. Therefore, additional monitoring was undertaken in 2014 to evaluate periphyton community structure and biovolume to better understand the relationship between water column chemistry and productivity.

7.1 Study Area

The productivity data was collected weekly from late July through early-September. Analysis involved investigating periphyton growth rates and community structure/density on artificial substrates at each of the nearshore locations in Lake Pend Oreille (Table 5). For this analysis, the lake was divided into two parts. The northern end of the lake is separated from the mid/southern region of the lake due to influence from the Pack River, the Clark Fork River, and the stormwater from the cities of Sandpoint, Kootenai, and Ponderay. Ambient light levels and water temperatures, two critical environmental factors impacting periphyton communities, were also collected. Each substrate included a submersible light/temperature data logger that measured differences in the microhabitats at each station.

7.2 Methods

Artificial substrates were deployed at all nearshore locations during the week of July 20, 2014, and were visited weekly for the following 6 weeks. They were retrieved the first week of September 2014. Periphyton samples were collected and analyzed for chlorophyll *a* concentrations each week. Analysis of chlorophyll *a* in the periphyton was used to determine a rate of growth and a relative measure of productivity. During the retrieval, an additional periphyton sample was taken for periphyton taxa identification and enumeration.

These artificial substrate stations were selected to be near as possible to long-term water quality stations but needed to be moved toward the shoreline to be in appropriate water depths. Human influence and approximation of number of people per square mile was based on 2010 census information. Human influence was determined within 0.5 miles of the station and relates the number of dwellings and infrastructure (development) needed to support those people (Table 5).

Table 5. Productivity monitoring stations on Lake Pend Oreille.

Station Name	Lake Area	Human Pressure	People/ sq. mi. [b]	Latitude[a]	Longitude[a]
[c] Bayview Nearshore	Mid/South	Moderate	45	W 116° 33' 26.002"	N 47° 58' 56.416"
Bottle Bay	North	Moderate	28	W 116° 26' 36.833"	N 48° 14' 13.364"
Camp Bay	Mid/South	Low	17	W 116° 22' 56.915"	N 48° 11' 57.556"
Ellisport Bay	North	Low	7	W 116° 17' 23.716"	N 48° 14' 15.582"
Garfield Bay	Mid/South	Low	25	W 116° 25' 50.760"	N 48° 10' 50.430"
Glengary Bay	North	Moderate	36	W 116° 22' 16.205"	N 48° 13' 27.004"
Granite	Mid/South	Low	3	W 116° 25' 39.887"	N 48° 5' 12.755"
Idlewilde Bay	Mid/South	Low	10	W 116° 34' 25.118"	N 47° 57' 6.757"
Kootenai Bay	Mid/North	High	200+	W 116° 31' 25.942"	N 48° 18' 12.923"
Lakeview	Mid/South	Low	5	W 116° 27' 31.176"	N 47° 58' 18.679"
Oden Bay	North	High	147	W 116° 27' 52.205"	N 48° 18' 23.616"
Sunnyside	North	High	62	W 116° 25' 7.309"	N 48° 17' 7.440"
Talache	Mid/South	Low	21	W 116° 28' 43.646"	N 48° 7' 42.298"
Trestle	North	High	50[b]	W 116° 21' 13.147"	N 48° 16' 53.001"

[a] Datum WGS84
[b] Population estimate increased to include summer RV park inhabitants
[c] Bayview Nearshore was a new site established for the productivity monitoring study. It is not in the same location as the long-term trend site, Bayview North

7.3 Sampling Methods

Artificial substrates were deployed by boat during the week of July 20, 2014, at an intended depth of approximately 3 m below surface. Depths were measured with the boat's sonal depth finder prior to sampling. Depths were recorded on field forms at each of the stations and vary between 1.7 and 4.2 m. The sonar was not working during week 5 of the study. Depths at stations vary because of lake stage and boat drift during sampling (Table 6).

Table 6. Productivity monitoring station depths (meters).

Station Name	Deployment	Week 1	Week 2	Week 3	Week 4	Week 5	Retrieval	Average
Bayview Nearshore	2.4	1.7	1.9	1.9	1.9	n/a	n/a	2.0
Bottle Bay	2.7	3.1	3.1	3.2	n/a	n/a	n/a	3.0
Camp Bay	3.4	3.1	3.3	3.1	3.4	n/a	3.3	3.2
Ellisport Bay	2.7	2.7	3.1	3.0	n/a	n/a	3.4	3.0
Garfield Bay	2.1	2.3	2.3	2.3	2.3	n/a	2.3	2.3
Glengary Bay	3.4	3.8	3.7	3.8	3.9	n/a	3.5	3.7
Granite	2.9	1.9	1.9	2.3	n/a	n/a	2.3	2.3
Idlewilde Bay	3.4	3.1	3.9	3.9	4.2	n/a	n/a	3.7
Kootenai Bay	2.7	2.7	2.9	2.8	2.7	n/a	2.7	2.8
Lakeview	2.7	2.4	2.4	2.4	n/a	n/a	2.6	2.5
Oden Bay	3.0	n/a	3.2	3.2	3.2	n/a	3.2	3.2
Sunnyside	2.4	2.6	2.5	2.5	n/a	n/a	2.7	2.5
Talache	2.7	3.0	2.7	n/a	n/a	n/a	2.8	2.8
Trestle	2.3	2.4	2.3	2.4	2.4	n/a	2.4	2.4

n/a = depth not recorded on field form.

The substrate consists of an expanded polystyrene block mounted to plywood (Figure 5). The plywood is bolted to a piece of concrete flagstone to provide added support and ballast. The expanded polystyrene substrates were large enough (1 square foot) for weekly sampling for 6 consecutive weeks. On each of the expanded polystyrene blocks, a light and temperature data logger was secured. The artificial substrates were deployed without a line connecting them to a surface object in order to avoid entanglement and to reduce potential vandalism. Two artificial substrates were placed at each station: one as a primary and the other as a back-up.

For each consecutive week, the substrates were retrieved and sampled. The artificial substrates were usually visible from the boat, which was then anchored with both bow and stern anchors to hold the boat directly over the artificial substrate. A snorkel diver attached a haul line to the ring on the artificial substrate, and then the artificial substrate was slowly winched up by another person to a depth just below the water surface (approximately 0.1 m) for sampling. Care was taken to ensure the substrate was not dewatered at any time during the sampling effort.

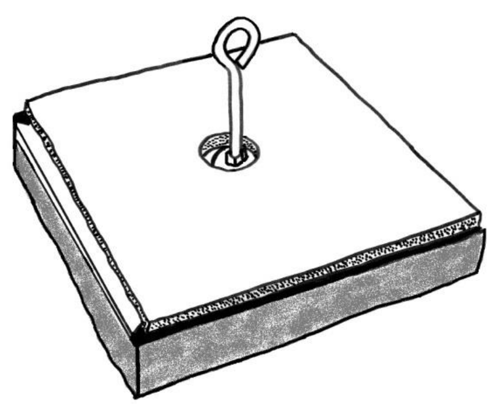


Figure 5. Illustration of artificial substrate.

The artificial substrates were deployed in areas believed to be not susceptible to vandalism. Intentional or unintentional vandalism may have affected results, especially if the artificial substrate was dewatered. The snorkel diver visually inspected artificial substrate for vandalism during each retrieval event.

Chlorophyll *a* sampling was conducted during weeks 1–6 from the expanded polystyrene. Two 241-square-millimeter samples were hole-punched from the polystyrene and placed into a 20-

millilter (mL) plastic scintillation vial. The caps and labels were placed on the vials, and the vials were each wrapped in foil and placed on dry ice in a darkened cooler. The samples were placed in a freezer within 10 hours of collection until delivered to the lab. One sample was used by the lab for analysis of chlorophyll *a* concentrations. The other sample was for a back-up, if necessary.

Prior to redeployment, the condition of the artificial substrate was evaluated, taking care not to expose it to air. The light sensor and temperature data were also downloaded.

During retrieval (week 6), two additional samples were collected from each of the expanded polystyrene substrate—again with a hole punch and placed in a 20-mL plastic scintillation vial—for periphyton taxonomy and enumeration. The sample was preserved by adding analyte-free water to the vials along with 2 drops of Lugol’s solution. The caps and labels were placed on the vials. These vials were not placed in a cooler but were kept out of direct light.

Expanded polystyrene foam (EPS) is a low-weight, rigid, tough, closed-cell foam. Many of the sample bottles that are commonly used for water quality monitoring are made of polystyrene. EPS is inert, nonbiodegradable, and 90% air. For this project, 0.5-inch thick Insulfoam® Molded Expanded Polystyrene Foam R-Tech© was selected. This EPS is safe, noncorrosive, and nontoxic and contains no hydrochlorofluorocarbons (HCFCs) or formaldehyde. The EPS components selected include <2% pentane and <1% bromine flame retardant. Pentane is rapidly metabolized and is not a bioaccumulator; it degrades readily and rapidly in the presence of oxygen. Pentane is not toxic to aquatic organisms (LC50 shows no mortality in fish [*Oncorynchus kisutch*] at 100 mg/L in 96 hours). The bromine flame retardant is in the form hexabromocyclododecane (HBCD). HBCD is pervasive in the environment, slightly soluble, and is bioaccumulative. HBCD may be at extremely low concentrations on the surface of the EPS, and HBCD has the potential of being toxic to algae.

DEQ placed a natural substrate (flat skipping stone) on each of our original artificial substrates with the intent of measuring comparative algae chlorophyll *a* concentrations, but funding was insufficient for analysis. A comparison between growth rates, and possible periphyton taxon, between natural and artificial substrates is still needed.

Periphyton chlorophyll *a* concentration analysis, periphyton taxonomy, and enumeration was conducted by Advanced Eco-Solutions Inc., a subcontractor for SVL Analytical, 25011 E. Trent Ave. Ste. A., P.O. Box 201, Newman Lake, Washington, 99025. Results are presented in section 9.

8 Summary and Analysis of Current Water Quality Data and Trophic Status

Since 1974, water quality data have been collected on Lake Pend Oreille. The following is an evaluation of data collected from 1989 through 2014. Data collected included the following water chemistry and productivity data: (1) Secchi depth and water column profiles of chemical and physical parameters including water temperature, pH, dissolved oxygen, and electrical conductivity; (2) analytical laboratory analysis data including TP, TN, and chlorophyll *a*; and

(3) periphyton data collected off artificial substrates for analysis of chlorophyll *a*, biomass determination, and periphyton identification and enumeration.

Routine trophic and productivity monitoring was done in 1989–1990 and 2003 under Falter (Falter 1992, 2004). During these years, 14 monitoring sites representative of variable nearshore conditions throughout the lake were visited. In 2006, monitoring resumed under the direction of the Tri-State Water Quality Council. This monitoring continued through summer 2008 (Hydrosolutions 2011). The DEQ Coeur d'Alene Regional Office has conducted trophic monitoring on Lake Pend Oreille since 2009.

Funding constraints in 2006–2009 limited data collection to 6 nearshore stations: Oden and Sunnyside in the northern lake, Garfield and Talache in the mid region of the lake, and Lakeview and Bayview North in the southern lake. No funding was available for monitoring from July 2010 through 2011. Since 2012, lake trophic monitoring has been supplemented by Avista. During 2012 and 2013, it was decided a good baseline had been established at the 6 nearshore stations, and there was a concern as to the condition of the 8 other monitoring stations evaluated by Falter. Therefore, sampling was conducted at other sites on the lake to get a general idea of what TP concentrations were at those sites.

With funding from AVISTA and a separate grant from the US Environmental Protection Agency, DEQ was able to conduct monitoring on all 14 nearshore sites (with some modification), to better understand the relationship between water column chemistry and productivity. This monitoring followed closely the monitoring design of Falter (1992, 2004).

8.1 Data Quality Objectives and Data Reporting

Data representativeness is the degree to which the sample data accurately and precisely represent site conditions. Data used for the following analyses were the only data that have been determined to be representative of site conditions through adherence to the representative criterion as defined in a quality assurance project plant (QAPP) or similar quality assurance documentation. Data that were below the laboratory reporting limit were included in the analysis as a value equal to 1/2 (method detection limit + method reporting limit) as recommended in USGS (1999).

8.2 Dissolved Oxygen

DO data from the nearshore waters of Lake Pend Oreille from 2000 to present was evaluated. Over this period, DO concentrations have remained relatively stable at all the monitoring stations on the lake; no water quality standard exceedances have occurred. DO concentrations at all stations were consistently above 8 mg/L, and it was common to observe concentrations above 10 mg/L.

During summer stratification, the thermocline prevents DO produced by photosynthesis from reaching the deeper hypolimnion. The oxygen supply in the hypolimnion is gradually consumed by bacteria that decompose organic matter. In more productive lakes, DO in the hypolimnion can be exhausted quickly, creating unfavorable conditions for fish. In lower productivity lakes, DO can be retained in the hypolimnion for very long periods of time. Only Ellisport, Bayview North, and Idlewilde were observed to stratify on a regular basis early in the summer, and this was because they were deeper than the other stations. When these sites were stratified, DO concentrations would change with the temperature profile; however, DO levels in the hypolimnion were always above 8 μg/L at these sites. An example of stratified conditions and a change in DO is illustrated in Figure 6.

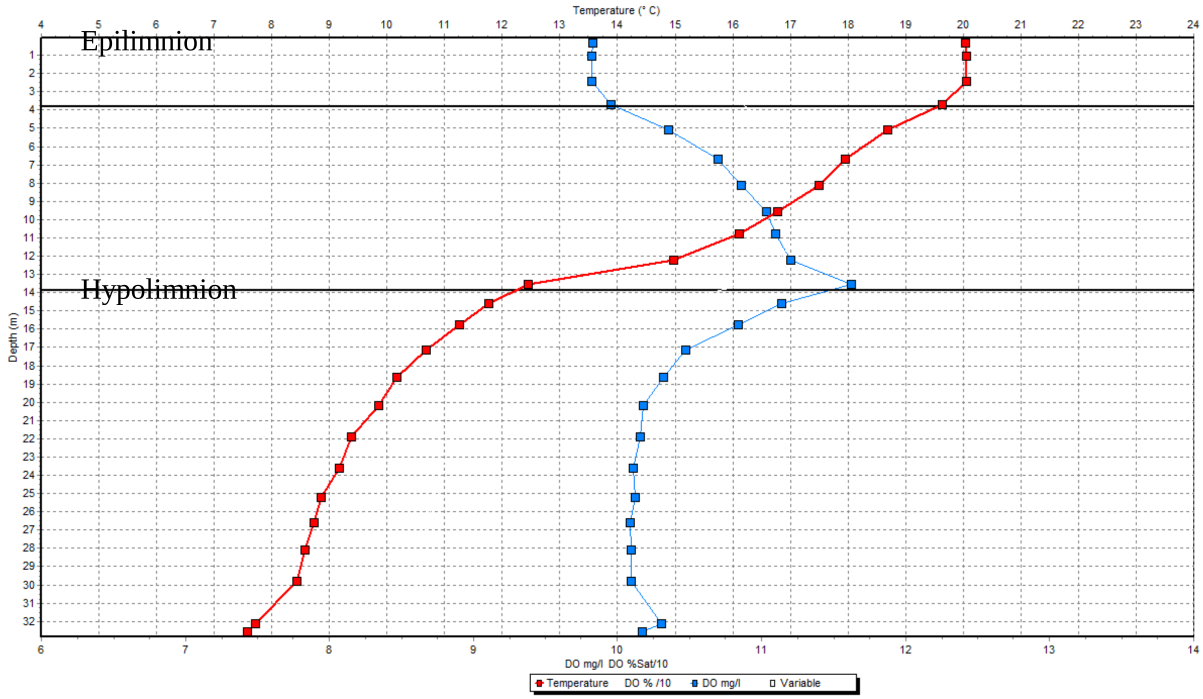


Figure 6. Profile of dissolved oxygen and temperature at Idlewilde, August 2, 2012.

When a monitoring site is thoroughly mixed from top to bottom, isothermal conditions exist, and there is no thermocline to prevent DO produced by photosynthesis from reaching the deeper hypolimnion or aeration from the epilimnion reaching the hypolimnion. In such conditions, DO concentrations tend to be the same throughout the profile (Figure 7). Except for the stations listed above, most of the nearshore stations on Lake Pend Oreille had isothermal conditions through the summer months.

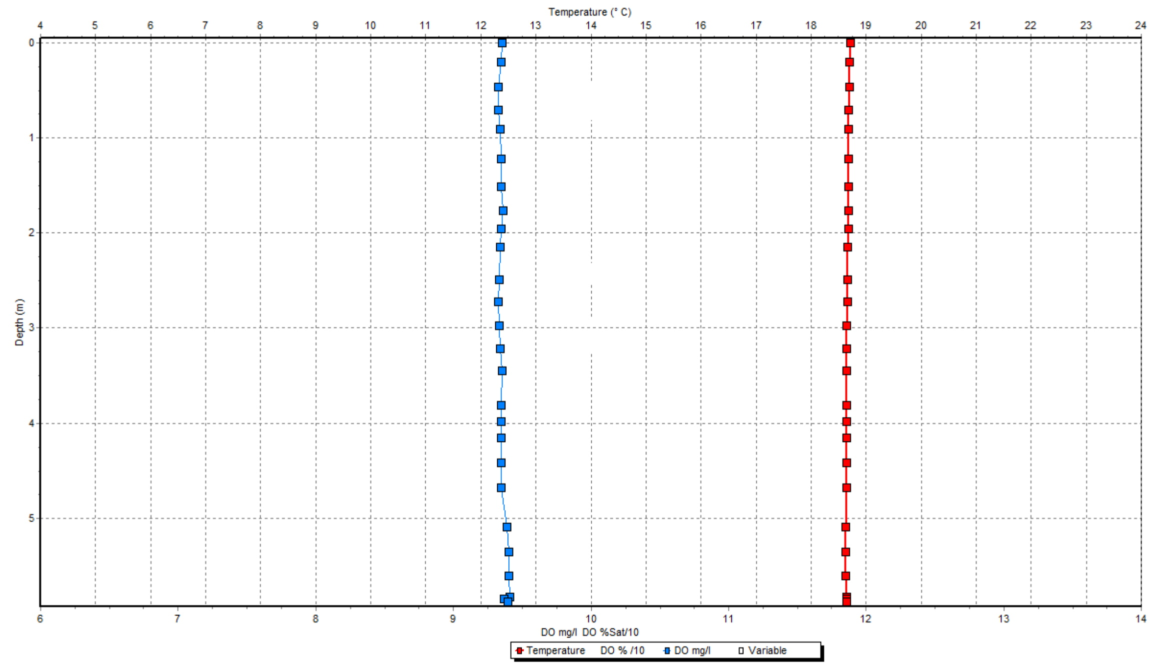


Figure 7. Profile of dissolved oxygen and temperature at Glengary, September 3, 2014.

8.3 Secchi Depth

Water transparency directly affects lake aesthetics, and it is primarily affected by algae and suspended sediment. Water transparency is measured with a Secchi disk, which is lowered into the water column until the disk disappears at a determined depth. The deeper the disk is seen, the better the water transparency. One variable in calculating trophic status of a lake is Secchi depth.

Secchi depth data on Lake Pend Oreille dates back to the 1970s, but for the purposes of this report, the data were evaluated back to the time of studies by Falter (Falter 1992). Measurement of water transparency is often limited by the depth of the monitoring location. A shallow location may have water transparency to the lake bottom, thus the depth of transparency exceeds overall depth. In these instances, Secchi depth is not recorded. The water in the northern region of Lake Pend Oreille is very shallow. For example, Sunnyside and Oden Bays have median depths of 3.4 and 3.6 m, respectively. Kootenai and Trestle are also very shallow, with median depths of 3.1 and 2.1 m. At these sites, depth often precluded the ability to record a Secchi depth across the period of record.

Secchi depths in the northern lake posed a problem. The observed Secchi depths in 1989–1990 were deeper than the depth of the current monitoring location in northern bays. It is suspected that Falter collected that data further out in those bays. In addition, due to the shallow nature of most of the northern bays, the Secchi depth was not recorded, thus biasing the reading towards lower water transparency. Due to these anomalies, Secchi depths for the northern end of the lake were excluded from the following analysis.

Prior to running any statistical analysis on Secchi depth data, it was important to understand whether the data were normally distributed. Secchi depth data were not normally distributed, even when the data were $\log_{10}$ and log normally transformed. Therefore, nonparametric statistical analyses were run on the data. The results follow.

8.3.1 Nearshore Monitoring Sites

Median Secchi depth from the mid and southern regions of the lake was plotted with 95% confidence intervals for each monitoring station for 1989–2003 and 2006–2014 (Figure 8). This time division was the most logical due to the number of data points in each data set. The preferable division would have been in 5- to 6-year sets, but the low number of data points within each station precluded any meaningful statistical analysis. General statistics for the period of record and for these time periods are listed in Appendix B (Tables B-1 and B-2).

Under the Falter studies (1989–2003), the maximum water transparencies were observed at Bayview North and Granite, with Secchi depths of 11.5 and 11.3 m, respectively. Under the same studies, the highest median water transparencies were observed at Granite and Lakeview, with depths of 11.0 and 9.9 m, respectively. Idlewilde Bay was not sampled under the Falter study.

While water transparency has decreased at monitoring stations over time, the highest water transparencies continue to be observed in the southern end of the lake.

During 2006–2014, the highest water transparencies were observed in the southern end of the lake. Lakeview and Idlewilde had the highest transparencies observed, with Secchi depths of 13.1 and 11.8 m, respectively. The highest median Secchi depths observed were at Idlewilde, Bayview North, and Ellisport at 8.1, 8.0, and 6.3 m, respectively.

In the mid/southern region of the lake, water transparency decreased from 1989–2003 to 2006–2014 for most of the sites with data, suggesting water transparency has decreased over time at those sites. During the 2006–2014 time period, a median could not be calculated at Camp and Glengary because the lake bottom was visible during each monitoring event. This would suggest water transparency has improved at these sites.

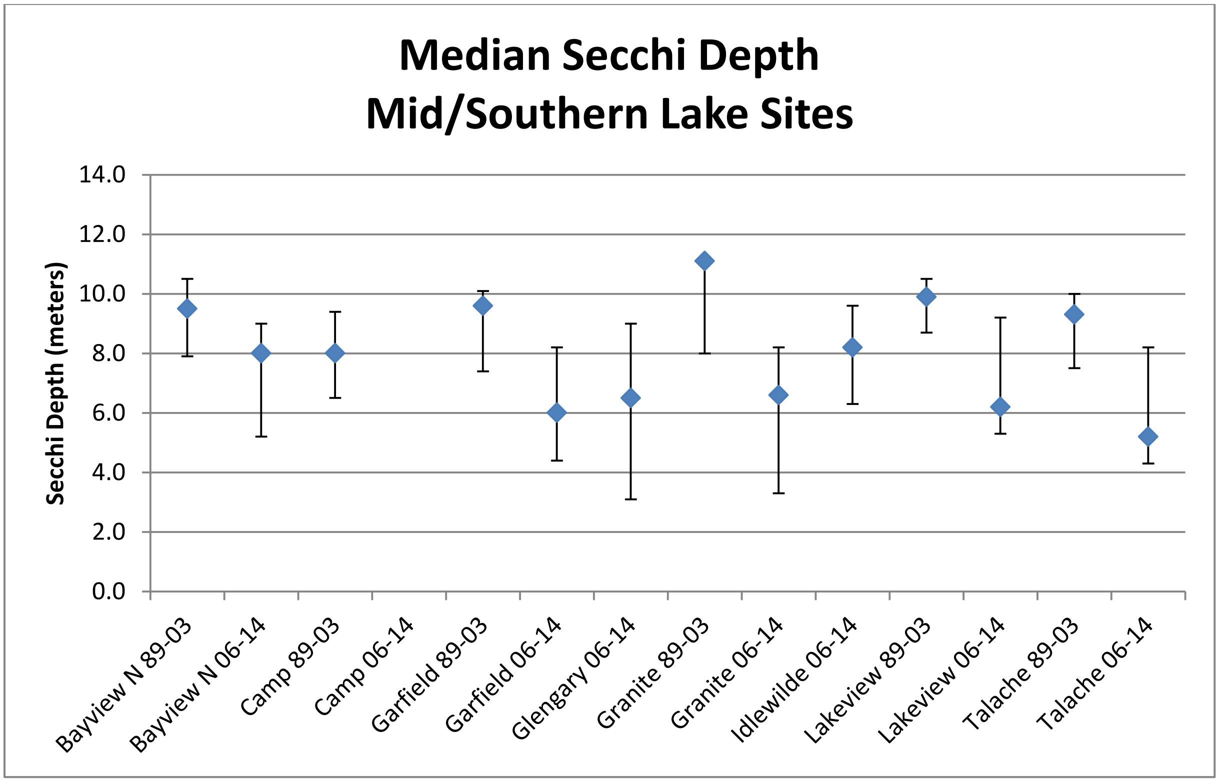


Figure 8. Median Secchi depth in mid and southern lake sites. Data collected under Falter (1989–2003) and others (2006–2014) .

8.3.2 Regional Trends: Lake Area

A regional trend analysis was performed by grouping together data from monitoring stations within the same lake area to understand differences in water transparency in that region of the lake over the following time periods: (1) 1989–1990, (2) 2003–2008, and (3) 2009–2014. The regional trend analysis was necessary due to data gaps between 2006 and 2013 at individual monitoring stations. Between 2006 and 2009, DEQ conducted annual water quality monitoring at six nearshore sites on the lake. Monitoring at other sites took place from 2011–2014. By grouping stations, a larger data set can be used for statistical analysis. Station lake area is defined in Table 4. Because the northern lake data were excluded from the analysis, the lake was divided into two locations: mid and southern. Data were graphed by median with 95% confidence intervals (Figure 9). General descriptive statistics are given in Table B-3 in Appendix B.

Regional trend analyses were performed by grouping together data from monitoring stations within the same lake area. The regional trend analysis was necessary due to the data gaps at stations within each of the lake areas.

The Kruskal-Wallis one-way analysis of variance (ANOVA) is a nonparametric statistical method similar to the Mann-Whitney test, but it compares two or more groups of independent samples. The null hypothesis is that the medians of all groups are equal. The alternative hypothesis is that at least one median from a group is different from at least one other. The Kruskal-Wallis test determined there was no significant difference between the median Secchi depths in the mid lake in 1989–1990 and 2003–2008 and the southern part of the lake in 2003–2008 and 2009–2014 ($p = 0.179$). A drop in the median in the mid lake in 2009–2014 made it significantly lower than the previous years ($p = 0.000$). When comparing the 1989–1990 data with 2003–2008 data in the southern lake, the decrease in Secchi depth in 2003–2008 was also significant ($p = 0.035$).

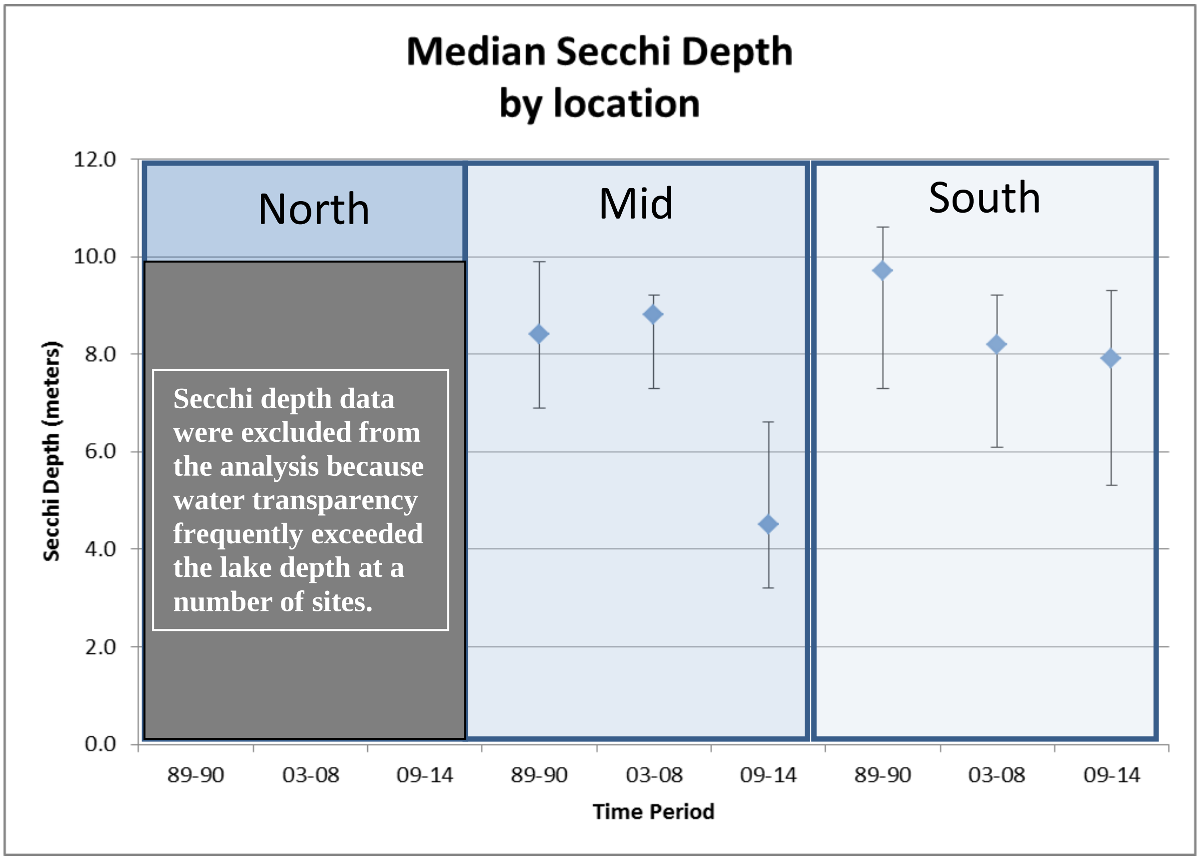


Figure 9. Median Secchi depth by lake location and time period, plotted with 95% confidence intervals.

8.3.3 Regional Trends: Summer Months

A regional trend analysis was also performed by grouping together data from monitoring stations within the same lake area to understand differences in water transparency across the summer months in the mid and southern regions of Lake Pend Oreille. Secchi depth was broken out by month and by three time periods: (1) 1989–1990, (2) 2003–2008, and (3) 2009–2014. The regional trend analysis was necessary due to the data gaps at stations within each of the lake areas. By grouping stations, a larger data set can be used for statistical analysis. Data were graphed by median with 95% confidence intervals (Figure 10). General descriptive statistics on which these box plots are based are listed in Appendix B (Table B-4).

The regional trend analysis showed Secchi depths in June and July are significantly lower than those in August and September.

Water transparency data in the mid/southern regions of the lake was evaluated by month using the Kruskal-Wallis one way ANOVA. This analysis found no significant difference between Secchi depths in the months of August and September across the time periods ($p = 0.086$). When the Sept 2009–2014 data were excluded, the p value went up ($p = 0.412$), indicating the Sept 2009–2014 was the most different from the others. While there was also no significant difference between median Secchi depths in July across the time periods ($p = 0.813$), median Secchi depths in July were significantly lower than in August and September ($p = 0.000$). There was also a significant difference between June and July, with June being significantly lower ($p = 0.000$).

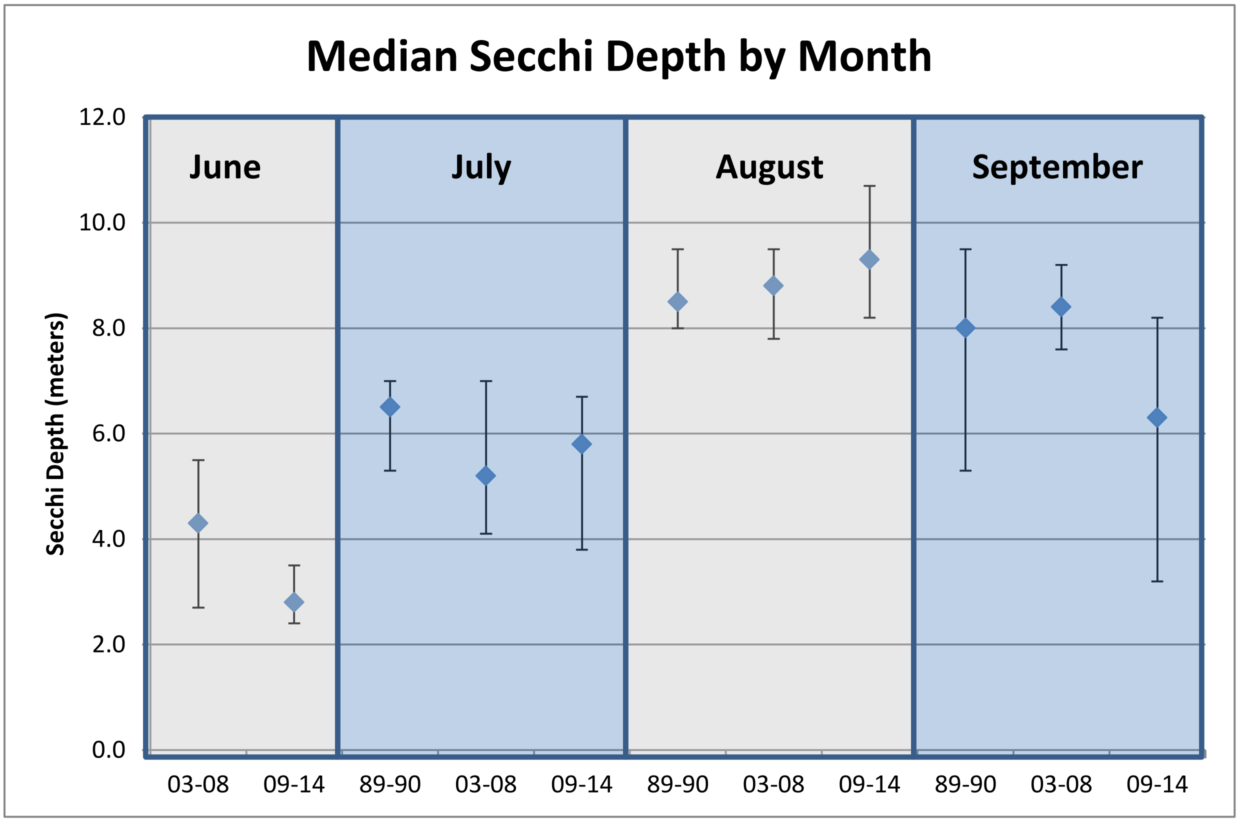


Figure 10. Secchi depth box plot of mid/southern Lake Pend Oreille by month.

8.3.4 Long-Term Trend Monitoring Stations

A comparison was made between the results of the regional analysis of Secchi depths with Secchi depths of long-term trend sites in the mid (Talache and Garfield) and southern (Bayview North and Lakeview) regions of the lake. Secchi depth data at these sites were analyzed using Lakewatch software.

The regional analysis showed a significant drop in Secchi depth from 2003–2008 to 2009–2014 in both the mid and southern regions of the lake. At Talache, there was a significant drop in Secchi depth that dates back to 1989 studies under Falter ($p = 0.057$) (Figure 11). When looking at the trend line for Garfield, it shows a significant drop in Secchi over time ($p = 0.050$), with the biggest drop occurring between 2008–2010 (Figure 12). However, this trend was not observed at the long-term stations in the southern region of the lake, where no significant change in Secchi depth was observed at Bayview North or Lakeview ($p = 0.344$ and 0.796, respectively) (Figure 13 and Figure 14).

The regional analysis across summer months showed Secchi depths significantly lower in June and July. This same trend was observed in the mid-lake at Talache and Garfield (Figure 15 and Figure 16). The same trend was not observed in the south at Bayview North and Lakeview, where Secchi depths were lower in May through July (Figure 17 and Figure 18).

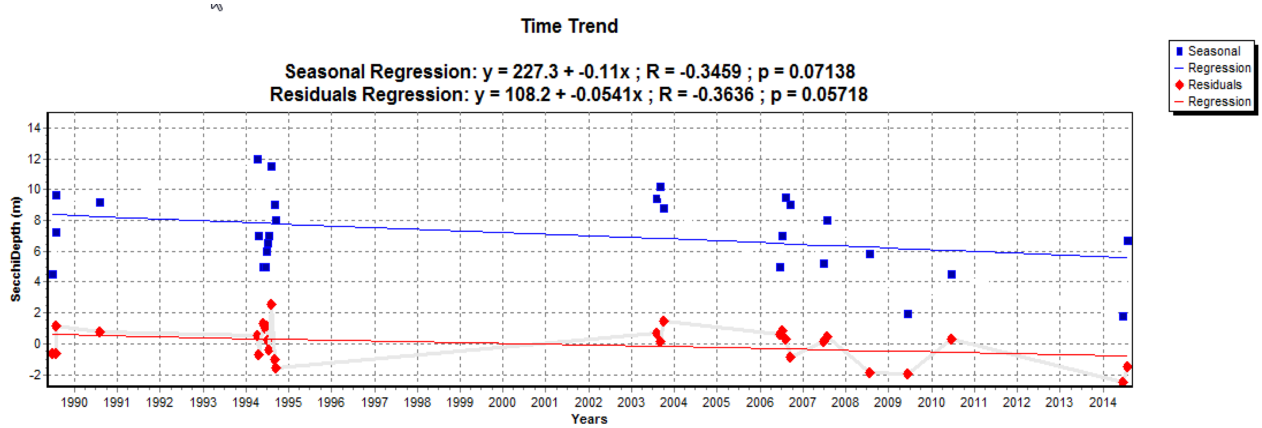


Figure 11. Yearly trend in Secchi depth at Talache (mid-lake long-term trend site).

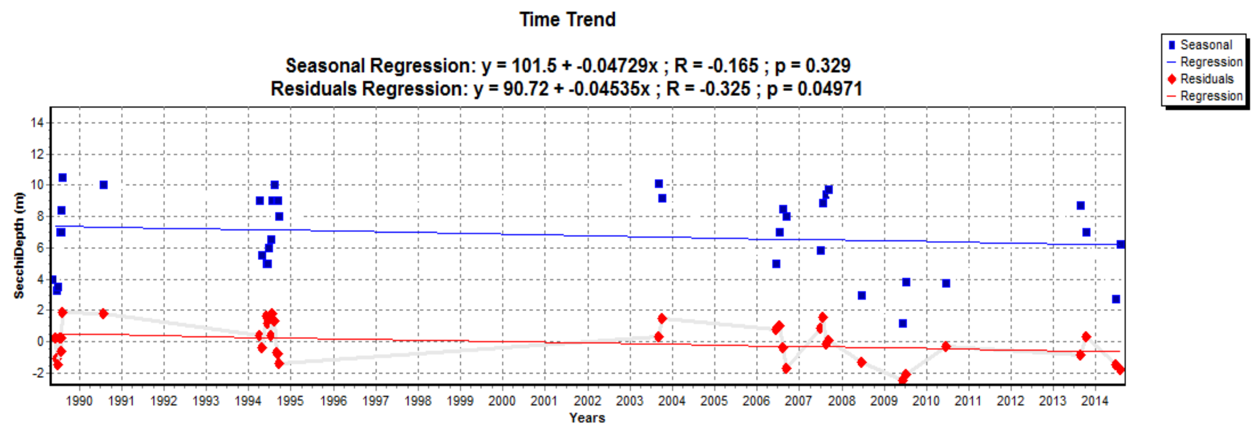


Figure 12. Yearly trend in Secchi depth at Garfield (mid-lake long-term trend site).

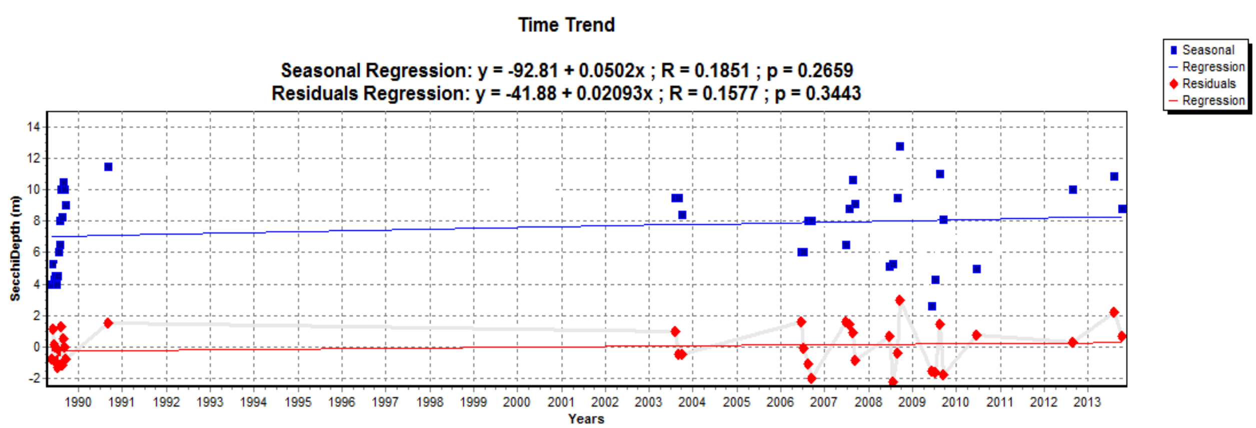


Figure 13. Yearly trend in Secchi depth at Bayview North (southern long-term trend site).

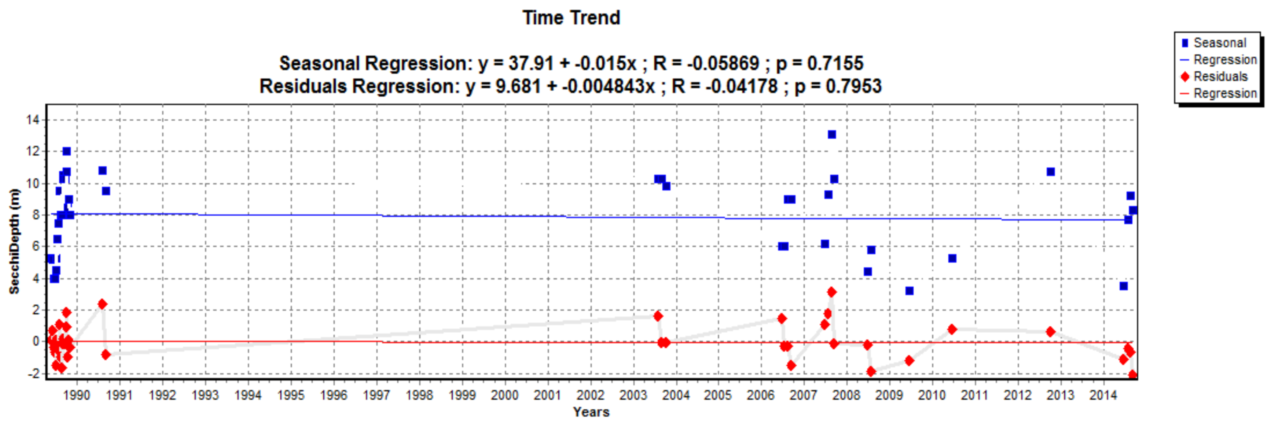


Figure 14. Yearly trend in Secchi depth at Lakeview (southern long-term trend site).

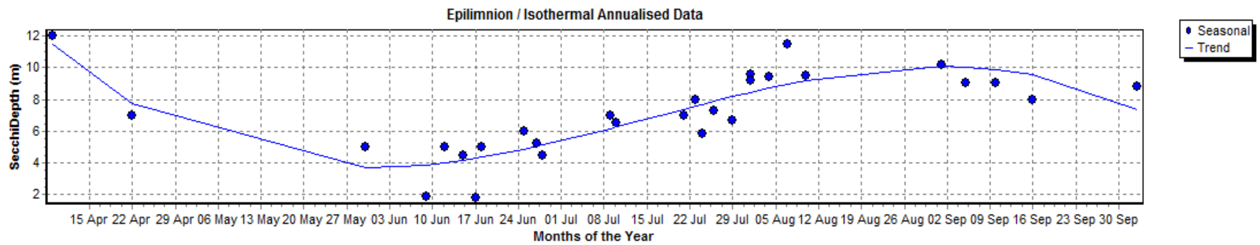


Figure 15. Monthly trend in Secchi depth at Talache (mid lake).

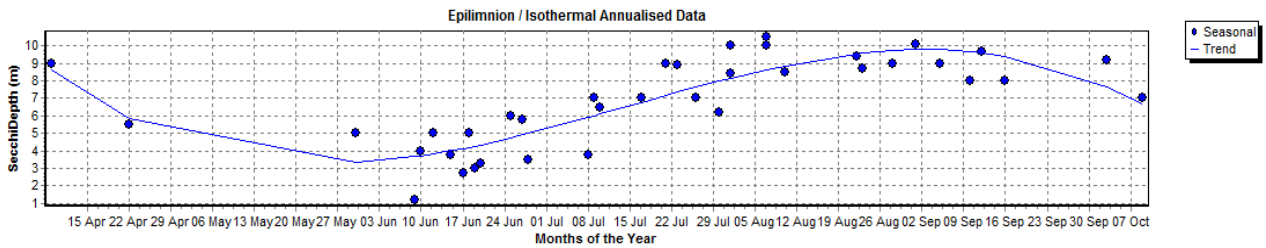


Figure 16. Monthly trend in Secchi depth at Garfield (mid lake).

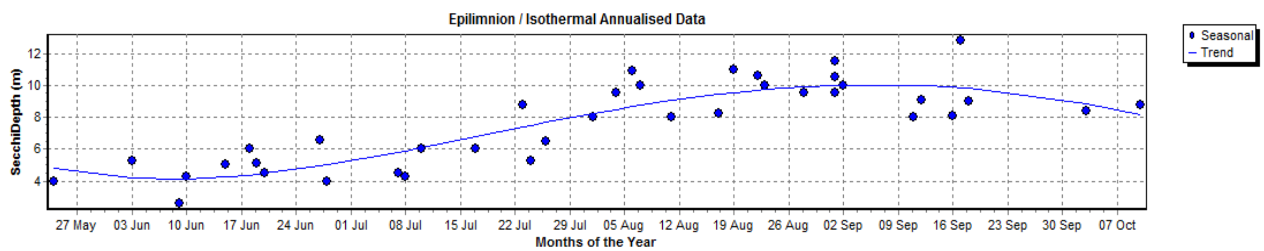


Figure 17. Monthly trend in Secchi depth at Bayview North (southern lake).

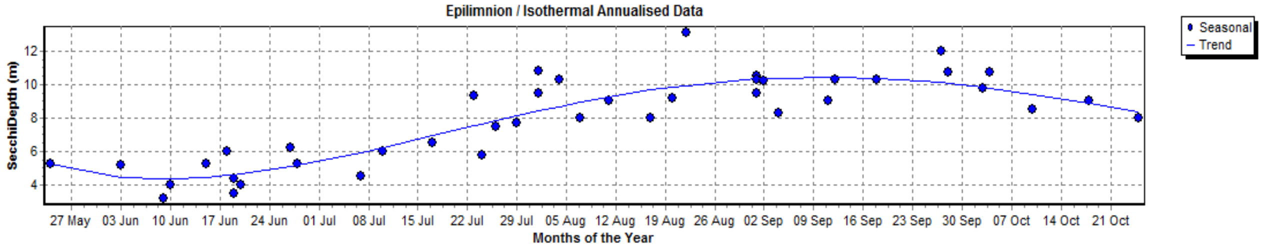


Figure 18. Monthly trend in Secchi depth at Lakeview (southern lake).

8.3.5 Discussion

Maximum and highest median water transparencies were observed in the southern end of the lake, with the deepest water transparencies observed at Idlewilde and Lakeview. The lowest water transparencies were observed in the northern region of the lake, with Kootenai being the lowest. Woods (1991a) attributed the lower water transparencies in the northern lake region to suspended sediment from the Clark Fork River and wind-induced resuspended sediment from the lake bottom and nearshore areas of the northern lake.

Due to discrepancies in location of Secchi depth measurements in the northern region of the lake across time and the shallow depth of the monitoring sites (Secchi disc would often be seen at the bottom of the lake), Secchi depth data from the northern region of the lake was discarded from statistical analysis of the data.

A regional trend analysis over the period of record showed water transparency deteriorating significantly in the mid-region of the lake during the 2009–2014 period. This trend was consistent with the mid-lake long-term trend sites, Garfield and Talache. The regional trend analysis in the southern end of the lake showed a decrease in Secchi depths from 1989–1990 to 2003–2008, remaining constant thereafter. This finding is not consistent with the long-term trend sites, Bayview North and Lakeview, where Secchi depth remained relatively constant.

A regional trend analysis of water transparency by month and divided across three time periods (1989–1990, 2003–2008, and 2009–2014) showed water transparency in June and July were significantly lower than August and September in all time periods. When looking at long-term trend sites, this trend was consistent in the mid-lake sites, but in the southern lake, Secchi depths in May–July were lower than the rest of the months.

The inconsistencies with the regional analysis of water transparency versus the long-term trend site data would suggest individual nearshore sites in the southern region of the lake may have unique characteristics, and more targeted routine monitoring at individual bays would help explain water transparency conditions at that site.

Inconsistencies with the regional analysis and long-term trend site data suggest individual nearshore sites in the southern region of the lake may have unique water transparency characteristics, and more targeted routine monitoring would help in understanding water transparency conditions.

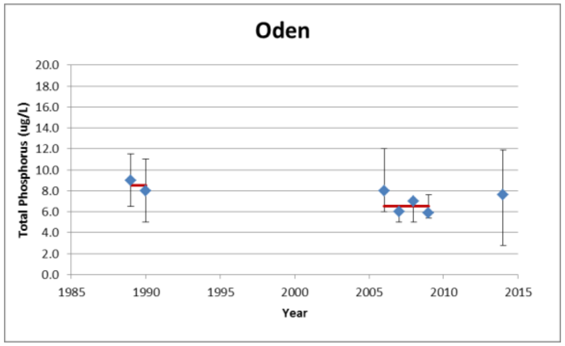
8.4 Total Phosphorus

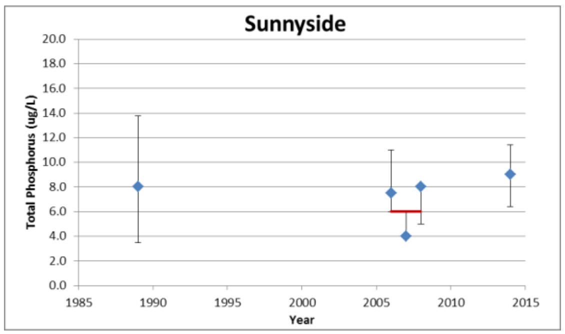
This section evaluates TP from the epilimnion during summer stratification and the photic zone during isothermal conditions over the period of record. The analysis is to understand trends and differences in TP concentrations across monitoring stations, by lake region, and by month. TP data were determined not to be normally distributed, so the data were $\log_{10}$ and log normal transformed, but they maintained a non-normal distribution. Therefore, nonparametric statistical analysis was performed, which included evaluating median TP concentrations as opposed to mean TP concentrations.

8.4.1 Trend Analysis: Nearshore Monitoring Sites

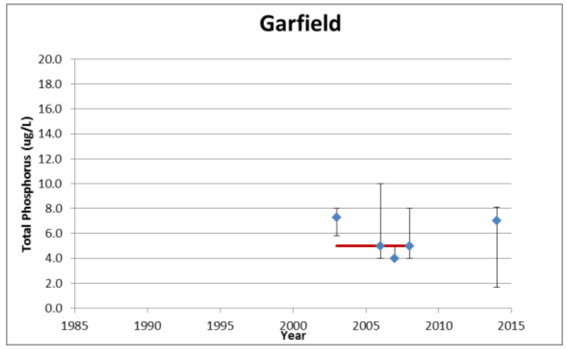
A good way to look at TP concentrations at one station over time is to plot the median TP concentration during each year. The median is a better representation of data that are not normally distributed. To calculate a median, a minimum of three data points are needed. Once the medians are graphed, it is helpful to compare the yearly median to the median over a set time period, in this case, the time intervals of 1989–1990, 2003–2008, and 2009–2014. Due to the limited number of data points, this analysis was only valid on the long-term trend sites: Oden, Sunnyside, Garfield, Talache, Bayview North, and Lakeview. Graphs of the medians of these stations over time are displayed in Figure 19. From this analysis, it appears that the northern lake site medians are slightly higher than the mid and southern lake median TP concentrations. The variability in the northern lake sites is also much higher than the mid and southern lake sites.

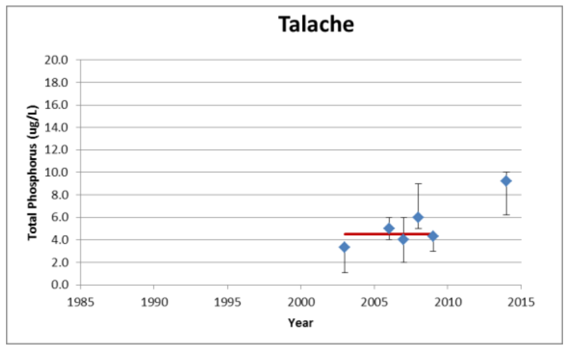
Oden and Sunnyside are long-term monitoring stations in the **northern** region of Lake Pend Oreille.



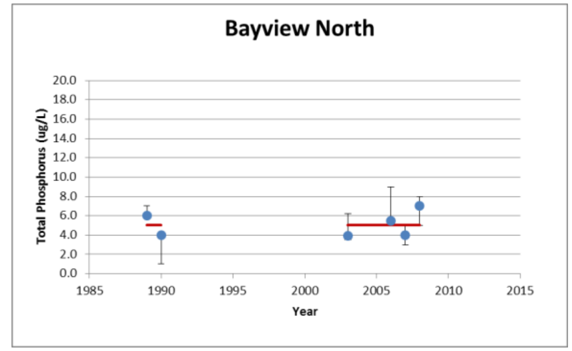


Garfield and Talache are long-term monitoring stations in the **mid-lake** region of Lake Pend Oreille.





Bayview North and Lakeview are long-term monitoring stations in the **southern** region of Lake Pend Oreille.



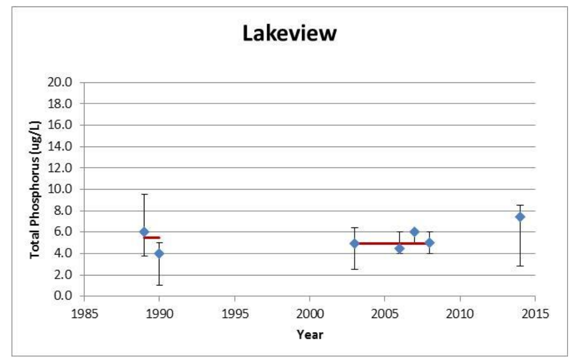


Figure 19. Median total phosphorus concentrations over time with 95% confidence intervals. The red line is the median total phosphorus concentration over the time intervals 1989–1990 (where available), 2003–2008, and 2009–2014.

8.4.2 Nearshore Monitoring Sites

To understand TP concentrations at each station over time, TP data from each station were grouped into two time periods: (1) 1989–1990 and 2003 (the time period of data collected by Falter) and (2) 2006–2014. This grouping was the most logical due to the number of data points in each data set. The preferable division would have been in 5- to 6-year sets, but the low number of data points within each station precluded medians from being calculated at each station. The median and 95% confidence intervals of TP concentration at each monitoring station is represented by 3 regions of the lake: northern, mid, and southern regions (Figure 20 through Figure 22). General statistics for the period of record and for these time periods are listed in Appendix B (Tables B-5 and B-6).

At the northern monitoring stations, median TP concentrations remained relatively constant over time, except in Oden Bay, where concentrations decreased after 2003. During both time periods, median TP concentrations in the north were approximately 6 µg/L or higher with high variability. The highest median TP concentrations were observed at Kootenai, Oden, and Trestle, with median total phosphorus concentrations of 8.0, 8.5, and 8.0 µg/L, respectively.

At the mid-lake monitoring stations, there was a high variability in TP at most of the stations. The highest median concentration was at Glengary at 7.9 µg/L. The lowest was observed at Talache at 4 µg/L. There appears to be a decrease in TP at Garfield from 1989–2003 to 2006–2014. An increase in TP was observed at Granite from 1989–2003 to 2006–2014. TP remained relatively the same at Camp and Talache.

At the southern lake monitoring stations, TP concentrations remained relatively constant over time, with low variability. Median TP concentrations were at or below 6 µg/L at all southern sites. The lowest concentrations were observed at Bayview North and Lakeview (4 and 5 µg/L, respectively).

A Kruskal-Wallis one-way ANOVA was attempted to compare medians across stations; however, there were not enough data points to provide any certainty in the results. Therefore, a general statement can only be made that TP concentrations appear to be greater in the northern stations of the lake and variability is the highest at these stations as well. In the northern region, variability is likely a reflection of the number of data points at the site, with the lowest variability at the long-term trend sites (Oden and Sunnyside). In addition, TP was lower in the mid and southern regions of the lake.

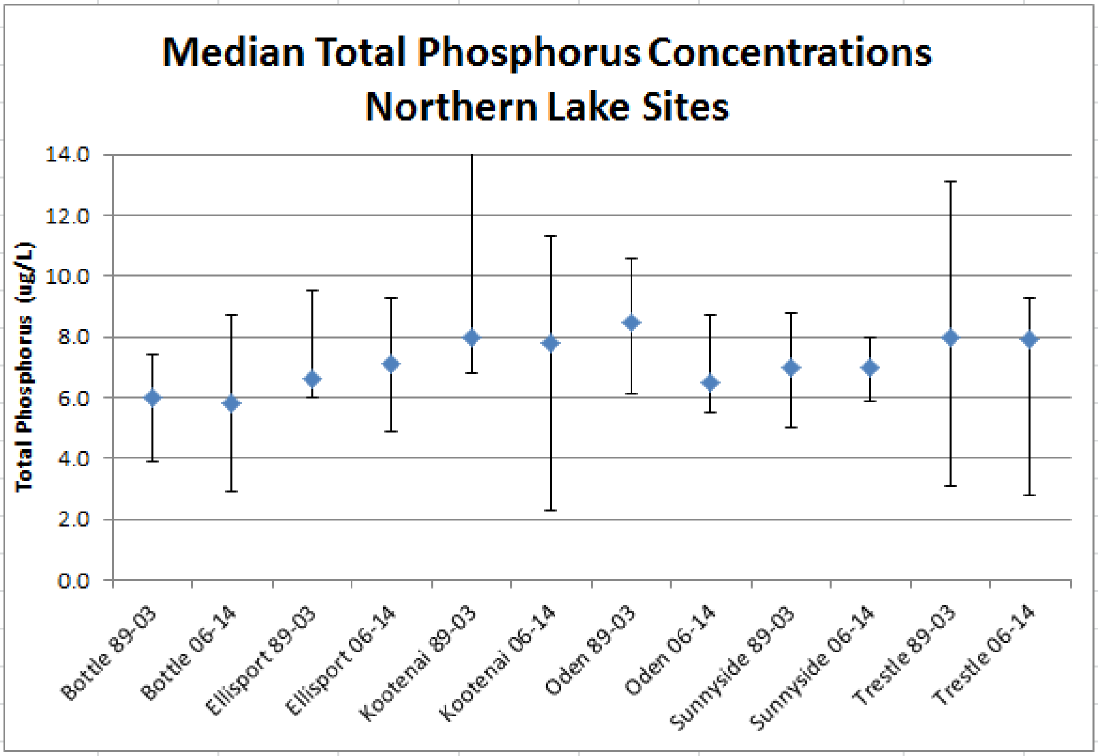


Figure 20. Median total phosphorus concentrations of northern lake stations graphed with 95% confidence intervals.

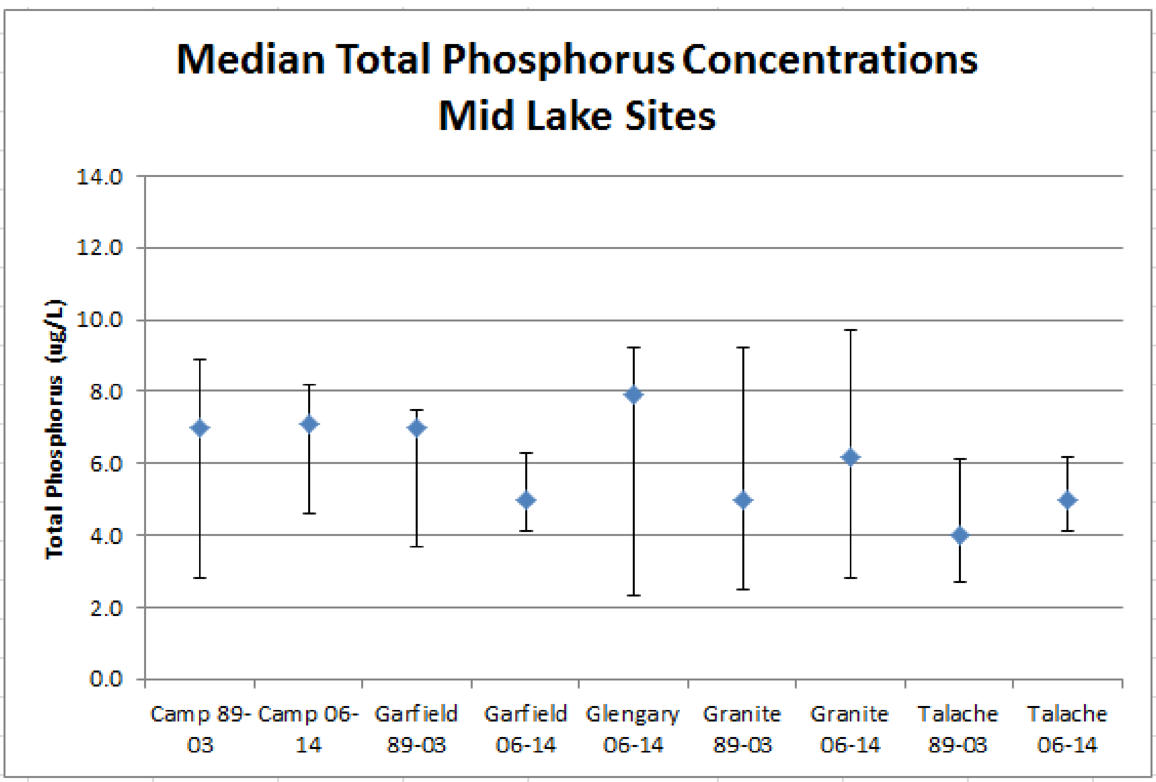


Figure 21. Median total phosphorus concentrations of mid lake stations graphed with 95% confidence intervals.

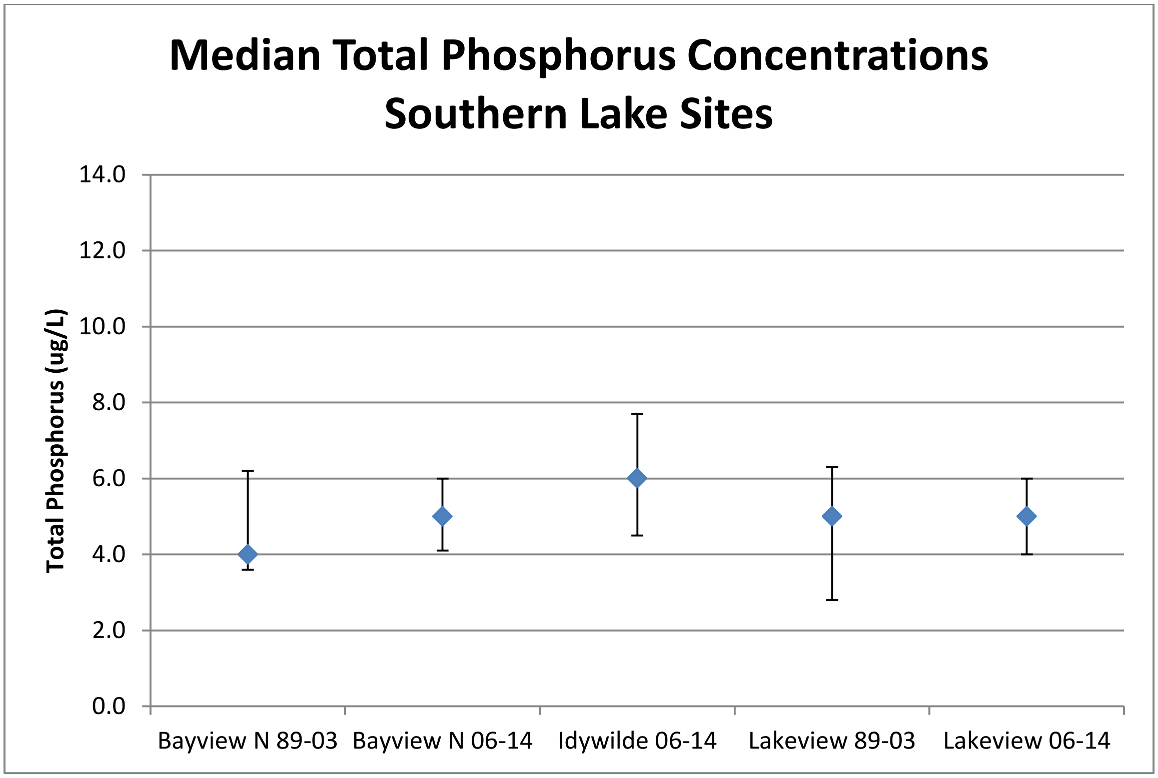


Figure 22. Median total phosphorus concentrations of southern lake stations graphed with 95% confidence intervals.

8.4.3 Regional Trends: Lake Area

A regional trend analysis was performed by grouping together data from monitoring stations within the same lake area to understand trends in TP data over time.

The regional trend analysis was necessary due to the data gaps at stations within each of the lake areas. TP data were evaluated based on three time periods: (1) 1989–1990, (2) 2003–2008, and (3) 2009–2014. The lake was divided into three areas: northern, mid, and southern. The data was plotted by median with 95% confidence intervals (Figure 23). General descriptive statistics are given in Table B-7 in Appendix B.

The Kruskal-Wallis one-way ANOVA test was also run on data from the northern region of the lake comparing median TP concentrations across time periods. Under this analysis, the null hypothesis that the medians are equal was rejected ($p = 0.024$). Median TP in 1989–1990 was 8.0 μg/L, which was greater than the median in the other two time periods. A Mann-Whitney test showed median TP concentrations to be significantly different between 1989–1990 and both 2003–2008 ($p = 0.0091$) and 2009–1014 ($p = 0.04$). A Mann-Whitney test showed no significant difference between median TP concentrations in 2003–2008 and 2009–2014 ($p = 0.635$).

Results of the regional trend analysis show TP in the northern region of the lake was significantly higher than the mid and southern regions of the lake.

The Kruskal-Wallis one-way ANOVA test was run to compare median TP concentrations in the northern region against the mid/southern regions across time periods. Under this analysis, TP in the northern region of the lake was significantly higher than the mid and southern regions ($p = 0.009$).

The Kruskal-Wallis one-way ANOVA test was run on median TP concentrations from the mid and southern region of the lake across the three time periods. This analysis showed no significant difference between the medians of these lake regions across time ($p = 0.330$).

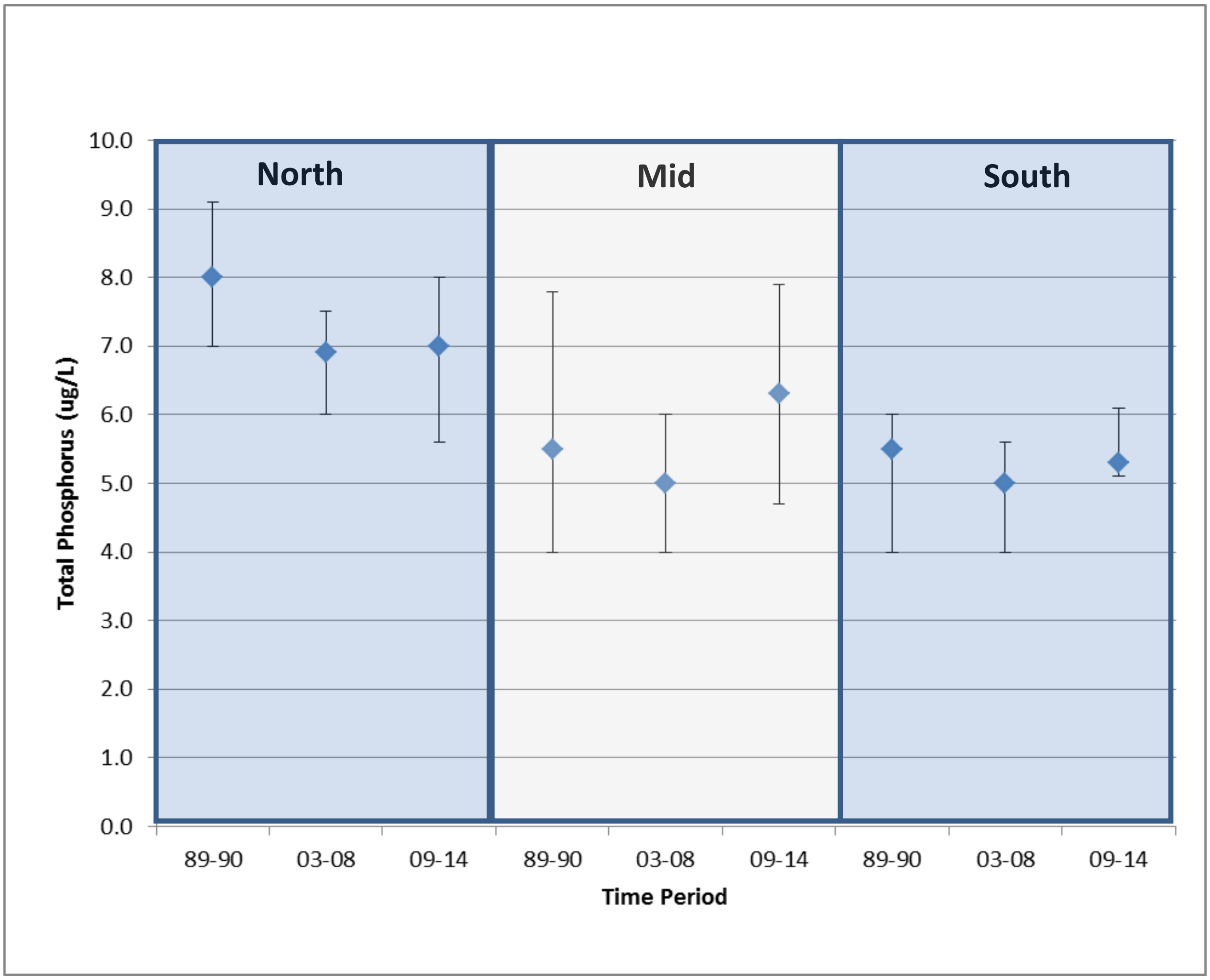


Figure 23. Median total phosphorus concentration of nearshore areas of the lake—comparison across region and time periods with 95% confidence intervals.

8.4.4 Long-Term Trend Stations: Lake Area

A comparison was made between TP concentrations from the regional analysis with concentrations of long-term trend sites. The regional trend analysis in the northern lake showed TP concentrations were significantly higher in 1989–1990 than they were in 2003–2008 and 2009–2014. This trend was not observed at the long-term trend sites in the north—Oden and Sunnyside—where there was no significant change in TP over time ($p = 0.564$ and $p = 0.878$, respectively) (Figure 24 and Figure 25).

Regional results in the mid and southern region of the lake show TP concentrations did not change significantly over time. At the mid-lake long-term trend stations, TP concentrations did not change over time at Garfield (p = 0.618); however, there was a slight increase at Talache (p = 0.102) (Figure 26 and Figure 27). At the southern long-term trend stations, a significant decrease in TP concentrations was observed at Bayview North (p = 0.015); however, concentrations increased slightly at Lakeview (p = 0.329) (Figure 28 and Figure 29).

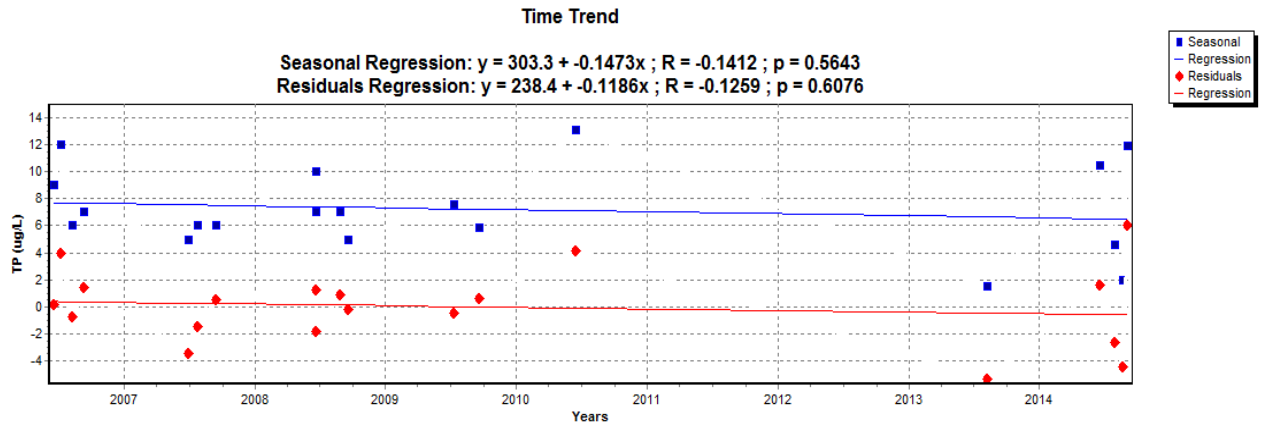


Figure 24. Yearly trend in total phosphorus at Oden Bay.

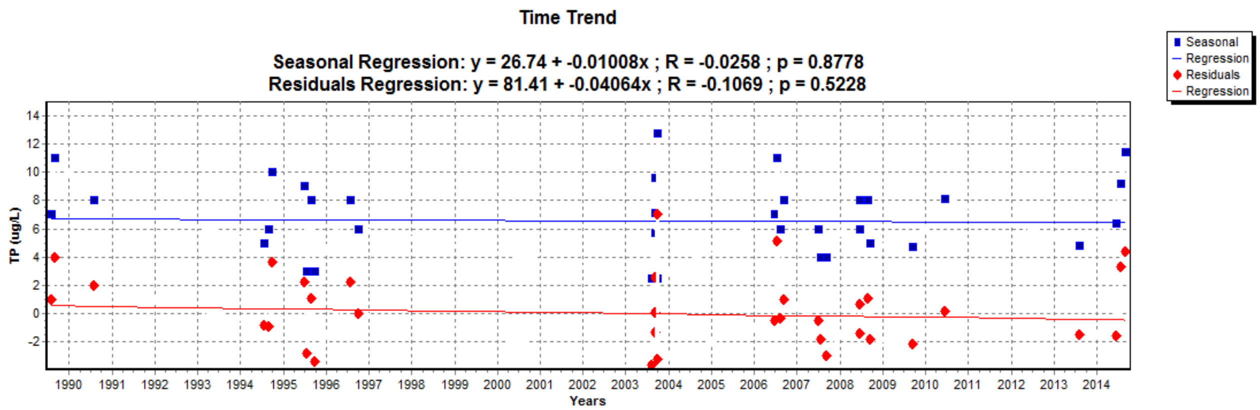


Figure 25. Yearly trend in total phosphorus at Sunnyside.

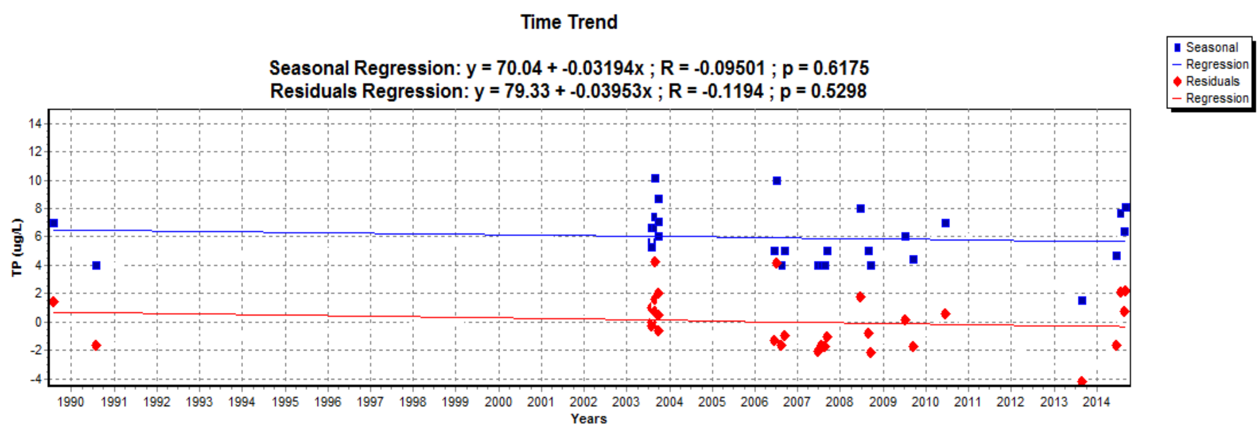


Figure 26. Yearly trend in total phosphorus at Garfield.

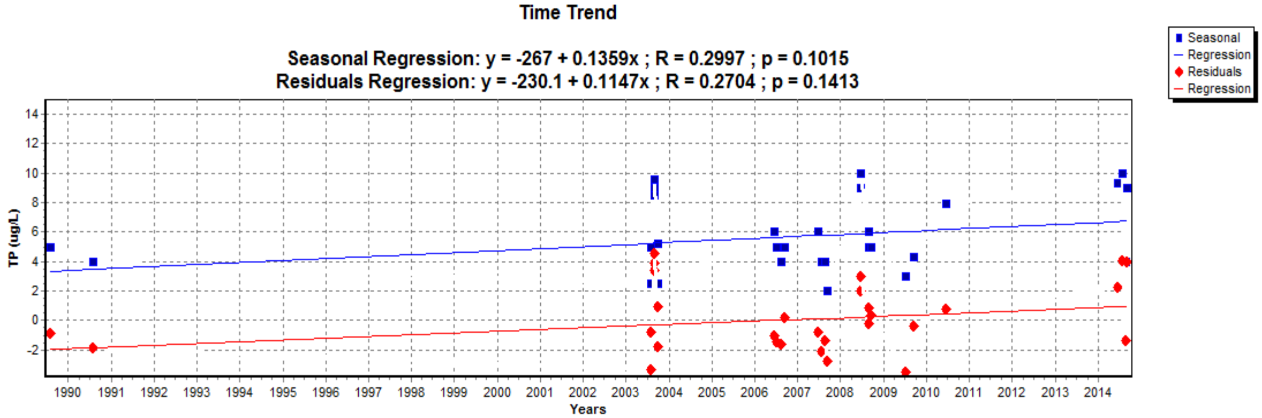


Figure 27. Yearly trend in total phosphorus at Talache.

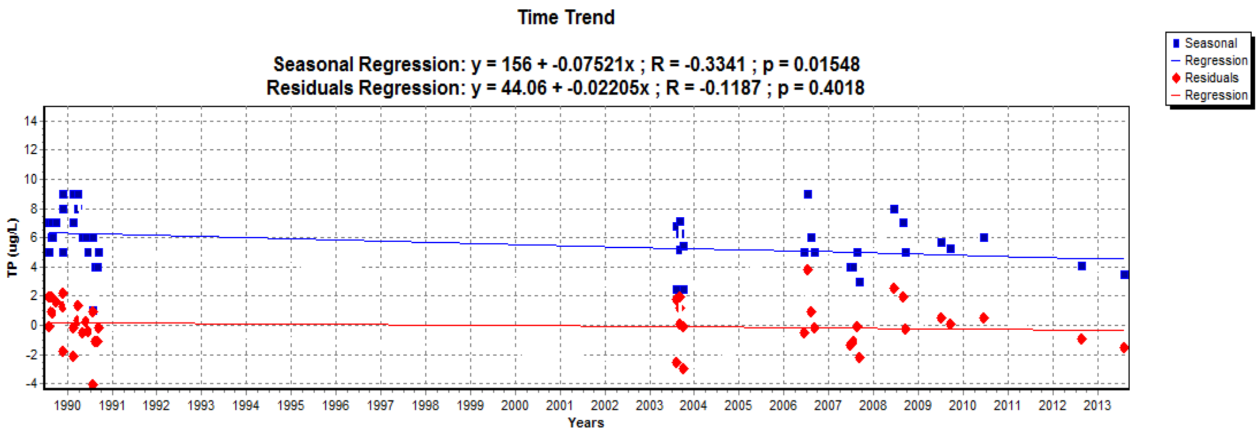


Figure 28. Yearly trend in total phosphorus at Bayview North.

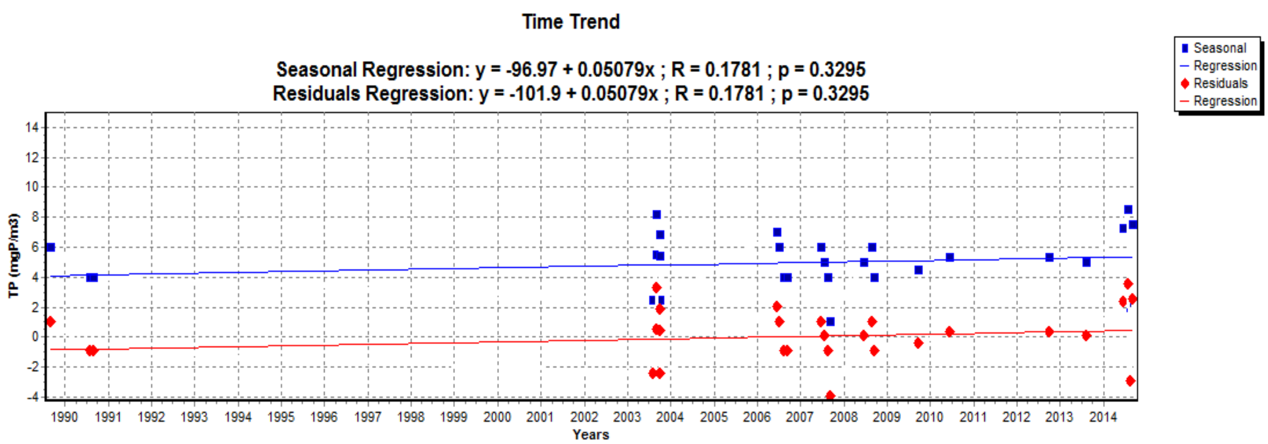


Figure 29. Yearly trend in total phosphorus at Lakeview.

8.4.5 Regional Trends: Summer Months

TP concentrations in the summer months were differentiated between the northern and mid/southern lake and for the time period of data collected by Falter (1989–2003) and others (2006–2014). This division was the most logical due to the number of data points in each data set. The preferable division would have been in 5- to 6-year sets, but the low number of data points within each month precluded any meaningful statistical analysis. Median TP concentration with the 95% confidence intervals was graphed by lake location and time period. General descriptive statistics on which these box plots are base are listed in Appendix B (Tables B-8 and B-9).

Median TP concentrations from the northern region of the lake were evaluated by month using the Kruskal-Wallis one-way ANOVA. No significant difference was observed between June, July, and September across the time periods ($p = 0.663$). When all data were run under the Kruskal-Wallis one-way ANOVA, median TP concentrations in August 2006–2014 were determined to be significantly different than the other month/time periods ($p = 0.019$) (Figure 30).

The regional trend analysis concluded total phosphorus is significantly lower in August, particularly in the mid/southern regions of the lake.

Median TP concentrations from the mid/southern region of the lake were evaluated by month using the Kruskal-Wallis one-way ANOVA. No significant difference was observed between June, July, and September across all time periods ($p = 0.892$), and median concentrations in August were determined to be significantly different than the other month/time periods ($p = 0.000$) (Figure 31).

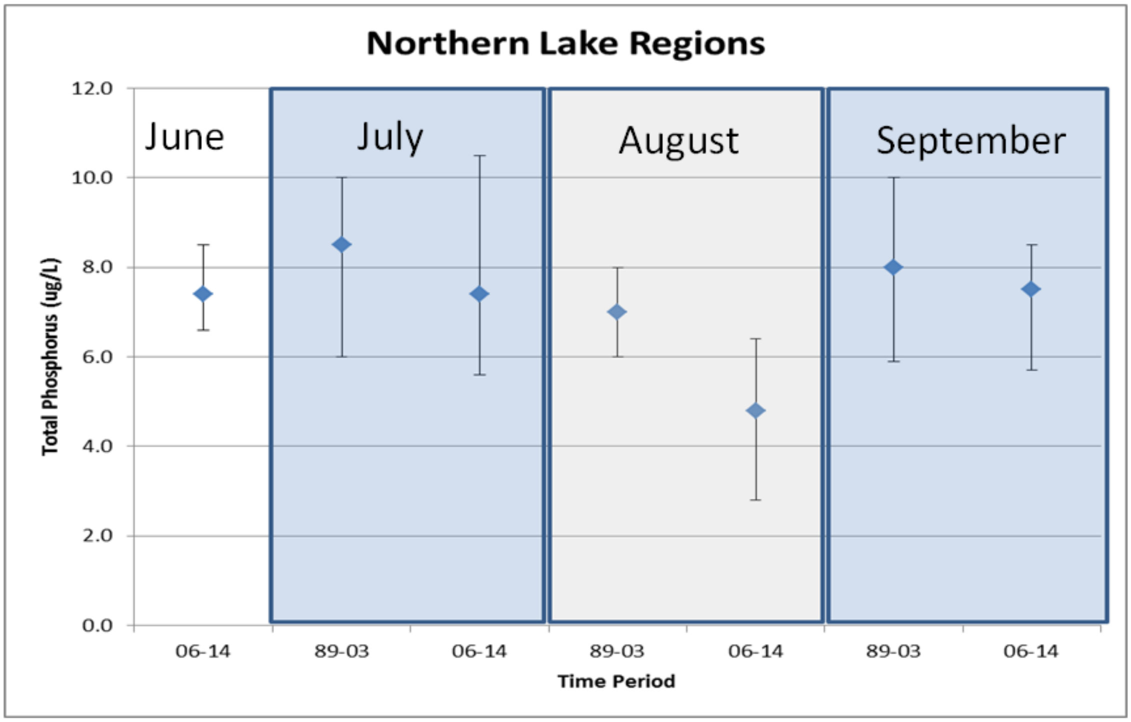


Figure 30. Median total phosphorus concentrations for the northern lake region graphed with 95% confidence intervals.

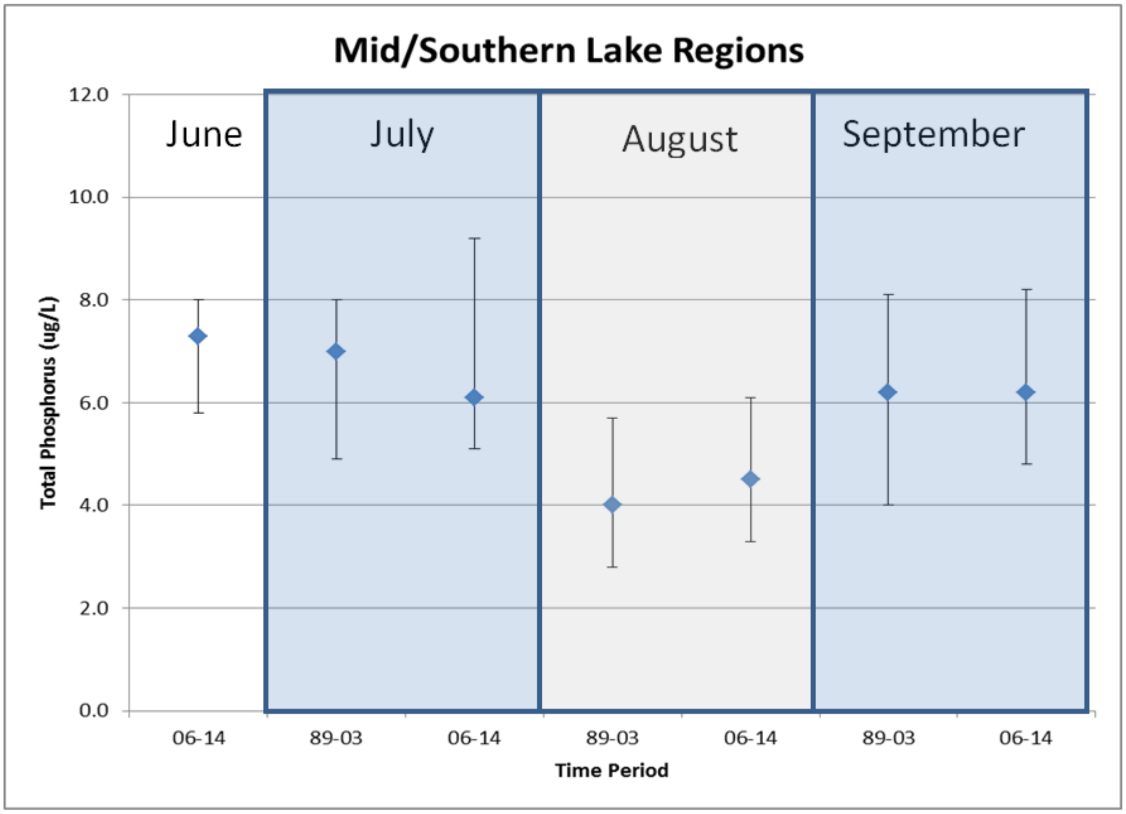


Figure 31. Median total phosphorus concentrations across the summer months for the mid/southern lake regions graphed with 95 % confidence intervals.

8.4.6 Long-Term Trend Stations: Summer Months

A comparison was made between TP concentrations in the summer months from the regional analysis with TP concentrations of long-term trend sites. In the north, a regional trend of lower phosphorus was observed during August 2006–2014. This trend was not observed at Oden, and was slightly apparent at Sunnyside (Figure 32 and Figure 33). In the mid and southern regions of the lake, phosphorus decreased during the month of August across all time periods. This trend was very slight at Garfield and more pronounced at Bayview North. At Talache, there was a downward trend from June to September, and at Lakeview, no trend was apparent (Figure 34 through Figure 37).

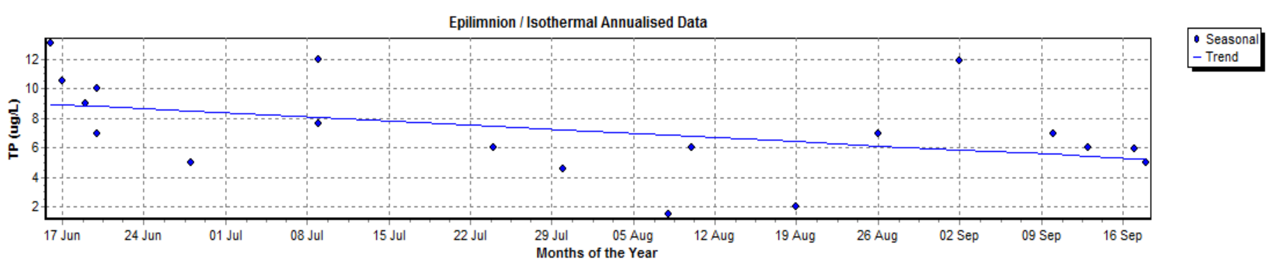


Figure 32. Monthly trend in total phosphorus at Oden.

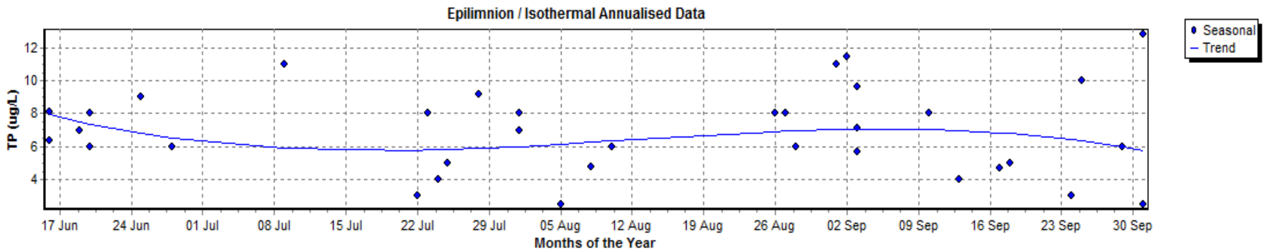


Figure 33. Monthly trend in total phosphorus at Sunnyside.

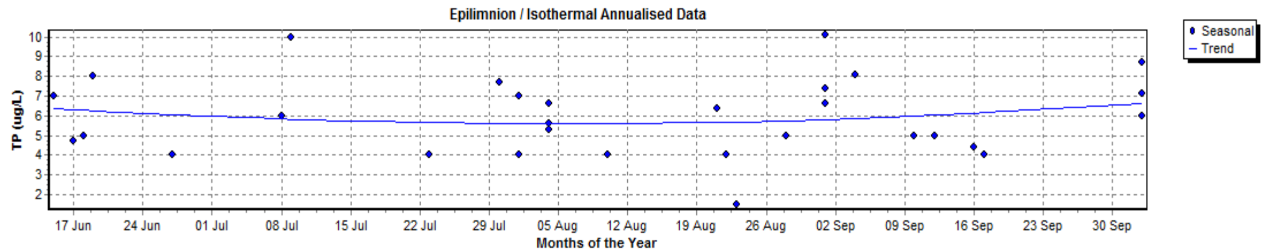


Figure 34. Monthly trend in total phosphorus at Garfield.

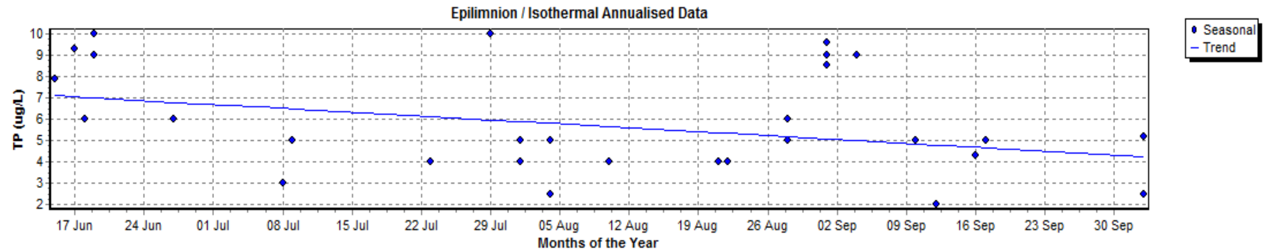


Figure 35. Monthly trend in total phosphorus at Talache.

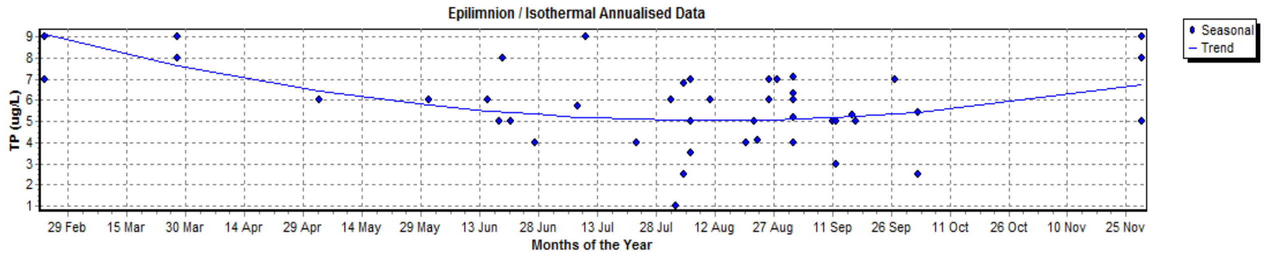


Figure 36. Monthly trend in total phosphorus at Bayview North.

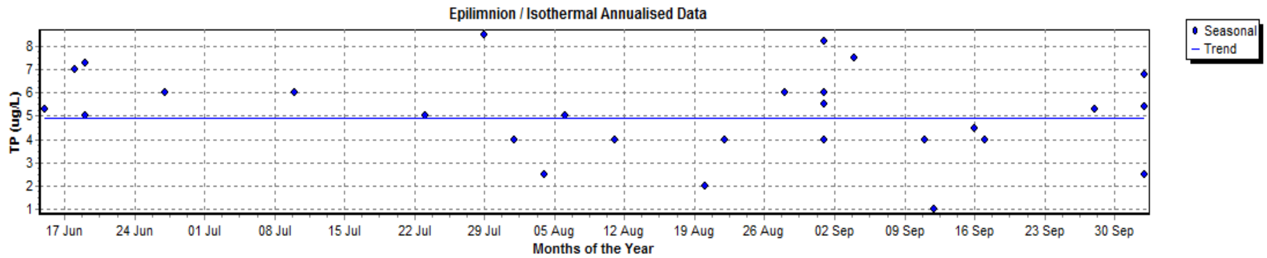


Figure 37. Monthly trend in total phosphorus at Lakeview.

8.4.7 Discussion

Due to a lack of resources, a long-term TP data set for all the monitoring stations established by Falter (1992) does not exist. However, long-term data exist at two stations in each of the northern, mid, and southern region of the lake. These data were compared to a regional analysis of the data, which grouped stations from the northern, mid, and southern regions of the lake.

When looking at the data from each of the monitoring stations, TP concentrations in the north and mid regions of the lake are higher than the southern part of the lake. Data from the northern stations remained relatively constant from the 1990s to present, except at Oden Bay, where TP decreased over time. TP at the mid-lake stations was not consistent over time, and the variability at these stations was high. Much of that variability can be attributed to the low number of data points at those sites. TP at the southern stations remained constant over time, with little variability.

The regional trend analysis in the northern lake shows TP concentrations were significantly higher in 1989–1990 than in both 2003–2008 and 2009–20014. This trend was not observed at both long-term trend sites in the north, where there was no significant change in TP over time.

The regional trend analysis in the mid and southern region of the lake show TP concentrations did not change significantly over time. At the mid-lake long-term trend stations, TP concentrations did not change over time at Garfield, but they did increase slightly at Talache. At the southern long-term trend stations, a significant decrease in TP concentrations was observed at Bayview North, but concentrations increased slightly at Lakeview.

Results of the regional trend analysis showed a significant decrease in TP in the month of August in all regions of the lake. Long-term trend sites did not always follow this pattern.

The discrepancy between results from the regional trend data and results from the long-term trend sites may be due to unique conditions at individual monitoring stations. While the regional trend analysis gives a broad representation of what is going on in specific regions of the lake, more consistent monitoring at individual monitoring stations is needed to better understand phosphorus conditions and trends at individual sites.

While the regional trend analysis gives a broad representation of what is going on in that region of the lake, more consistent monitoring at individual monitoring stations is needed. This consistent monitoring will provide a better understanding of total phosphorus conditions and trends at individual sites.

8.5 Total Nitrogen

This section evaluates TN in the epilimnion during summer stratification and the photic zone during isothermal conditions to understand trends and differences in TN concentrations across monitoring stations, lake region, and summer months. TN data were determined not to be normally distributed, so the data were $\log_{10}$ and log normal transformed, but they maintained a non-normal distribution. Therefore, DEQ performed nonparametric statistical analysis, which included evaluating median TN concentrations as opposed to mean TN concentration.

8.5.1 Regional Trends: Lake Location

Due to the large data gaps for TN at sites other than the long-term trend sites, we were unable to evaluate TN at each station over time; therefore, a regional trend analysis was performed on data from the northern, mid, and southern regions of the lake. The data were also grouped into three time periods: (1) 1989–1990, (2) 2003–2008, and (3) 2006–2014. The median and 95% confidence intervals of TN concentration for each time period were graphed by region (Figure 38). General statistics are provided in Appendix B (Table B-10).

Data during the 2003–2008 time period were dominated by the long-term trend sites, Garfield and Talache. In addition, much of the data during 2006 and 2007 was reported below the reporting limit. With that said, a Kruskal-Wallace ANOVA showed a significant increase in TN from the period of 2003–2008 to 2009–2014 ($p = 0.000$).

A Mann-Whitney test comparing data in 1989–1990 and 2009–2014 revealed a significant increase in nitrogen only in the southern part of the lake ($p = 0.001$).

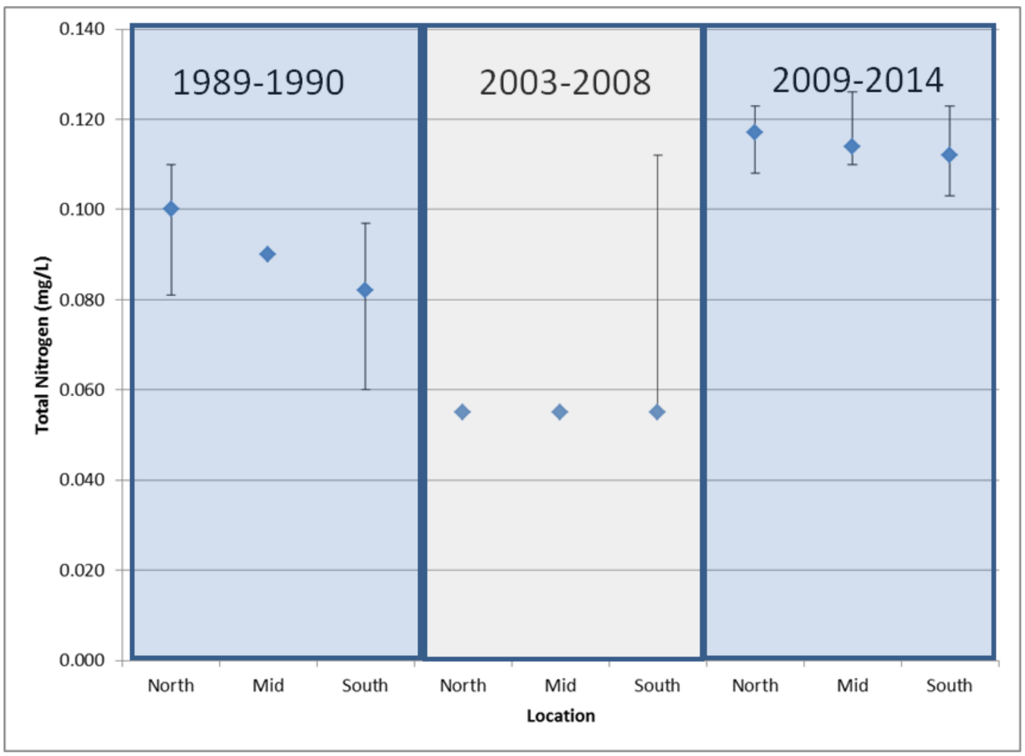


Figure 38. Total nitrogen concentration of nearshore areas of the lake—comparison across region and time periods.

8.5.2 Long-Term Trend Stations

An evaluation of TN at the long-term trend stations shows a significant increase at all stations but the Lakeview station, where there was a slight increase of TN across time ($p = 0.14$) (Figure 39 through Figure 44). The Lakeview station had much variability in the data, particularly since 2006.

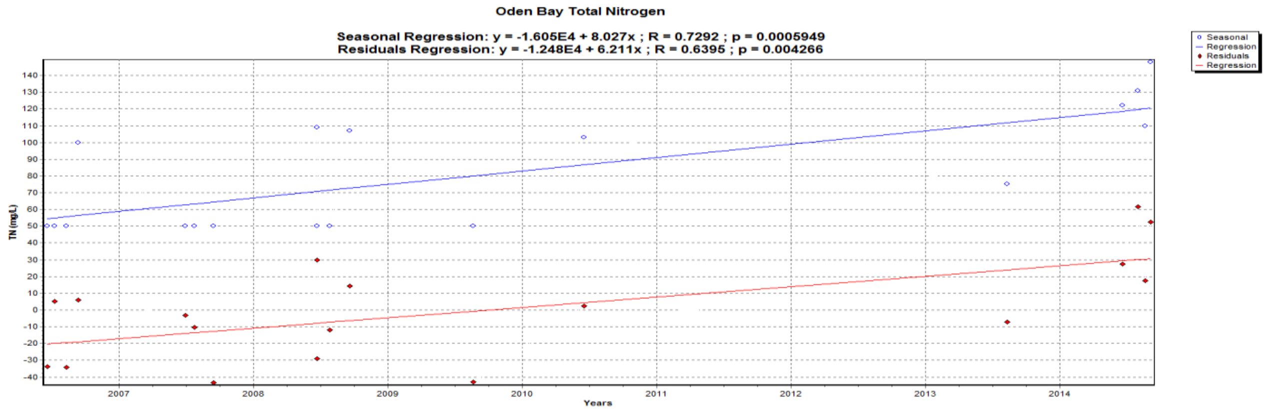


Figure 39. Yearly trend in total nitrogen at Oden Bay.

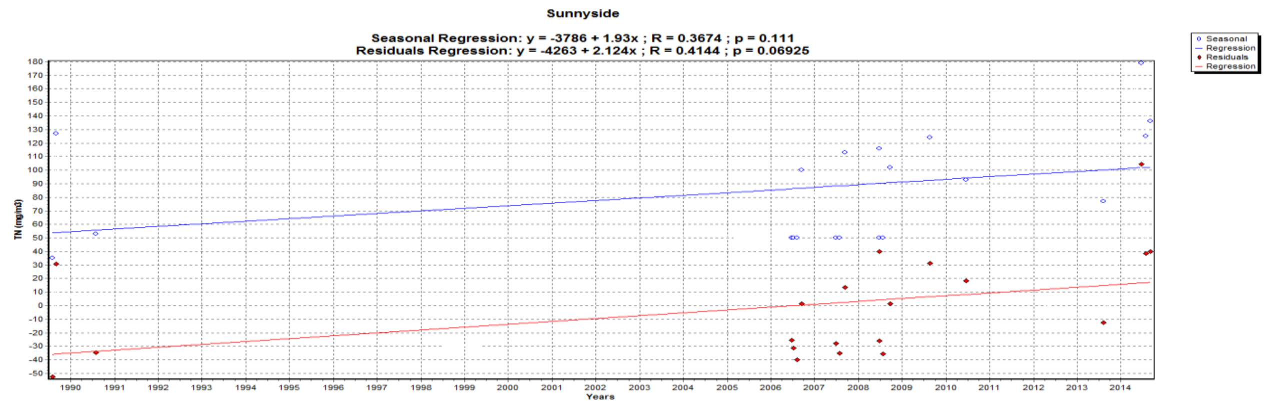


Figure 40. Yearly trend in total nitrogen at Sunnyside.

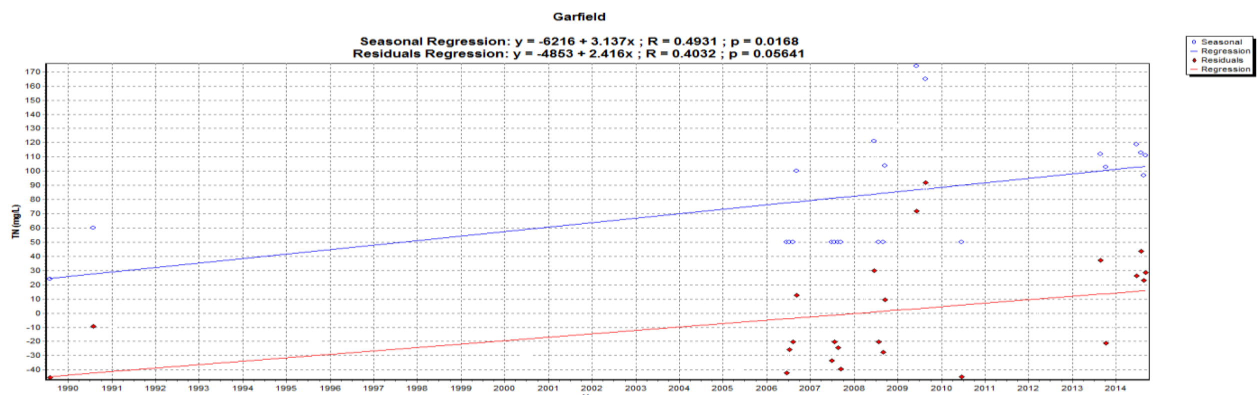


Figure 41. Yearly trend in total nitrogen at Garfield.

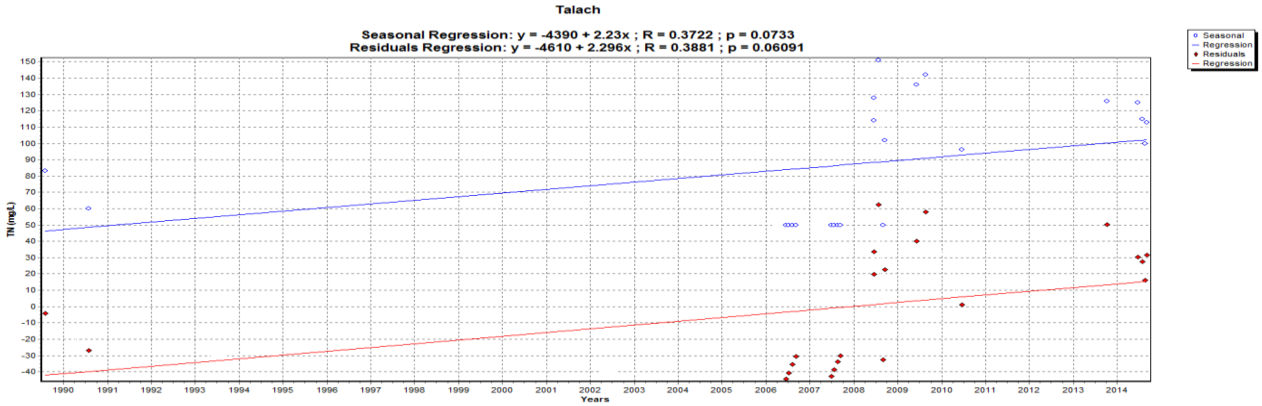


Figure 42. Yearly trend in total nitrogen at Talache.

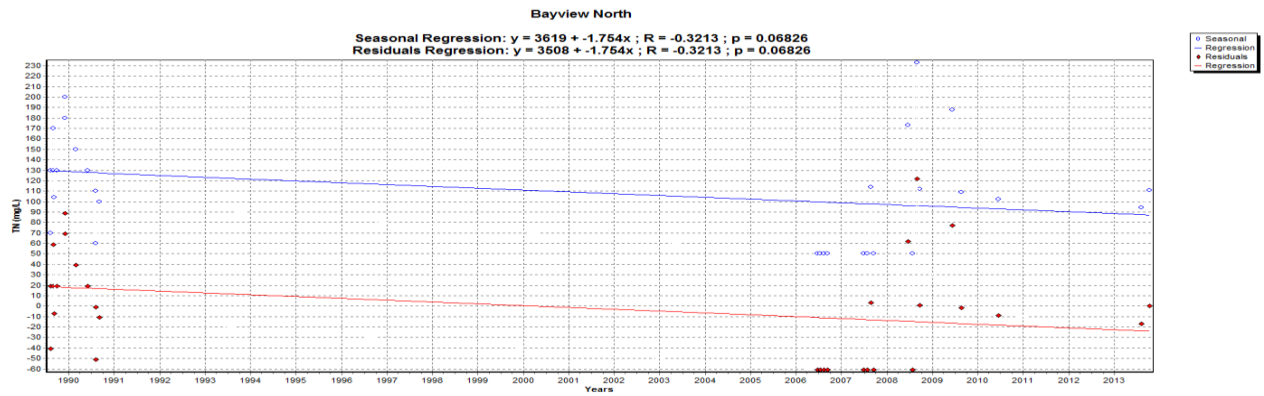


Figure 43. Yearly trend in total nitrogen at Bayview North.

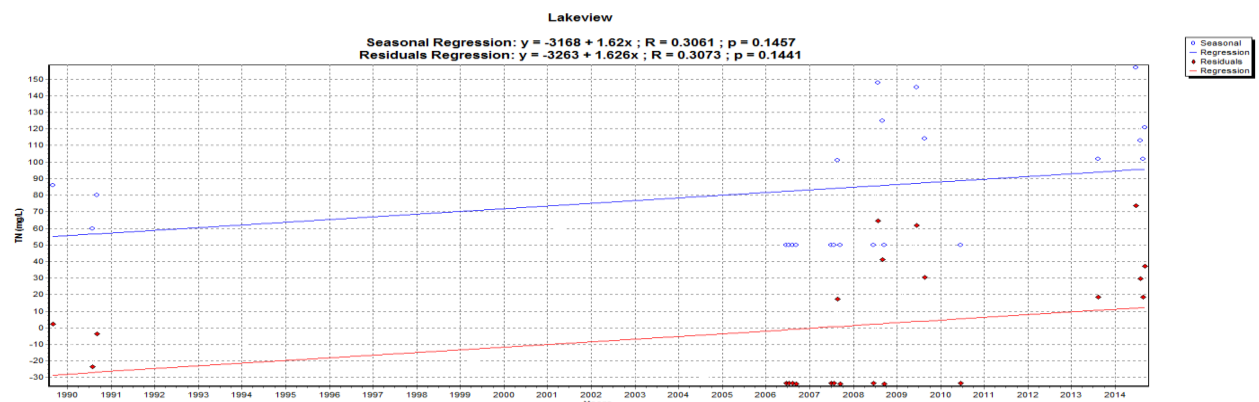


Figure 44. Yearly trend in total nitrogen at Lakeview.

8.5.3 Regional Trends: Seasonality

No significant difference was observed in TN across the summer months during all three time periods in the northern lake (Figure 45) and the mid/southern region of the lake (Figure 46). General statistics are provided in Appendix B (Table B-11 and B-12).

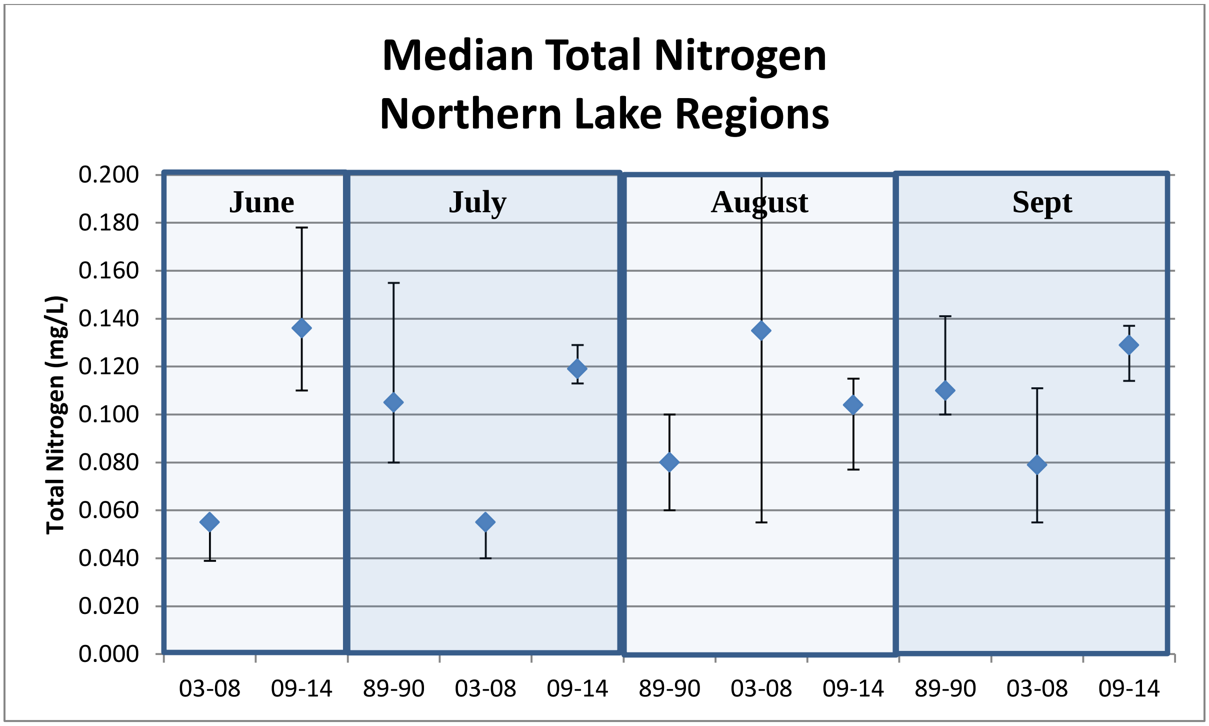


Figure 45. Median total nitrogen concentrations across the summer months for the northern lake regions graphed with 95% confidence intervals.

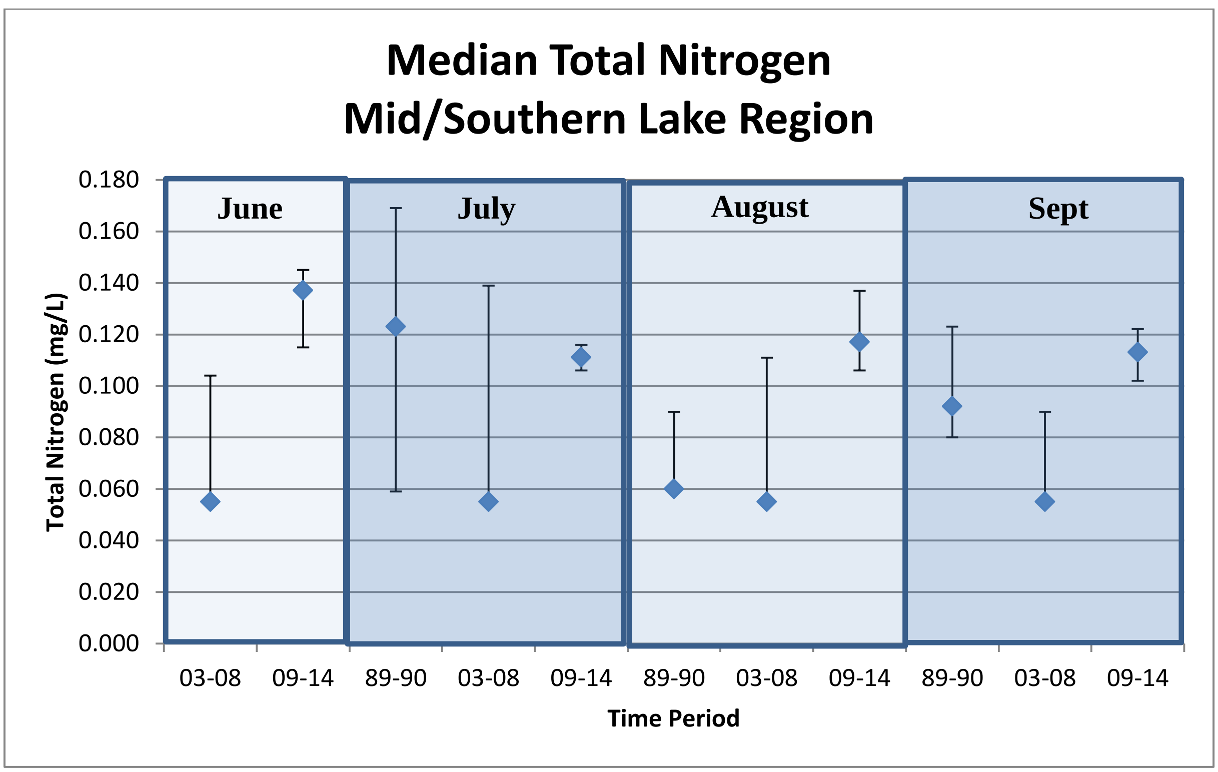


Figure 46. Median total nitrogen concentrations across the summer months for the mid/southern lake regions graphed with 95% confidence intervals.

8.5.4 Discussion

While TN concentrations in Lake Pend Oreille have been historically low, they were at their lowest during 2003–2008, with exceptionally low concentrations in 2006 and 2007. During 2006–2007, much of the data were reported below the laboratory reporting limit. During 2009, TN concentrations were significantly higher than in the 2003–2008 period.

The regional trend analysis concluded total nitrogen concentrations in Lake Pend Oreille have been historically low. They were lowest during the 2003–2008 time period, with exceptionally low concentrations in 2006 and 2007.

The Lakeview site appears to be an outlier due to the high variability. This fluctuation is believed to be a result of something in the watershed. Further investigations are recommended, including more detailed speciation of nitrogen in water chemistry monitoring to better understand the source(s) of nitrogen.

TN is an important component in the TN:TP ratio, where low TN:TP can favor conditions for cyanobacteria abundance. TN:TP is discussed further in section 8.8. Unlike TP, there appears to be no seasonal pattern with TN across the summer months.

8.6 Chlorophyll *a*

Chlorophyll *a* is a photosynthetic pigment found in algae, including blue-green algae. High concentrations of chlorophyll *a* are an indicator of high nutrient concentrations and high algae productivity. Low chlorophyll concentrations indicate low nutrient concentrations and low algae productivity.

A regional trend analysis was performed on data from the northern, mid, and southern regions of the lake. The data were also grouped into two time periods: (1) 2006–2008 and (2) 2009–2014. Chlorophyll *a* data were not collected under the Falter studies. The median and 95% confidence intervals of chlorophyll *a* concentration for each time period is represented by three regions of the lake: northern, mid, and southern (Figure 47). General statistics are provided in Appendix B (Table B-13).

Median chlorophyll *a* concentrations in all regions of the lake are very low. Chlorophyll *a* concentrations below 2 mg/L are indicative of very low-productivity (oligotrophic) waters. A Kruskal-Wallis ANOVA showed no significant difference in median chlorophyll *a* concentrations across the three locations in the 2006–2008 time period ($p = 0.500$) and in the 2009–2014 time period ($p = 0.367$). While there was a small decrease in chlorophyll *a* between the two time periods, there was no significant difference between the medians of the three locations across both time periods ($p = 0.250$).

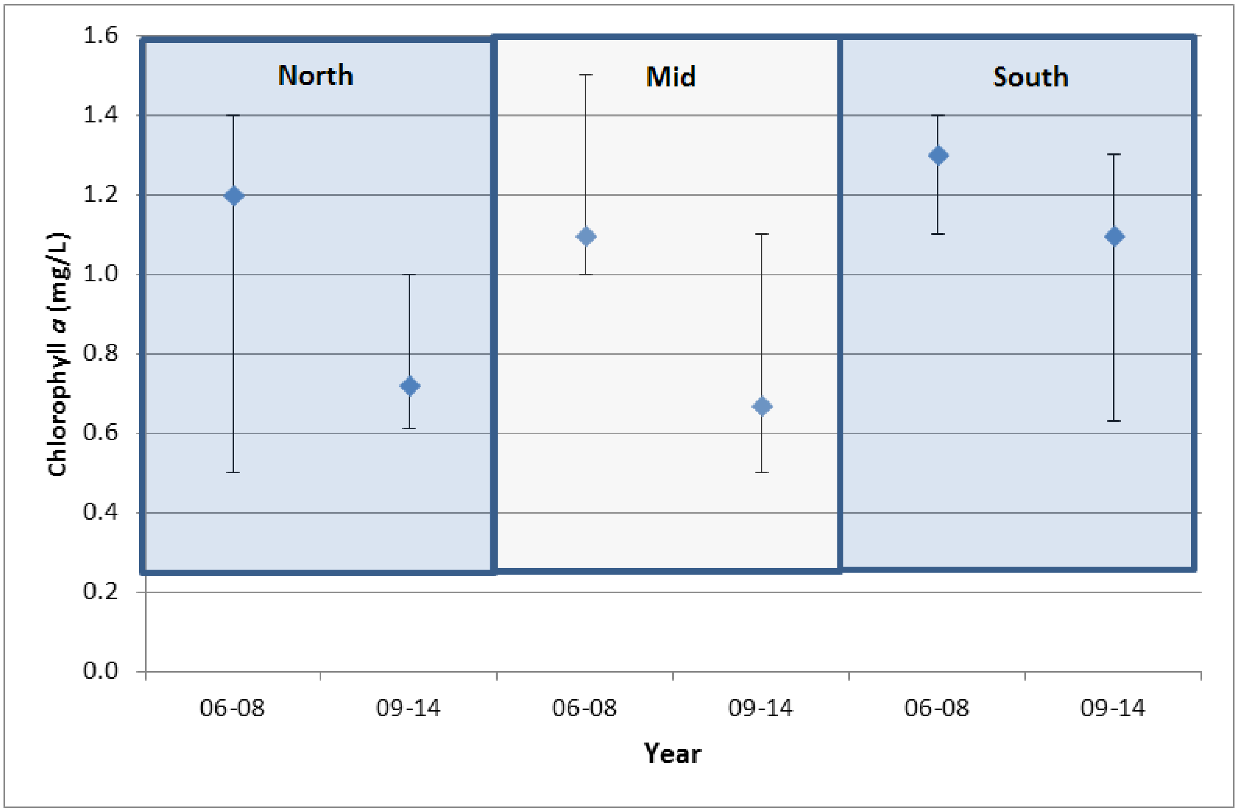


Figure 47. Median chlorophyll *a* concentrations of nearshore areas of the lake—comparison across region and time periods.

8.7 Trophic Status

The Carlson's Trophic State Index (TSI) is a common way to classify the overall trophic state of a lake. It assumes algal biomass is the basis for trophic state classification. Algal biomass is independently estimated by three metrics: TP, chlorophyll *a*, and water transparency measurements (Carlson 1977). Rather than having distinct breaks in trophic status classification, the TSI assumes the trophic state of a lake lies on a continuum. An oligotrophic lake has low nutrient (phosphorus) concentrations, low phytoplankton productivity, and high water clarity. A eutrophic lake has high nutrient (phosphorus) concentrations; high phytoplankton productivity, which can include nuisance blue-green algae; and low water clarity. The relationship between chlorophyll *a*, phosphorus, and Secchi depth in the index were defined by a score based on a number of equations derived by Carlson (1977) and further defined by Carlson and Simpson (1996) (Table 7). Carlson's TSI scores used in this study are described in Table 8.

Table 7. Relationship between chlorophyll *a*, phosphorus, and Secchi depth in the Carlson's Trophic State Index (Carlson 1996).

Trophic Index Score	Chlorophyll *a* (mg/L)	Total Phosphorus (µg/L)	Secchi Depth (meters)	Trophic Classification
<30–40	0–2.6	0–12	>8–4	Oligotrophic
40–50	2.6–20	12–24	4–2	Mesotrophic
50–70	20–56	24–96	2–0.5	Eutrophic
70–100+	50–155+	96–384+	0.5–<0.25	Hypereutrophic

Trophic status over time was compared for each of the nearshore areas of Lake Pend Oreille. Only in 1989 and 2014 were data available from each of the monitoring sites established by Falter. Therefore, the comparison was made between those years. To better understand what was happening in the lake between 1989 and 2014, data from the long-term trend sites in 2007 were included in the analysis. Results of this analysis show while the nearshore region of the lake as a whole remains in an oligotrophic state, the Carslon TSI score has increased at a number of sites (Table 8).

Table 8. Carlson's Trophic State Index scores and trophic status classification by Carlson and Simpson [1996]).

Station	Chlorophyll-a			Secchi Depth			Total Phosphorus			Trophic Status
	1989	2007	2014	1989	2007	2014	1989	2007	2014	
Northern Stations										
Bottle			31.0				31.1		30.1	Oligotrophic
Ellisport			37.5				30.0		34.4	Oligotrophic
Kootenai			29.9				43.7		32.8	Oligotrophic
Oden		30.3	28.4					29.2	32.7	Oligotrophic
Sunnyside		32.6	32.7				35.8	26.4	35.8	Oligotrophic
Trestle			35.7						35.1	Oligotrophic
Mid-Lake Stations										
Camp			32.8	34.5		46.8	32.2		31.7	Oligotrophic
Garfield		30.7	33.9	33.6	29.3	38.5	32.2	25.0	31.6	Oligotrophic
Glengary			35.4			32.1			34.1	Oligotrophic
Granite			30.6	25.3		34.8	27.4		30.3	Oligotrophic
Talache		31.4	30.1	31.7	32.8	39.1	27.4	24.1	34.3	Oligotrophic
Southern Stations										
Bayview Nearshore			31.1						33.2	Oligotrophic
Lakeview		29.5	31.6	30.5	27.2	31.6	30.0	24.1	30.8	Oligotrophic
Idlewilde			33.2			31.0			33.5	Oligotrophic

8.8 Total Nitrogen to Total Phosphorus Ratio

Cyanobacteria are microscopic bacteria also known as blue-green algae. Many species of cyanobacteria are naturally occurring in surface waters. They may occur as single cells or groups of cells. They are photosynthetic, and some species are noted for their ability to fix nitrogen, meaning that the organisms can use gaseous nitrogen as an energy source. Blooms generally occur in eutrophic conditions during late summer and fall when temperatures are warm. The physical appearance of cyanobacteria blooms can be unsightly, often causing thick mats along shorelines. The blooms can vary in color but typically appear as a split-pea soup, iridescent green paint, or a globular, brownish color.

Cyanobacterial harmful algal blooms (HABs) are blooms that are harmful to the health of humans and animals. Certain species of cyanobacteria produce dangerous toxins that are released to the water as the bacteria die. The toxins produced by cyanobacteria can target the nervous system, liver, kidneys, skin, and gastrointestinal tract. There are currently no known antidotes for exposures to the toxins associated with cyanobacteria.

Both humans and animals can experience the effects of these toxins after exposure. Exposure is from contact with a water body experiencing a HAB through the following mechanisms: ingestion through drinking water or recreation in the water body; inhalation from water activities such as jet-skiing or boating; and inhalation of water used for irrigation. People and animals using water bodies for recreational purposes are most likely to experience maximum exposure when a HAB develops and forms surface scums near recreational areas and beaches. Wind-driven accumulations of surface scums can result in a significant increase in toxin concentrations. Pets are particularly susceptible, due to their susceptibility to ingest the water where surface scums are present. Using water for drinking water from a lake experiencing a HAB is dangerous if toxins are present, and the toxins cannot be removed by boiling or filtering the water.

A low nitrogen to phosphorus ratio (TN:TP) favors dominance of cyanobacteria within the phytoplankton community. Smith (1983) showed N:P ratios less than 30 increase risk of cyanobacterial blooms. However, the N:P ratio of 30 was questioned in more recent studies where cyanobacterial dominance and toxin production were observed at much higher levels (as summarized in Harris et al. [2014]).

A large data gap exists for TN data at sites other than the long-term trend sites. Therefore, the data analysis included an evaluation of N:P ratios at long-term trend sites and an evaluation of N:P ratios during the 2014 monitoring season. Median N:P ratios for the long-term monitoring stations were graphed across time with the 95% confidence intervals (Figure 48). Median TN:TP ratios at all long-term sites except Lakeview were below the 30 threshold described by Smith (1983), indicating a risk at those sites for cyanobacterial blooms. This possibility is particularly evident at the mid-lake sites, Garfield and Talache, where the ratios were very low and variability was also low. Ratios at Lakeview were quite variable, and this site appears to be an outlier.

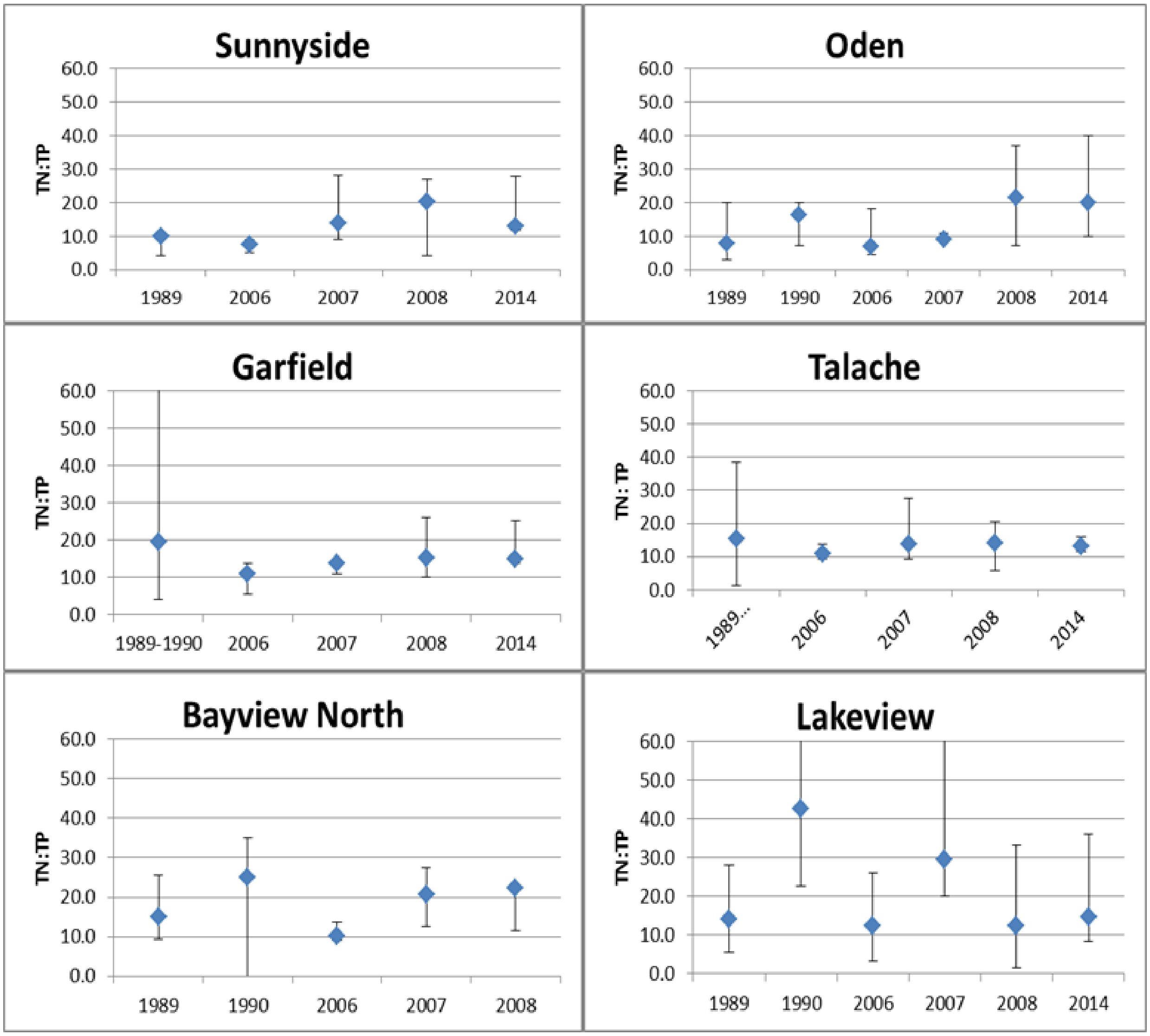


Figure 48. TN:TP ratios at the long-term monitoring stations over time.

An evaluation of TN:TP ratios during the 2014 summer monitoring season at each region provided some interesting results. The ratios were graphed by month (Figure 49 through Figure 51). At the northern monitoring stations, ratios increased in August, except at Bottle and Sunnyside where a decrease in TN:TP ratios was observed. The highest ratios were observed at Kootenai, Trestle, and Oden, where TN:TP ratios were at or near 40, reflecting the trend of lower TP observed in August.

TN:TP ratios remained relatively stable at the mid-lake stations, except at Granite, where a spike occurred in August. This spike can be attributed to nitrogen concentrations at Granite of 0.150 mg/L during August 2014.

At the southern monitoring stations, TN:TP ratios increased in August, with the highest ratio at Lakeview at 37. As stated earlier, Lakeview appears to be an outlier. During the 2014 monitoring season, the pattern of TN:TP ratios across the summer months was similar to other southern lake stations; however, the fluctuations are more pronounced at that site.

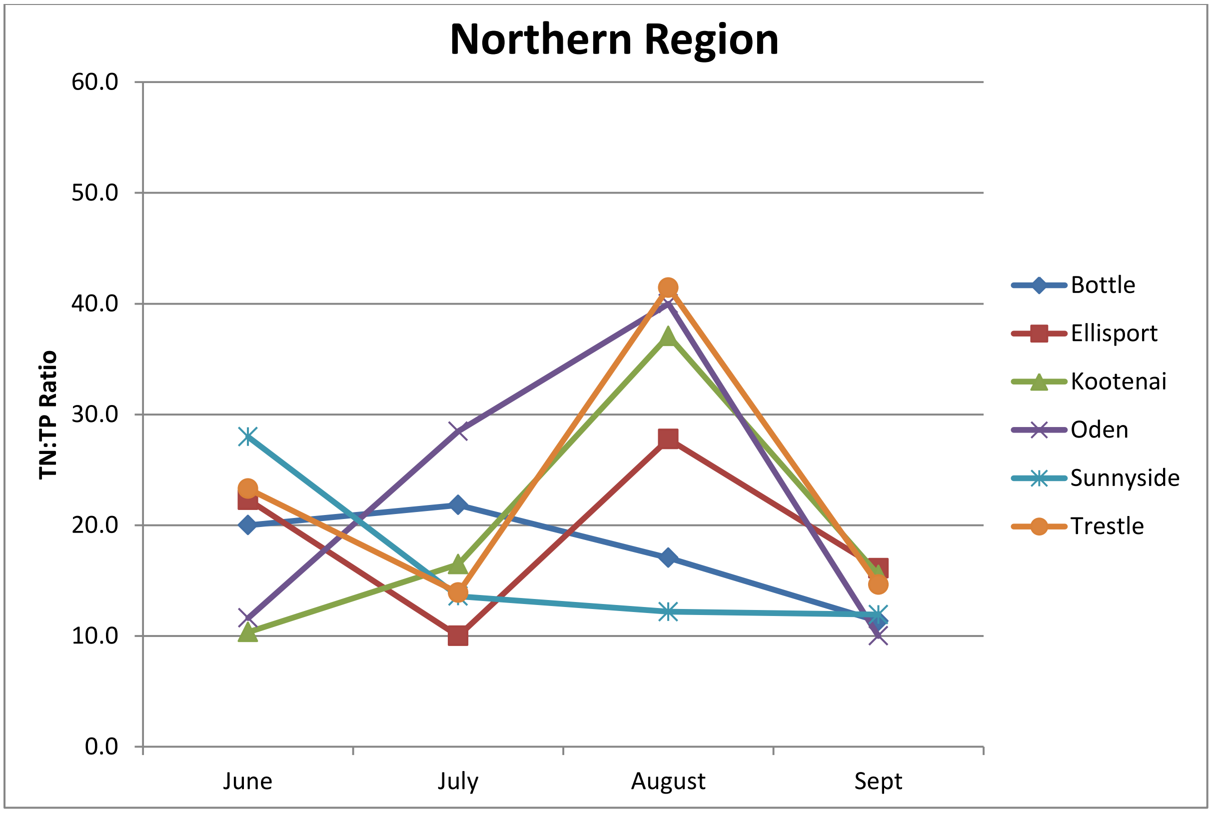


Figure 49. TN:TP ratios in the northern nearshore waters of Lake Pend Oreille, 2014.

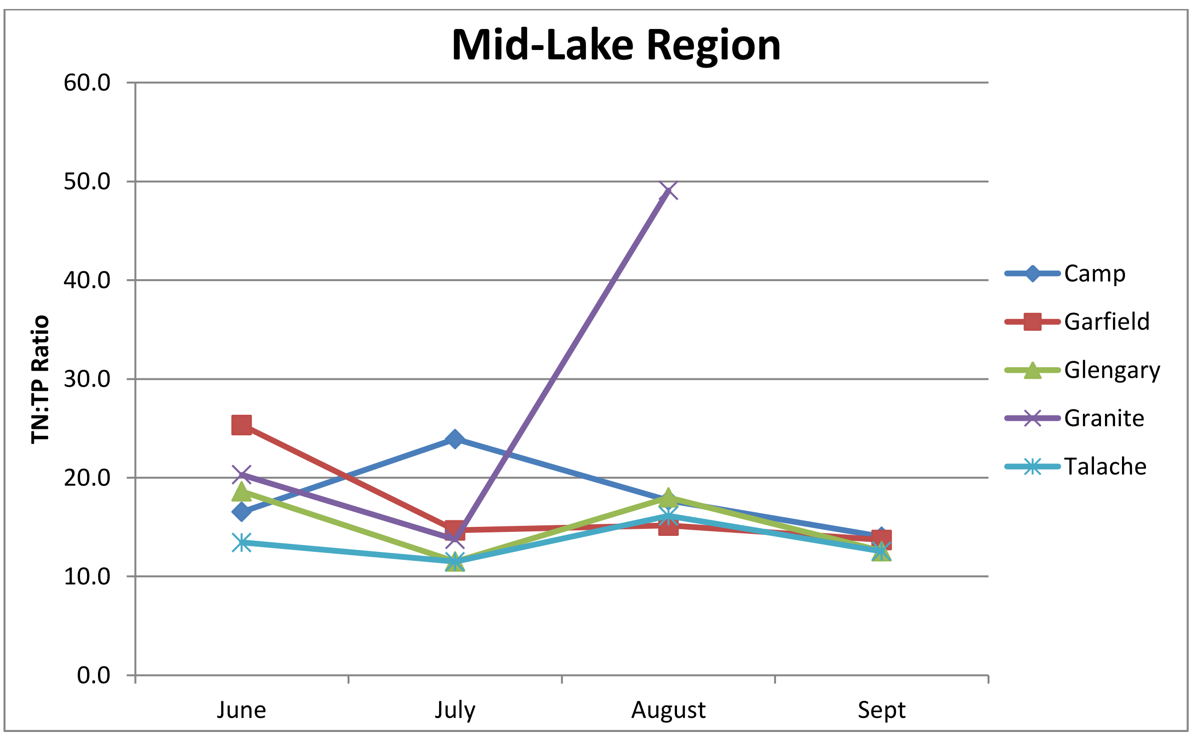


Figure 50. TN:TP ratios in the mid-lake nearshore waters of Lake Pend Oreille, 2014.

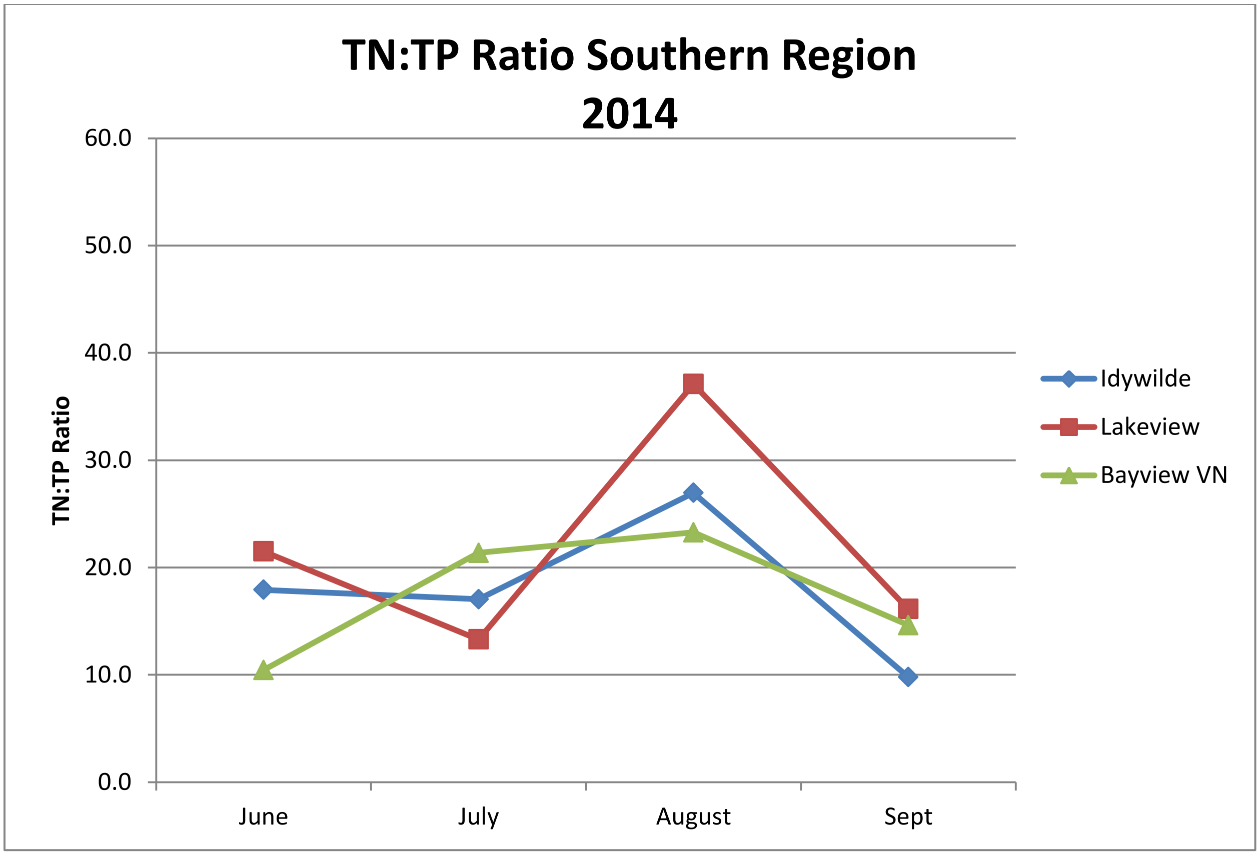


Figure 51. TN:TP ratios in the southern nearshore waters of Lake Pend Oreille, 2014.

The TN:TP ratios at the long-term nearshore stations of Lake Pend Oreille were mostly consistently below the 30 threshold described by Smith (1983), suggesting these sites are at risk of cyanobacterial blooms. However, during August 2014, TN:TP ratios were above 30 at three sites in the northern region of the lake (Kootenai, Oden, and Trestle) and two sites in the mid/southern region of the lake (Granite and Lakeview). More recent literature would suggest the TN:TP ratios observed at these sites may not be high enough to suppress cyanobacteria blooms. Therefore, monitoring is necessary to understand the phytoplankton community structure and risk of harmful cyanobacteria blooms.

The Lakeview site appears to be an outlier due to the high variability in TN:TP ratios over time. While TP at this station has remained stable over time, TN has fluctuated greatly. This fluctuation is believed to be a result of something in the watershed. Therefore, further investigations in the watershed are recommended. This would include more detailed speciation of nitrogen in water chemistry monitoring at the Lakeview site to better understand the source(s) of nitrogen.

9 Summary and Analysis of Productivity Monitoring Data

This project included monitoring periphyton, which is the assemblage of algae, diatoms, and cyanobacteria found on lake-bottom substrates. In addition to being the primary food source for macroinvertebrates, periphyton are considered early indicators for change in chemical and physical environmental factors within a lake. Periphyton growth can be light-limited, nutrient-limited, or both, and growth may also be influenced by temperature. They are also an important water quality indicator because they can quickly consume water column nutrients. DEQ has evaluated periphyton growth rate and community composition as further assessment of lake productivity and nutrient uptake within the nearshore areas of Lake Pend Oreille.

During the 2014 productivity monitoring, artificial substrates were placed at 14 locations throughout the nearshore portions of Lake Pend Oreille. The artificial substrates were sampled for temperature and light, chlorophyll *a*, and periphyton communities (section 7).

9.1 Purpose and Scope

Chlorophyll *a* concentrations, periphyton cell identification and enumeration (counts), relative temperature, and relative light measures were collected from artificial substrates to characterize productivity measures to accompany routine trophic monitoring.

Productivity monitoring was focused on the organisms living on the surfaces (periphyton) of the bottom (benthos) of the lake in the nearshore zone. Due to funding, this study did not include evaluation of plankton, zooplankton, or other higher organisms. Periphyton is representative of lake productivity because it remains in place (relatively nonmotile), is relatively easily sampled, and integrates a number of biotic and abiotic factors.

9.2 Vandalism

During the 2014 monitoring season, the level of vandalism was low, with only two artificial substrates appearing to have undergone some sort of vandalism. The Talache station backup artificial substrate was missing on the August 5 visit, but it did not seem that the original artificial substrate was touched. The Garfield bay station temperature and light sensor data logger was missing on the August 15 visit. The artificial substrate was likely removed from the water for some period of time, perhaps long enough to kill the periphyton that had grown prior to August 15. The Bottle Bay station artificial substrate may have been vandalized because it was not found after the third week of monitoring. However, the dense underwater plants (macrophytes) may have made finding the artificial substrate impossible.

9.3 Temperature and Light

Temperature and light loggers were placed with artificial substrates. The purpose of installing temperature data loggers was to determine whether the artificial substrate was placed in an area with significant ground water inflow. Ground water may influence chlorophyll *a* growth rates and the periphyton community. The purpose for installing light data loggers was to determine if locations were getting an equivalent amount of light. Stations with too much or too little light (macrophyte shading) may limit periphyton growth and the periphyton community. Table 9 shows the relative temperature, relative light, and average depth for each of the stations. The loggers used for this study did not all download correctly and were recalled by the manufacturer; missing values in Table 9 indicate data were not available. Relative temperature and relative light are calculated from the residual of the daily average of all stations minus the daily average at each station.

Table 9. Productivity monitoring stations relative temperature, relative light, and average depth.

Station Name	Stn	Relative Temperature (°C)	Relative Light (lux*10,000)	Average depth (m)
Bayview	BVV	0.6	6	2
Bottle Bay	BOB	-na-	-na-	3
Camp Bay	CB	0.1	2	3.2
Ellisport Bay	ESB	0.2	2	3
Garfield Bay	GFD	0.1	19	2.3
Glengary Bay	GLN	0	-12	3.7
Granite	GRN	-1	14	2.3
Idlewilde Bay	IWD	-0.2	0	3.7
Kootenai Bay	KB	-na-	-na-	2.8
Lakeview	LV	-na-	-na-	2.5
Oden Bay	OB	-na-	-na-	3.2
Sunnyside	SS	0.5	-1	2.5
Talache	TCH	-0.2	13	2.8
Trestle	TRC	-1.5	-2	2.4

The Trestle and Granite stations were the coldest. Trestle artificial substrate may have a slight ground water influence because of its location. Granite artificial substrate was adjacent to the deep pool of Lake Pend Oreille, and the cooler temperatures may have resulted from mixing with deeper/cooler waters. The Glengary Bay station appears to have had the least light, which may be explained by both the depth of the artificial substrate and its proximity to a piling (<1 m). The Garfield Bay station had the highest light intensity.

9.4 Chlorophyll *a*

The chlorophyll *a* rate of production clearly identified stations with higher productivity. Chlorophyll *a* concentrations ranged from 0.058 µg/m^2 to 4.58 µg/m^2 and are shown in Appendix C. Table 10 shows the stations and their chlorophyll *a* growth rates from highest growth rate to lowest. Plots of growth rates can be found in Appendix D. The Garfield Bay station had the lowest growth rate of 0.007 µg/m^2/day. However, Garfield Bay may have had less growth due to vandalism.

Maximum chlorophyll *a* is also shown in Table 10. Maximum chlorophyll *a* was usually found in the samples collected upon retrieval (week 6). An exception is the Bottle Bay station. The substrate was not found after week 3. Using the growth rate found at Bottle Bay, the maximum chlorophyll *a* for the Bottle Bay station was projected.

Table 10. Productivity monitoring stations chlorophyll *a* growth rate and maximum concentrations.

Station Name	Alias	Chla growth rate (ug/m²/day)	Maximum Chla (ug/m²)
Ellisport Bay	ESB	0.103	4.58
Kootenai Bay	KB	0.102	4.5224
Sunnyside	SS	0.089	3.4818
Glengary Bay	GLN	0.076	3.7088
Oden Bay	OB	0.072	3.5062
Bottle Bay†	BOB	0.069	2.898
Trestle	TRC	0.065	2.733
Granite	GRN	0.039	1.8642
Lakeview	LV	0.036	1.7046
Bayview	BVV	0.033	1.5726
Camp Bay	CB	0.030	1.4738
Idlewilde Bay	IWD	0.026	1.0762
Talache	TCH	0.013	0.6248
Garfield Bay	GFD	0.007	0.3894

†Bottle Bay maximum Chla projected from growth rate

The growth rate plots shown in Figure 52 have very solid regressions for biologic measures. The study should have been run longer to capture a leveling off of the growth rate, where the periphyton is fully stocked and additional growth is limited by space. The stations with growth rates greater than 0.06 µg/m²/day were all located in the northern portion of Lake Pend Oreille, and the stations less than 0.06 µg/m²/day were all in the mid/southern portion. Stations in the northern portion of the lake also had higher levels of maximum chlorophyll *a* density. Chlorophyll *a* data suggest that water column nutrients in the northern portion of the lake support higher periphyton productivity than do the nutrients in the mid/southern portion of the lake.

Chlorophyll a *data suggest that water column nutrients in the northern portion of the lake support higher periphyton productivity than do the nutrients in the southern portion of the lake.*

The growth rates of chlorophyll *a* in 2014 appear to be much lower than the growth rates reported in 2003 and 1989–90. “Chlorophyll accrual rates in 2003 averaged 0.048 mg chlorophyll day^{-1} (48 µg/m²/day) compared to 0.091 mg chlorophyll day^{-1} (91 µg/m²/day) in 1989–90 and 0.122 mg chlorophyll day^{-1} (122 µg/m²/day) in 1986” (Falter and Ingman 2004). Again, Table 10 shows 2014 chlorophyll *a* growth rates orders of magnitude lower than those reported by Falter. At this time, it is uncertain if methods for collecting and analyzing chlorophyll growth rates is comparable, but the decrease is worth noting.

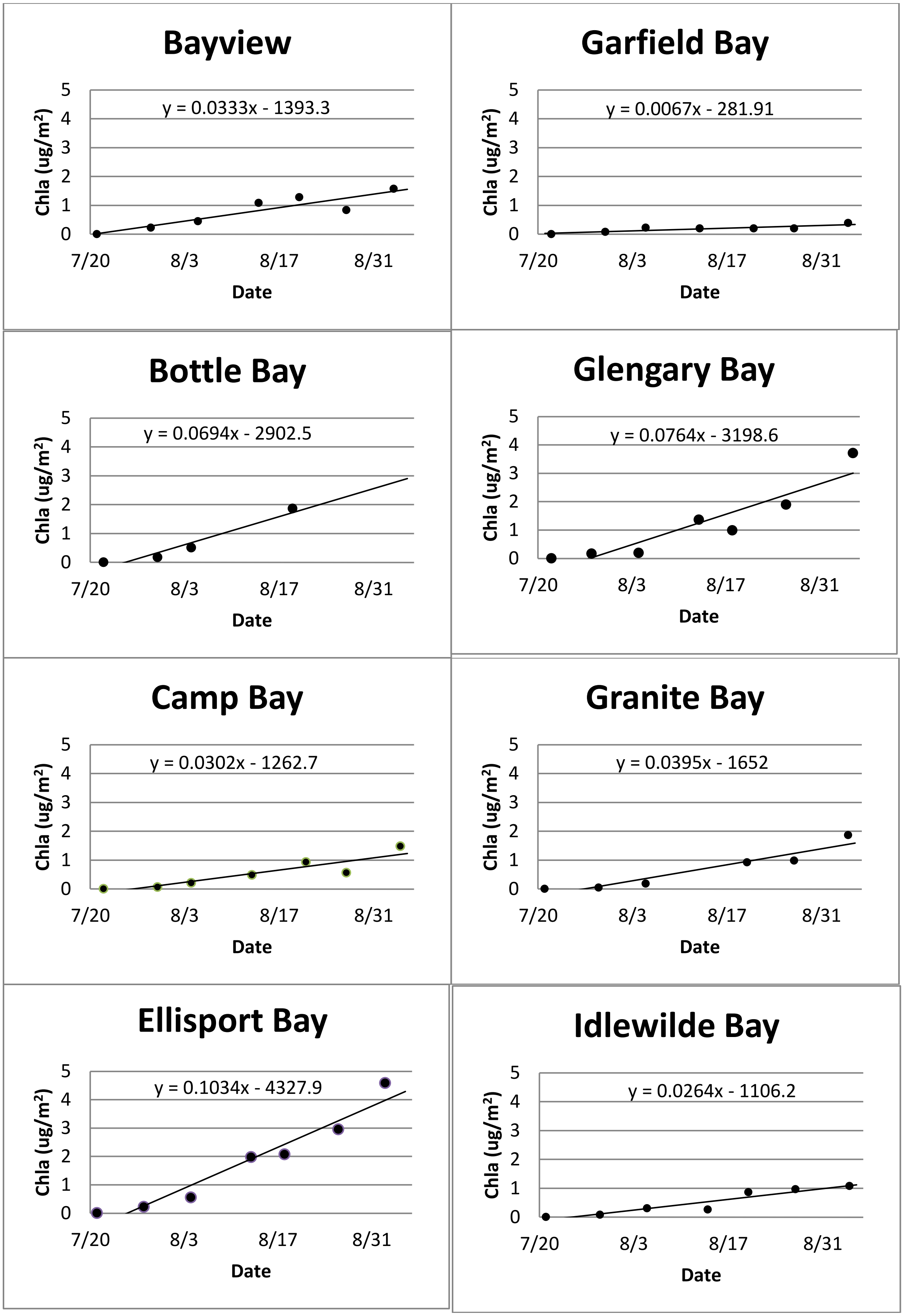


Figure 52. Periphyton growth rates as expressed by chlorophyll *a* concentration in periphyton.

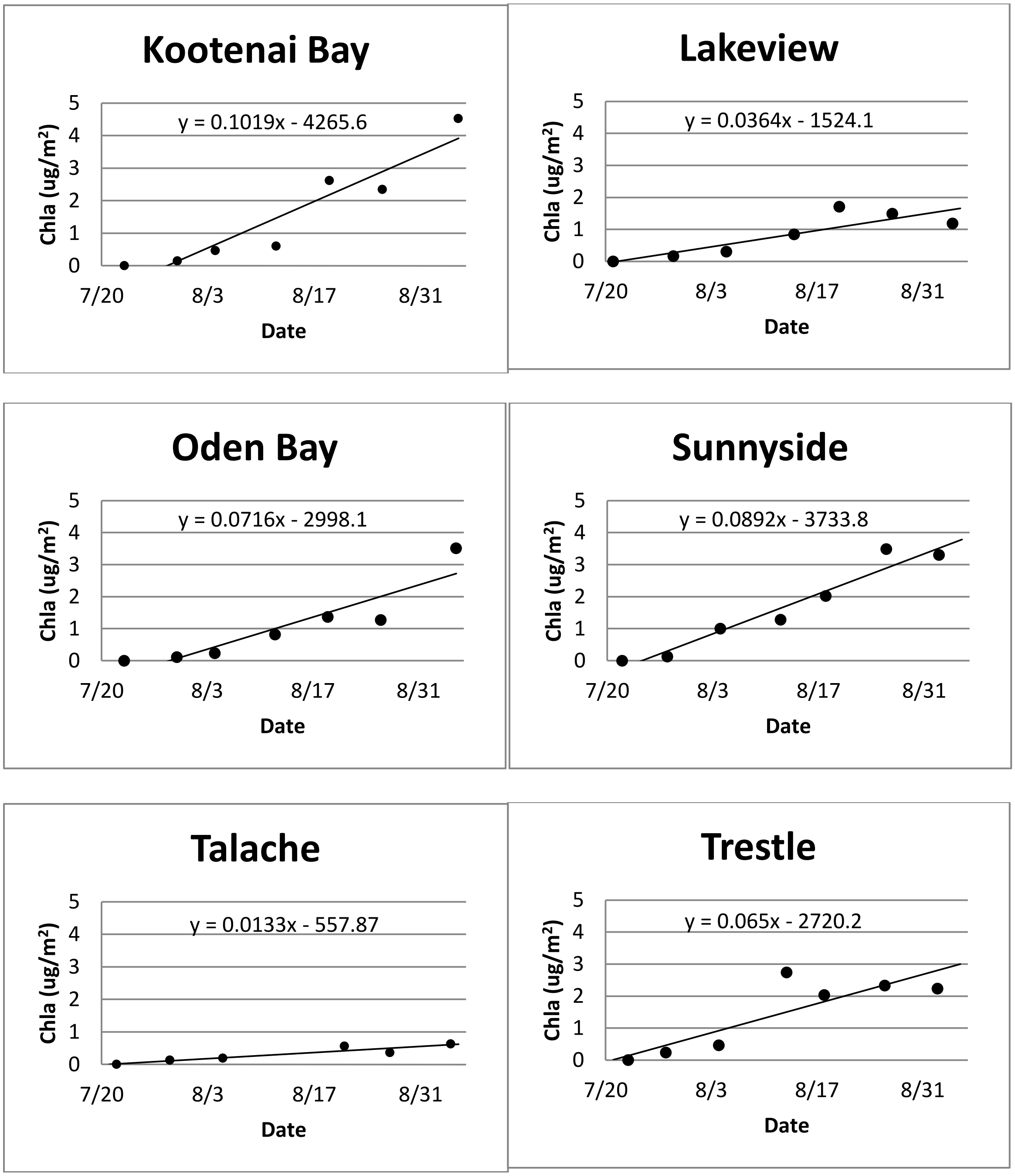


Figure 52 (cont.). Periphyton growth rates as expressed by chlorophyll *a* concentration in periphyton.

9.5 Periphyton Communities

Periphyton community structure and abundance provide an additional line of evidence that the stations in the northern portion of the lake support higher periphyton productivity than do the stations in the mid/southern portion of the lake. Appendix D includes the identification (taxa) and enumeration (cell counts) of the organisms from samples taken during the retrieval (week 6); 49 individual taxa were identified from 5 separate classes:

- *Bacillariophyte*, commonly known as diatoms
- *Chlorophyceae* (coccoid greens, desmids, etc.), commonly known as green algae
- *Chryso- and Cryptophyceae*, commonly known as flagellates
- *Cyanophyceae* (colonial and filamentous blue-greens), commonly known as cyanobacteria
- *Dinophyceae*, commonly known as dinoflagellates

While many of the taxa were benthic organisms and attached to the substrate, some were free floating or swimming planktonic organisms and happened to be part of the periphyton community. Appendix D also includes a relative taxa frequency for each taxa present.

Periphyton community structure and abundance provide an additional line of evidence that the stations in the northern portion of the lake support higher periphyton productivity than do the stations in the mid/southern portion of the lake.

Dominate periphyton taxa collected in 2014 show a major shift in community structure when compared to the dominate taxa collected and reported 11 years prior (Falter and Ingman 2004). The top four 2003 dominate genera based on cell counts were *Rivularia*, *Mougeotia*, *Zygnema*, and *Spirogyra.* The top four 2014 dominate taxa based on cell counts were Coccoid Green, *Aphanothece minutissimum*, *Nostoc* sp., and micro rods. Of the top four 2003 dominate genera, all are missing from 2014 communities except *Mougeotia*, which only occurs in low cell counts. The top four 2003 dominate genera based on biovolume were *Mougeotia*, *Spirogyra*, *Zygnema*, and *Ulothrix*. The top four 2014 dominate taxa based on biovolume were *Euglena* sp., *Chroococcus* (CELLS), *Rhopalodia* sp., and *Coleochaete* sp. The collection methods in 2003 differed from 2014; artificial substrate was brick material, target depths were 1 meter, and collection methods included scraping periphyton from artificial substrate rather than taking an undisturbed sample.

Table 11 shows the cell counts by all taxon and class. Bottle Bay was excluded because the artificial substrate was not recovered and therefore was not analyzed for cell counts. With the exception of Lakeview, the stations with relatively higher cell counts of all taxa are located at the northern stations, with Trestle, Oden, and Kootenai having the highest cell counts. The lowest cell counts were at the mid/southern regions of the lake at Granite, Talache, Bayview Nearshore, and Garfield. Garfield, however may have been vandalized.

Table 11. Productivity monitoring stations cell counts summary (in order of all taxon cell count).

		Cell Count (cells/cm2)					
Station Name	Alias	All Taxon	Diatom	Green Algae	Flagellate	Cyanobacteria	Dinoflagellate
Lakeview	LV	2,000,000	84,000	540,000	8,800	1,400,000	
Trestle	TRC	1,300,000	220,000	990,000	22,000	88,000	
Oden Bay	OB	1,100,000	79,000	600,000	13,000	380,000	
Kootenai Bay	KB	960,000	62,000	620,000	18,000	260,000	
Sunnyside	SS	880,000	120,000	400,000	22,000	350,000	
Camp Bay	CB	820,000	40,000	400,000	8,800	380,000	
Glengary	GLN	800,000	92,000	430,000	4,400	270,000	4,400
Ellisport Bay	ESB	770,000	92,000	510,000	26,000	150,000	
Idlewilde Bay	IWD	630,000	35,000	270,000	8,800	320,000	
Granite	GRN	550,000	35,000	290,000	8,800	220,000	
Talache	TCH	480,000	53,000	250,000		170,000	
Bayview	BVV	440,000	53,000	260,000		140,000	
Garfield	GFD	340,000	31,000	240,000	8,800	62,000	

The artificial substrate at the Lakeview station has an inordinately large number of cyanobacteria cells (1.4 million cells/cm^2), which greatly outweigh the number of green algae (0.5 million cells/cm^2) at that station. Cyanobacteria are typically smaller and many more fit into the same area as would green algae. There may be some sort of green algae suppression in the Lakeview area, one where the cyanobacteria is less susceptible. Two streams flow into Lake Pend Oreille near the Lakeview station: North Gold Creek and South Gold Creek. The area has a colorful history as a heavy metal mining boomtown community in the 1800s, with mining claims dotting the mountainside between North and South Gold Creeks. Heavy metal mining operations are still intermittently active on South Gold Creek. The Lakeview station is also proximal to the ruins of International Portland Cement Companies shore facility. Limestone mining quarries were established in the Gold Creek watersheds, which may also influence water chemistry at the Lakeview station. Acidity at the Lakeview station appears to be consistent with other southern lake stations, between 8 and 9 pH units. Future monitoring at this station may include dissolved cadmium, dissolved lead, dissolved zinc, methylmercury fish tissue, weak acid dissociable cyanide, and hardness characterization as possible green algae suppressants. The Lakeview station appears to be an outlier when looking at cell counts because of the large number of cyanobacteria cells.

Rare taxa only occurred at a few of the stations. Notable rare taxa include the presence of *Coleochaete* sp. at the Trestle station. It appears in some years that *Coleochaete* sp. may dominate and cause bright green masses at the Trestle station. The artificial substrate was intentionally placed in an area where bright green periphyton masses had been observed in the past. *Coleochaete* is a genus of parenchymatous charophyte green algae in the order Coleochaetales. *Coleochaete* sp. are characterized by true multicellular organization creating planar sprawling discs or rising into three-dimensional cushions on stream and lake bottom substrate. Coleochaetales are implicated as the closest living relatives to terrestrial plants and are distributed worldwide. The bright green periphyton masses were not observed to be as abundant in 2014 as they had been in previous years. It is likely that the bright green masses are *Coleochaete* sp. The Trestle station had the highest green algae cell counts, for which over a third was from *Coleochaete* sp.

Navicula sp. (Med) may be an indicator of higher productivity. Common taxa were investigated for patterns of occurrence. *Navicula* sp. was found in all but one of the northern stations and none of the southern stations. *Navicula* sp. is a diatom. The *Navicula* genus of diatoms comprises approximately 1,000 species. There would be value in determining which species is present in the northern stations to better understand the distribution in regards to pollution tolerance.

9.6 Quantitative Comparison of Cell Count

A quantitative assessment that ranks chlorophyll *a* growth rate, maximum chlorophyll *a*, and selected cell counts is another line of evidence that the stations in the northern portion of the lake support higher periphyton productivity than the stations in the south. Darren Brandt of Advanced Eco-Solutions Inc. provided a quantitative method for evaluating and comparing chlorophyll *a* and cell counts using ranking scales. In this method, chlorophyll *a* growth rate, maximum chlorophyll *a*, and cell counts excluding cyanobacteria are given a ranking between 0 and 1 depending on the measured chlorophyll *a* concentrations and cell counts at each station. A ranking of 1 represent the highest (most productive) concentration or cell count, and a ranking near 0 represent the lowest (least productive) concentration or cell count. These rankings were then summed with equal weight given to chlorophyll *a* growth rate, maximum chlorophyll *a*, and cell counts excluding cyanobacteria.

Table 12 shows the ranking values and the sum of rankings for each of the stations. Bottle Bay was excluded because the artificial substrate was not recovered and therefore was not analyzed for cell counts. Northern stations Kootenai, Ellisport, Trestle, Sunnyside, Oden, and Glengary stand out as the most productive stations (sum of rankings > 1.5). Mid/southern stations Lakeview, Granite, Camp, Bayview Nearshore, Idlewilde, Talache, and Garfield are the least productive stations (sum of rankings < 1.5). The lowest sum of rankings was at Garfield Bay, which was also the artificial substrate that had possibly been vandalized.

Table 12. Productivity monitoring stations quantitative ranking (most productive to least productive).

		Chla growth rate (ug/m2/day) ranking	Maximum Chla (ug/m2) ranking	Cell Count no BG Taxa(cells/cm2) ranking	Sum of rankings
Kootenai Bay	KB	0.990291262	0.987423581	0.571942446	2.549657289
Ellisport Bay	ESB	1	1	0.510791367	2.510791367
Trestle	TRC	0.631067961	0.596724891	1	2.227792852
Sunnyside	SS	0.86407767	0.760218341	0.438848921	2.063144931
Oden Bay	OB	0.699029126	0.765545852	0.564748201	2.029323179
Glengary	GLN	0.737864078	0.809781659	0.431654676	1.979300413
Lakeview	LV	0.349514563	0.372183406	0.517985612	1.239683581
Granite	GRN	0.378640777	0.407030568	0.269784173	1.055455517
Camp Bay	CB	0.291262136	0.321790393	0.363309353	0.976361881
Bayview	BVV	0.32038835	0.343362445	0.251798561	0.915549356
Idlewilde Bay	IWD	0.252427184	0.234978166	0.255395683	0.742801034
Talache	TCH	0.126213592	0.136419214	0.248201439	0.510834245
Garfield Bay	GFD	0.067961165	0.085021834	0.226618705	0.379601704

9.7 Discussion

The biologic condition of Lake Pend Oreille is generally oligotrophic with TSI (Carlson and Simpson 1996) generally ranging from 25–35 TSI units. Lake Pend Oreille has varying levels (spatially) of nutrient concentrations and a pronounced productivity response to higher levels of nutrients. The biologic condition of Lake Pend Oreille varies each year depending on inflow quantities, inflow water quality, and weather conditions during the summer months (June–September). The 2014 sampling year happened to have biologic conditions slightly higher than average (+2 TSI units).

The nearshore portions of Lake Pend Oreille have varying nutrient concentrations, some of which are influenced by human uses. In this study, stations were selected that represent both a spatial range and a range of human influences. The northern stations (Bottle Bay, Ellisport, Glengary, Kootenai, Oden, Sunnyside, and Trestle) have the highest human influence and also the highest productivity. Nonpoint sources of excess nutrients from these higher human influence areas are likely to be a contributing factor to periphyton growth on the substrates at these stations. If nutrients increase in the nearshore areas, it is likely that nuisance aquatic growths will further impair beneficial uses. The patterns seen in periphyton are likely to exist in epiphyton, plankton, and zooplankton communities as well. At stations with higher productivity, the phosphorus and nitrogen in the cells of aquatic organisms are part of the total nutrient budget in those areas. Water column concentrations in areas with higher productivity do not account for the productivity component of the total nutrient budget. In other words, the water column samples would have higher concentrations if productivity was lower.

Nonpoint sources of excess nutrients from higher human influence areas are likely to be a contributing factor to periphyton growth on the substrates at northern stations. If nutrients increase in the nearshore areas, it is likely that nuisance aquatic growths will further impair beneficial uses.

More project-specific conclusions follow:

- The chlorophyll *a* rate of production clearly identified stations with higher productivity.
- Chlorophyll *a* data suggest that water column nutrients in the northern portion of the lake support higher periphyton productivity than do the nutrients in the southern portion.
- Periphyton community structure and abundance provide an additional line of evidence that stations in the northern portion of the lake support higher periphyton productivity than do stations in the mid/southern portion of the lake.
- Some sort of green algae suppression is likely in the Lakeview area, one where the cyanobacteria is less susceptible.
- It appears in some years that *Coleochaete* sp. may dominate and cause bright green masses at the Trestle station.
- *Navicula* sp. (Med) may be an indicator of higher productivity.
- A quantitative assessment that ranks chlorophyll *a* growth rate, maximum chlorophyll *a*, and selected cell counts is another line of evidence that stations in the northern portion of the lake support higher periphyton productivity than do stations in the mid/southern portion.
- The level of vandalism was low, with two of the fourteen artificial substrates appearing to have undergone some sort of vandalism during the 2014 monitoring season.
- Temperature and light loggers suggested that one station (Trestle) is likely to have ground water influence and identified stations that received more and less light than others.

Determining whether the growth on the artificial substrates is considered a “nuisance aquatic growth that is impairing beneficial uses” as defined in Idaho water quality standards is difficult because it is a subjective determination. Most people agree that the amount of growth accumulated in a 6-week period in an oligotrophic lake on the artificial substrates deployed at Kootenai and Glengary are at nuisance levels. Most people also agreed the substrate at Idlewilde is not at nuisance levels. Nuisance levels were determined through an internal survey conducted of 29 DEQ water quality scientists, where four photos of artificial substrates were provided and ranked (Figure 53 through Figure 56).

Future monitoring may consider addressing the following:

- A comparison between growth rates, and possibly periphyton taxon, between natural and artificial substrates is needed.

- There would be value in determining which species of *Navicula* sp. (MED) is present in the northern stations to better understand the distribution in regards to pollution tolerance.
- In oligotrophic/mesotrophic lakes like Lake Pend Oreille, longer deployment periods may better capture maximum chlorophyll *a* concentrations.

Figure 53. Artificial substrate after 6 weeks of incubation in Ellisport Bay.

Figure 54. Artificial substrate after 6 weeks of incubation in Kootenai Bay.

Figure 55. Artificial substrate after 6 weeks of incubation in Glengary Bay.

Figure 56. Artificial substrate after 6 weeks of incubation in Idlewilde Bay.

10 Review of Implementation Plan and Activities

10.1 TMDL Implementation Plan

DEQ recognizes that implementation planning efforts are more likely to be successful when a collaborative community approach is taken. DEQ enlisted the assistance of the Tri-State Water Quality Council (TSWQC), a diverse stakeholder group, to help develop the *Pend Oreille Lake Nearshore Nutrient TMDL Implementation Plan* (DEQ 2004). Working with DEQ, the TSWQC organized and facilitated the efforts of the Lake Pend Oreille Planning Team. This stakeholder group now serves as a subcommittee under the Pend Oreille River and Tributaries WAG.

From fall 2002 through spring 2004, the planning team researched nutrient pollution problems, compiled existing pollution control programs, and developed management actions and potential opportunities for improving the water quality of Lake Pend Oreille and its watershed. The team met with agencies responsible for, or participating in, key existing water pollution control programs, including DEQ, Bonner County Planning Department, Bonner County Public Works Department, Idaho Transportation Department, Idaho Department of Lands, US Forest Service, Panhandle Health District, City of Sandpoint, Bonner Soil and Water Conservation District, Selkirk Cooperative Weed Management Area, and US Coast Guard Auxiliary. The team also held a public workshop in October 2003 to gather ideas from the public about actions that could be taken to protect the lake's nearshore water quality from nutrient pollution.

From this variety of sources, the team assembled management actions that could serve to protect lake water quality by enhancing or expanding on existing programs, with a focus on activities that take place in the immediate nearshore drainage area. A resulting list of actions was the focal point of the implementation plan. A total of 82 recommended actions include education projects and on-the-ground implementation projects. These actions were written into the *Pend Oreille Lake Nearshore Nutrient TMDL Implementation Plan* (DEQ 2004). The following is a list of those action items and a short description of whether those action items have been completed and/or are ongoing.

10.1.1 Education Projects

1. Lake Pend Oreille*A*Syst: This program, launched in 2006, reaches out to landowners around the lake helping them to implement best management practices (BMPs) at their homes. Topics covered are stormwater, lawn and garden management, wastewater treatment, hazardous waste management, forest lot and riparian management, and pasture management.
2. Lake Pend Oreille Boater's Guide: This guide, published in 2005, includes locations of pump-out stations and information on milfoil, grey water and litter, and boater safety. The guide has been distributed throughout the community, is handed out at boat inspection stations, and is available with Lake*A*Syst materials. The guide has been reprinted several times when supplies are low.
3. Coordinate with county waterways committee on education programs and funding programs.
4. Educational campaign: In 2009–2010, an educational campaign was launched to reach out to landowners along waterways using quarterly mailed newsletters, newspaper articles, and radio ads. Topics included those covered by Lake*A*Syst and others relevant to protecting lake water quality.
5. Stormwater Erosion and Education Program (SEEP): In 2007, this program was launched to educate contractors, excavators, engineers, and design professionals about stormwater BMPs at construction sites. The program involves 1 day in the classroom and 1 day in the field installing BMPs. Participants who complete the training get SEEP certification. The program occurs annually in Sandpoint.
6. Vegetative buffers: In addition to this topic being covered by Lake*A*Syst, additional education was done through a mini-grant to develop a plant list for vegetative buffers and a demonstration project where these plants have been successfully incorporated into a vegetative buffer.
7. Milfoil education: The Bonner County Invasive Species Task Force provided education through participation in the Bonner County Land Use Code Committee.

8. Forestry and agriculture landowner BMP education: This project is ongoing through the Natural Resources Conservation Service and the Bonner Soil and Water Conservation District.
9. Boater education: This effort focuses on education of boat owners about impacts from boat washing and cleaning hulls, greywater and other disposal, and boat wakes. This education is done through distribution of the boater's guide and outreach at the marinas.
10. Children's education: This outreach effort is done through individual classrooms and through the Waterfest, which invites all 6th graders from the area to the Riley Creek Campground on the Pend Oreille River.
11. Realtor education: In 2014, a realtor education program was implemented to provide important information to realtors about natural resources, permitting, regulations, septic, and BMPs important for natural resource conservation.

10.1.2 Citizen's Monitoring

In 2012, Lake Pend Oreille Waterkeeper (LPOW) implemented a citizen volunteer monitoring program that tracks changes to trophic indicators at 15 designated sites across Lake Pend Oreille and the Pend Oreille River. Monitoring efforts by LPOW will enhance understanding of trends in water quality throughout the lake, help identify problem areas that may direct more in-depth monitoring efforts, and most importantly, help inform changes in land-use practices to prevent further impairment and restore and attain water quality standards. Their collection of quality data is outlined in their QAPP—adherence to which provides credibility to their data.

10.1.3 Development/Shoreline Property Ordinance

Since 2008, Bonner County has implemented major water/natural resource related changes in the land-use code. Changes include shoreline buffers, shoreline fencing, native plantings, waterfront setbacks, wetland setbacks, landscaping, alpine standards, submerged lands, impervious surface, grading permits, stormwater, floodplain, and watershed reserve.

10.1.4 Invasive Species

The Idaho State Department of Agriculture coordinates a statewide aquatic invasive species management and control program, acting to protect the integrity of the state's water bodies from the biological degradation caused by aquatic organisms.

In 2009, the Bonner County Aquatic Invasive Species Task Force completed its strategic plan, and implementation is ongoing. In 2009, the mandatory Aquatic Invasive Species sticker program began, whereby boat owners must purchase the sticker from the state for their boats. Proceeds fund the aquatic invasive species program, which includes boat inspection stations throughout the state.

10.1.5 Recreation

1. Pump-out facilities: In 2008, Dover and Willow Bay facilities were installed.
2. Emergency spill clean-up kits and spill bibs: Distribution occurs frequently at each of the marinas around the lakes.

3. Vault toilets: In 2007, six existing plastic toilets were converted to vault toilets at the following nearshore recreation sites: Green Monarchs (2); Evans Landing (1); Maiden Rock (1); Clark Fork River delta (1); and Whiskey Rock (1).

10.2 Montana and Idaho Border Nutrient Load Agreement

One of the biggest efforts that came out of the *Montana and Idaho Border Nutrient Load Agreement* (TSWQC 2001) was the Voluntary Nutrient Reduction Program for the Clark Fork River in Montana. From 1989 to 2009, efforts under this program resulted in a 66% reduction annually in TP and 18% in TN.

10.3 The Lake Pend Oreille, Pend Oreille River, Priest Lake, and Priest River Commission

The Lake Pend Oreille, Pend Oreille River, Priest Lake, and Priest River Commission (Lakes Commission) was created in 2003. It was given authority by the Idaho Legislature to investigate and select ways and means of controlling the water quality and water quantity as they relate to waters of Lake Pend Oreille, Pend Oreille River, Priest Lake, and Priest River for the communities' interests and interests of the state of Idaho and for the survival of the fish species native to the Pend Oreille Priest Basin (Idaho Code §39-8503). The Lakes Commission is involved in invasive species management and control, fisheries issues, and issues related to water quality, including marina education and spill kit dissemination.

10.4 Clark Fork Delta Habitat Protection and Mitigation Program

The purpose of the Clark Fork Delta Habitat Protection and Mitigation Program is to prevent the loss of wildlife habitat in the Clark Fork Delta, or mitigate for that loss of habitat that would result from the continued operation of the Cabinet Gorge and Noxon Rapids hydroelectric projects. The program will build up the existing delta and minimize future erosion from the delta—erosion that results from delivery of sediment and nutrients to Lake Pend Oreille. Work was initiated on this program in 2014 as a result of a partnership among the Idaho Department of Fish and Game, Ducks Unlimited, United States Army Corps of Engineers, Bonneville Power Administration, Bureau of Land Management, Kalispel Tribe, and others.

10.5 Pack River Delta Restoration Project

The purpose of the Pack River Delta Restoration Project was to increase the geomorphic and vegetative diversity of the delta by installing a series of engineered log structures and other bioengineering techniques. The log structures and vanes redirect and slow the flow of the Pack River, thus settling out sediment, before it reaches Lake Pend Oreille. Restoration of aggradation of sediment at the delta has increased the height and stability of a portion of the summertime submerged islands, which has provided habitat for waterfowl and other birds. Work was completed in 2010 on this project as a result of a partnership between the Idaho Department of Fish and Game and Ducks Unlimited.

10.6 Wastewater Treatment Plant Upgrades

Since the TMDL was written, the following upgrades have occurred at wastewater treatment plants near Lake Pend Oreille:[1]

- Garfield Bay Sewer District—Around 2008, the district received approval to expand their forested irrigation site and constructed a new, lined storage lagoon. This expansion allowed them to add customers and continue to meet the recycled water permit conditions.
- Bottle Bay Recreational Water and Sewer District—The district will be starting an upgrade to expand its forested irrigation site and add lagoon storage volume by constructing additional volume in one of the existing lagoons. Around 2010, it also expanded the irrigation piping system to allow for irrigating more acreage and reducing the nutrient and hydraulic loading rates. These improvements are being made so they can add customers.
- Kootenai-Ponderay—Around 2001, the Kootenai-Ponderay Sewer District constructed the recycled water irrigation site and storage lagoon to allow for seasonal irrigation of poplar trees. This significantly reduced the amount of wastewater discharged to Boyer Slough during the growing season (May–September).

11 Summary of Five Year Review

Previous studies on Lake Pend Oreille have shown that the trophic status of the nearshore areas of the lake is changing quicker than the open waters. Concern over water quality in the nearshore areas of the lake has been documented for decades. Most of the complaints have been over excessive algae (periphyton) growth on the bottom substrate in these areas. The excessive algae growth has impaired the recreation beneficial use.

In 1999, DEQ prepared a problem assessment on the lake, which recommended development of a TMDL for nutrients for the nearshore waters of the lake. In 2002, EPA approved the *Total Maximum Daily Load (TMDL) for Nutrients for the Nearshore Waters of Lake Pend Oreille, Idaho* (DEQ 2002). The TMDL addresses mitigation of increasing anthropogenic eutrophication along the shoreline of Lake Pend Oreille.

Correlations of TP in the water column and periphyton growth densities have been difficult to make. The TMDL targets of 9 μg/L and 12 μg/L were based on best available data and an evaluation of that data to understand trends in distribution. The targets were also established because they are consistent with EPA recommended regional criteria for nutrients.

The TMDL targets of 9 μg/L and 12 μg/L are reasonable targets and should remain in place. This determination was initially made based on a binomial distribution analysis of the data from the period of record and a baseline study of data collected on other lakes within north Idaho. The distribution analysis evaluated the probability of true exceedance of the 9 μg/L TMDL target based on sample size. In other words, it determined the probability that the nearshore waters of Lake Pend Oreille are impaired. The distribution analysis concludes the TMDL target has not been met in the northern region of the lake but is being met in the southern end. The binomial

[1] Personal communication with John Tindall, Engineering Manager, DEQ Coeur d'Alene Regional Office.

distribution analysis addressed only whether the TMDL target of 9 μg/L has been met. The premise that the 9 μg/L TMDL target, as a surrogate for a narrative nutrient standard, is protective of beneficial uses was validated by evaluating water quality and nearshore productivity in the different regions of the lake.

In 1989–1990 and 2003, Falter conducted water quality monitoring at 15 nearshore sites around the lake. Since 2006, DEQ has conducted annual water quality monitoring on Lake Pend Oreille, but funding constraints during 2006–2009 limited data collection to 6 long-term trend sites on the lake. Monitoring at sites other than the long-term trend sites took place from 2011–2014, thus creating data gaps at individual monitoring stations and making statistical analysis at individual monitoring stations difficult. Therefore, a regional approach was taken by grouping data sets of individual stations together with other stations within the same region of the lake. The lake was divided into three regions: northern, mid, and southern. The results of this analysis were then compared to an analysis of data from long-term trend sites—two at each of the three regions of the lake. The comparison was made to determine whether the regional analysis was representative of individual monitoring stations.

Results of the regional analysis showed TP decreased over time in the northern lake stations, but this decrease was not observed at the long-term trend stations. The regional trend analysis in the mid and southern region of the lake show TP concentrations have not changed significantly over time. In the northern region of the lake, TP concentrations were significantly higher than those observed in the mid and southern lake regions.

A 2014 study of periphyton algae on artificial substrates at 14 nearshore locations around the lake is evidence that the TMDL targets are appropriate and are protective of beneficial uses in the nearshore waters of Lake Pend Oreille. The study concluded that productivity conditions in the northern lake are higher than the mid and southern, and water column nutrients in the northern portion of the lake support higher periphyton productivity than do the nutrients in the southern portion. A survey of water quality professionals and a subcommittee of the Pend Oreille River Tributaries WAG identified nuisance periphyton growth on artificial substrates from the northern bays of Lake Pend Oreille (where the TMDL target of 9 μg/L has not been met). The same survey did not see nuisance periphyton growth on artificial substrates in the mid and southern regions of the lake (where the TMDL target has been met).

Results of the regional trend analysis showed a significant decrease in TP in August in the northern, mid, and southern regions of the lake. Long-term trend sites did not always follow this pattern. This decrease was pronounced in the TN:TP ratios at monitoring locations in the northern and southern lake. The decline in TP during August could be attributed to periphyton/phytoplankton growth during that month. The periphyton growth study undertaken in 2014 showed periphyton growth rates at their highest during August.

Because the northern region of the lake has the highest human influence, nonpoint sources of excess nutrients from these areas are likely a contributing factor to periphyton growth on the substrates at these stations. If nutrients continue to increase in the nearshore areas, nuisance aquatic growths will likely further impair beneficial uses. The patterns seen in periphyton are likely to exist in epiphyton, plankton, and zooplankton communities as well.

The TMDL was written to represent average loading limits for the entire nearshore area of the lake, with loading based solely on runoff from nearshore land and septic seepage through ground water. However, the higher phosphorus concentrations in the northern lake should also be attributed to loading from other sources in this region of the lake: the Clark Fork and Pack Rivers and stormwater from the cities of Kootenai and Ponderay.

Loading from both the Clark Fork and Pack Rivers into the northern nearshore waters of the lake is significant. The Pack River watershed encompasses approximately 185,600 acres, and the watershed contributes the highest ratio of nutrient per unit of land among all watersheds in the Pend Oreille Lake subbasin in Idaho (Golder Inc. 2003). This contribution is likely due to the geology of the watershed and the heavy land use in the lower reaches of the Pack River (Hoelscher et al. 1993). The Clark Fork River begins near Butte and drains an extensive area of western Montana before entering Lake Pend Oreille, in Idaho, at the lake's northeast corner. The Clark Fork River contributes 92% of the annual inflow into Lake Pend Oreille.

Stormwater loads from the cities of Kootenai and Ponderay may have been only partially accounted for in the TMDL. The width of the boundary of the nearshore drainage area used to calculate the load capacity is approximately 0.9 miles immediately adjacent to the shoreline. This land would include runoff and nutrient loading from the cities of Kootenai and Pend Oreille. However, it is unclear whether it included the land within the Cities of Kootenai and Ponderay beyond the 0.9-mile distance that delivers stormwater directly to Kootenai Bay.

11.1 Recommendations for Further Action

The discrepancy between results from the regional trend data and results from the long-term trend sites suggests unique conditions at individual monitoring stations. Consistent monitoring at individual monitoring stations throughout the summer months is recommended to better understand water quality conditions at individual sites. Due to the degrading conditions in the northern region of the lake, annual monitoring efforts should be prioritized to those stations first. While nutrients and productivity have remained relatively constant over time in the southern region of the lake, continuing a long-term data set at those sites is necessary to track long-term trends.

Lakeview stands out as an anomaly, both in trophic and productivity monitoring. The variability in TN:TP ratios at this site over time is significant. While TP at this station has remained stable over time, TN has fluctuated greatly. This fluctuation is believed to be a result of something in the watershed. Therefore, further investigations in the watershed are recommended, including more detailed speciation of nitrogen in water chemistry monitoring at the Lakeview site to better understand the source(s) of nitrogen.

Cyanobacteria were abundant in the periphyton community at the Lakeview station, and it appears there may be green algae suppression at the site as well. Historical mining efforts in North Gold Creek and South Gold Creek and active mining in South Gold Creek may be impacting phytoplankton growth at this site. Limestone mining quarries in the Gold Creek watersheds may also influence water chemistry at the Lakeview station. Future monitoring—including dissolved cadmium, dissolved lead, dissolved zinc, methylmercury fish tissue, weak acid dissociable cyanide, and hardness—is needed to better understand the suppression of green algae at this station.

TN:TP ratios at all the monitoring sites suggest conditions favorable to cyanobacteria growth, but the abundance of cyanobacteria in the phytoplankton community at individual stations is unknown. Therefore, monitoring the water-column phytoplankton community would provide understanding of the abundance of cyanobacteria and the risk at individual sites for a harmful algal bloom. Such monitoring would also provide data at individual sites on the availability of the more favorable green algae food source for zooplankton.

TMDL implementation is on-going. Individuals and partnerships from designated management agencies, other agencies, nonprofit organizations, and others are active in implementing management programs, on-the-ground projects, educational programs, and changes to local land-use code. More targeted TMDL implementation efforts in the northern region of the lake are necessary to improve trophic conditions, decrease productivity, and meet TMDL targets. Implementing BMPs in the mid and southern regions of the lake is also critical to maintaining the low-productivity, oligotrophic conditions in those regions.

Sources of nutrients and load reduction goals in the northern region of Lake Pend Oreille are addressed in *The Montana and Idaho Border Nutrient Load Agreement Technical Guidance* (TSWQC 2001), which directly addresses loading from the Clark Fork and addresses load reduction measures that should be taken. The *Pack River Nutrients Total Maximum Daily Load* (DEQ 2007) directly addresses nutrient loading from the Pack River and provides load reduction requirements from identified sources in the watershed. Implementation under these documents will continue to reduce phosphorus loading and aid in restoring the beneficial uses in the northern region of Lake Pend Oreille.

While stormwater loading from the cities of Kootenai and Pend Oreille is partially accounted for in the TMDL, this source of loading should be characterized and prioritized for TMDL implementation.

11.2 Watershed Advisory Group Consultation

This 5-year review of the *Total Maximum Daily Load (TMDL) for Nutrients for the Nearshore Waters of Lake Pend Oreille, Idaho* (DEQ 2002) was done with consultation of a subcommittee of the Pend Oreille River and Tributaries WAG. The WAG was formed for consultation on the TMDL for temperature on the Pend Oreille River. The WAG is made up of Washington state interests and has not been active since 2008. A subcommittee of this WAG is focused on implementing the 2002 TMDL. This WAG subcommittee meets on a bimonthly basis, and they were updated on this effort at every meeting since January 2014.

In November 2013, a technical group met that included professionals from state and federal agencies, the private sector, and the University of Idaho. The group discussed the 2002 TMDL, the TMDL targets, monitoring results, and ways to evaluate the link between TP and macrophyte/algae growth and visible aesthetic/recreation impairment. It was agreed that data gaps exists in understanding productivity in Lake Pend Oreille. Out of these meetings, it was decided additional monitoring would be undertaken in 2014 to evaluate periphyton community structure and biovolume to better understand the relationship between water column chemistry and productivity. Those results were presented in this 5-year review.

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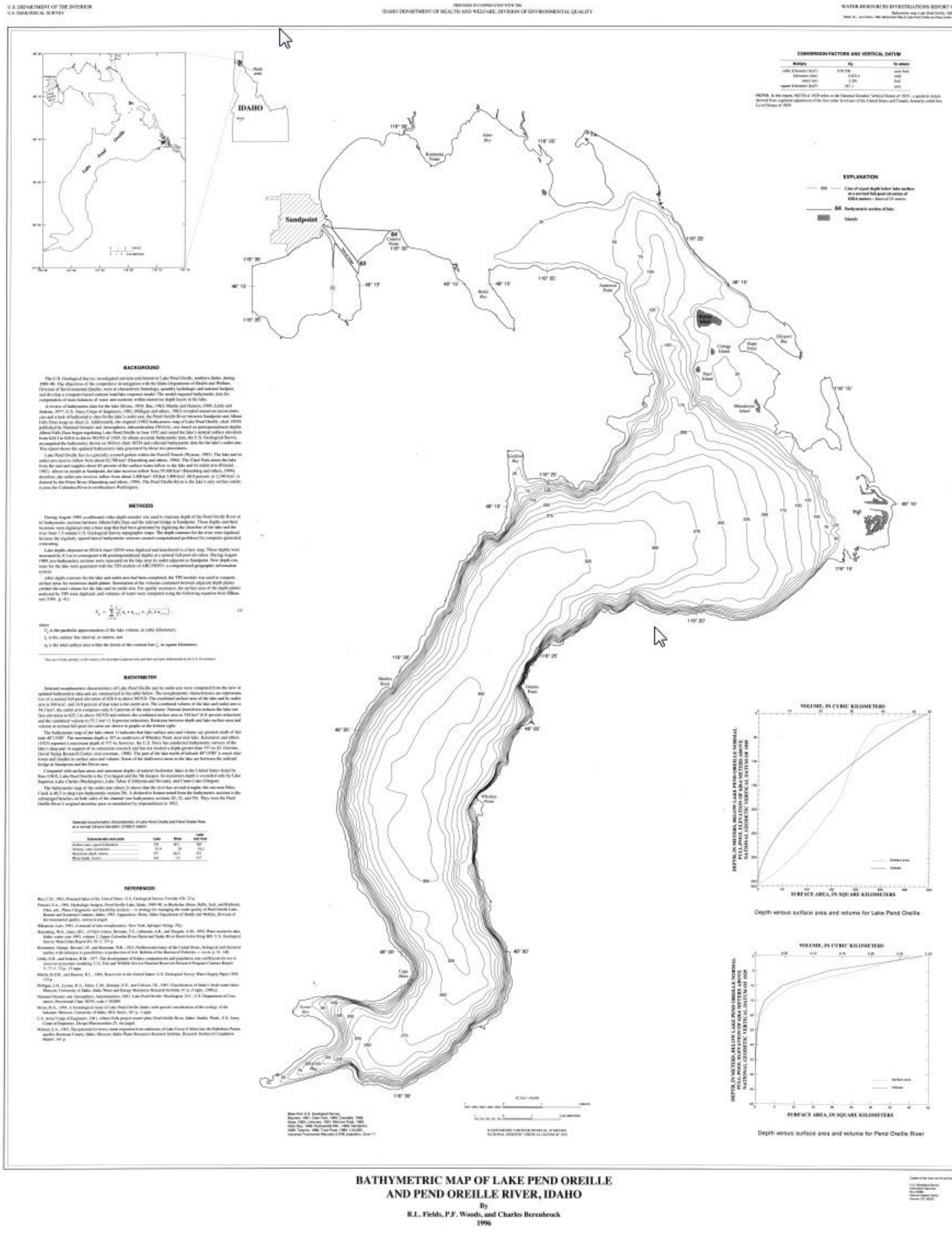
Appendix A. USGS Bathymetric Map of Lake Pend Oreille



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Appendix B. Descriptive Statistics

The data in the following tables has a non-normal distribution. Therefore the mean and standard deviation are not statistically reliable. However, they are provided for informative purposes only.

Table B-1. Secchi depth of nearshore waters of Lake Pend Oreille by location for period 1989, 1990 and 2003.

Station	N	Mean	SE Mean	StDev	Min	Q1	Median	Q3	Max
Bayview North	8	9.225	0.551	1.559	6.500	8.100	9.500	10.350	11.500
Bottle	7	7.871	0.495	1.310	5.400	7.500	7.900	8.500	9.700
Camp	6	7.917	0.522	1.280	6.200	6.800	7.950	8.850	9.900
Ellisport	6	8.383	0.450	1.103	6.500	7.475	8.600	9.350	9.500
Garfield	6	9.083	0.529	1.297	6.800	8.000	9.600	10.025	10.100
Granite	6	10.183	0.673	1.647	7.100	8.900	11.050	11.150	11.300
Kootenai	8	2.162	0.692	1.957	0.400	0.425	1.300	4.450	4.800
Lakeview	8	9.650	0.385	1.088	7.50	8.975	9.900	10.450	10.800
Oden	4	2.975	0.614	1.228	2.000	2.050	2.600	4.275	4.700
Sunnyside	6	7.017	0.233	0.571	6.000	6.675	7.100	7.400	7.700
Talache	6	9.000	0.479	1.173	6.800	8.300	9.300	9.750	10.200
Trestle	8	8.613	0.289	0.818	7.500	7.900	8.550	9.100	10.100

Table B-2. Secchi depth of nearshore waters of Lake Pend Oreille by location for period 2006–2014.

Station	N	Mean	SE Mean	St Dev	Min	Q1	Median	Q3	Max
Bayview North	20	7.305	0.559	2.679	2.600	4.850	8.000	9.775	11.00
Bottle	5	4.82	1.02	2.28	3.00	3.40	4.20	6.55	8.80
Ellisport	7	5.657	0.723	1.913	2.600	3.500	6.300	7.200	7.800
Garfield	18	6.083	0.611	2.593	1.200	3.800	6.000	8.600	9.700
Glengary	4	6.27	1.22	2.43	3.10	3.88	6.50	8.45	9.00
Granite	3	6.03	1.44	2.50	3.30	3.30	6.60	8.20	8.20
Idlewilde	10	8.005	0.703	2.223	3.800	6.287	8.150	9.575	11.800
Lakeview	17	7.229	0.672	2.772	3.200	5.250	6.200	9.250	13.100
Oden	16	2.653	0.141	0.566	1.500	2.200	2.850	3.000	3.500
Sunnyside	15	3.200	0.444	1.718	1.500	2.300	3.000	3.500	8.900
Talache	16	5.900	0.687	2.750	1.800	3.975	5.200	8.750	10.5

Table B-3. Secchi depth of nearshore waters of Lake Pend Oreille by lake location and time period.

Lake Location	Time Period	N	Mean	SE Mean	StDev	Min	Q1	Median	Q3	Max
Mid	89–90	15	8.460	0.446	1.728	6.000	6.800	8.400	10.000	11.100
South	89–90	10	9.420	0.506	1.600	6.500	7.875	9.700	10.575	11.500
Mid	03–08	37	7.889	0.375	2.279	2.700	5.600	8.800	9.500	11.300
South	03–08	28	7.932	0.425	2.251	4.300	6.000	8.200	9.500	13.100
Mid	09–14	21	4.971	0.532	2.438	1.200	2.900	4.500	6.750	9.400
South	09–14	24	7.290	0.586	2.872	2.600	4.475	7.900	9.725	11.800

Table B-4. Secchi depth of nearshore waters of the mid/southern region of Lake Pend Oreille by month.

Month	Year	N	Mean	SE Mean	StDev	Min	Q1	Median	Q3	Max
July	89-90	14	5.686	0.571	2.135	0.400	5.025	6.500	7.025	7.500
Aug	89-90	27	8.226	0.484	2.513	1.100	7.200	8.500	10.000	11.500
Sept	89-90	14	6.886	0.894	3.345	0.500	4.675	7.950	9.600	10.500
June	03-08	18	4.117	0.388	1.647	1.500	2.650	4.300	5.850	6.500
July	03-08	17	5.765	0.513	2.117	2.900	3.800	5.200	7.500	9.300
Aug	03-08	28	7.993	0.530	2.802	2.500	5.875	8.800	9.850	13.100
Sept	03-08	26	7.831	0.483	2.463	3.000	6.575	83400	9.800	11.100
June	09-14	28	3.064	0.263	1.248	1.200	1.900	2.850	3.800	6.250
July	09-14	13	5.592	0.573	2.065	2.600	3.800	5.800	6.750	9.800
Aug	09-14	12	9.225	0.461	1.598	6.300	8.200	9.300	10.675	11.800
Sept	09-14	12	6.200	0.775	2.686	2.700	3.200	6.300	8.250	10.800

Table B-5. Total phosphorus of nearshore waters of Lake Pend Oreille by station (1989–2003).

Station	N	Mean	SE Mean	StDev	Min	Q1	Median	Q3	Max
Bayview North	9	4.622	0.619	1.858	1.000	3.700	4.000	6.100	7.00
Bottle	8	6.33	1.11	3.14	2.5	4.25	6.00	7.000	13.10
Camp	7	6.37	1.29	3.41	1.0	3.50	7.00	8.000	11.50
Ellisport	7	7.471	0.652	1.725	6.000	6.000	6.600	9.300	1.0000
Garfield	7	6.014	0.703	1.859	3.000	4.000	7.000	7.300	8.000
Granite	7	5.71	1.28	3.39	1.00	3.00	5.00	9.00	9.60
Kootenai	8	10.63	2.11	5.95	3.4	7.15	8.00	17.25	20.00
Lakeview	9	4.867	0.708	2.123	1.000	3.250	5.000	6.200	8.000
Oden	6	8.500	0.847	2.074	5.000	7.250	8.500	10.250	11.000
Sunnyside	7	7.057	0.969	2.564	2.500	5.900	7.000	8.000	11.000
Talache	7	4.386	0.917	2.427	1.00	3.300	4.000	5.000	9.000
Trestle	9	7.98	1.43	4.3	2.5	3.75	8.00	12.00	14.00

Table B-6. Total phosphorus of nearshore waters of Lake Pend Oreille by station (2006–2014).

Station	N	Mean	SE Mean	StDev	Min	Q1	Median	Q3	Max
Bayview North	17	5.335	0.377	1.556	3.000	4.050	5.000	6.000	9.000
Bayview Nearshore	4	8.20	1.93	3.87	5.10	5.13	7.25	12.22	13.20
Bottle	8	5.906	0.904	2.556	2.250	3.550	5.800	8.150	9.800
Camp	4	6.750	0.865	1.729	4.600	4.975	7.100	8.175	8.200
Ellisport	7	7.157	0.887	2.348	4.500	5.000	7.100	8.500	11.300
Garfield	20	5.508	0.415	1.858	2.250	4.000	5.000	6.700	10.000
Glengary	5	6.81	1.22	2.73	2.25	4.38	7.90	8.70	9.20
Granite	5	5.87	1.19	2.65	2.75	3.38	6.20	8.20	9.60
Idlewilde	10	6.140	0.590	1.866	3.800	4.525	5.950	7.725	9.900
Kootenai	5	7.43	1.37	3.07	2.75	4.92	7.80	9.75	11.30
Lakeview	19	5.061	0.391	1.703	1.000	4.000	5.000	6.000	8.500
Oden	20	7.345	0.719	3.215	2.250	5.100	6.500	10.125	13.100
Sunnyside	19	7.068	0.490	2.137	4.000	5.000	7.000	8.100	11.400
Talache	20	5.670	0.510	2..282	2.000	4.000	5.000	7.475	10.000
Trestle	4	6.96	1.45	2.90	2.75	3.96	7.90	9.03	9.30

Table B-7. Total phosphorus of nearshore waters of Lake Pend Oreille by lake location and by time period.

Lake Location	Time Period	N	Mean	SE Mean	StDev	Min	Q1	Median	Q3	Max
North	89-90	39	8.974	0.633	3.950	4.000	6.000	8.000	10.000	20.000
Mid	89-90	20	5.600	0.578	2.583	1.000	3.250	5.500	8.000	9.000
South	89-90	12	4.833	0.626	2.167	1.000	4.000	5.500	6.000	8.000
North	03-08	38	6.666	0.399	2.461	2.500	5.000	6.900	8.000	13.100
Mid	03-08	37	5.630	0.443	2.697	1.100	4.000	5.000	6.850	14.000
South	03-08	28	4.943	0.309	1.633	1.000	4.000	5.000	6.000	9.000
North	09-14	40	7.056	0.471	2.979	2.250	4.850	6.950	9.075	13.100
Mid	09-14	32	6.248	0.399	2.257	2.250	4.325	6.300	8.100	10.000
South	09-14	28	6.073	0.418	2.209	2.750	4.700	5.300	7.450	13.200

Table B-8. Total phosphorus concentrations (µg/L) in nearshore waters of the northern end of Lake Pend Oreille by month.

Month	Year	N	Mean	SE Mean	StDev	Min	Q1	Median	Q3	Max
July	89–03	14	9.14	1.01	3.78	5.00	6.00	8.5	10.25	20.00
Aug	89–03	20	7.480	0.928	4.152	2.500	5.250	7.000	8.300	20.000
Sept	89–03	14	8.69	1.06	3.97	4.00	5.75	8.00	10.25	19.00
June	06–14	18	7.883	0.628	2.665	3.000	6.300	7.350	9.375	13.100
July	06–14	12	7.750	0.767	2.657	4.000	5.625	7.350	10.550	12.000
Aug	06–14	13	4.912	0.622	2.244	2.250	2.750	4.800	6.550	8.700
Sept	06–14	19	7.358	0.515	2.245	4.000	5.400	7.500	8.600	11.900

Table B-9. Total phosphorus concentrations (µg/L) in nearshore waters of the mid/Southern end of Lake Pend Oreille by month.

Month	Year	N	Mean	SE Mean	StDev	Min	Q1	Median	Q3	Max
July	89–03	14	6.429	0.562	2.102	3.000	4.750	7.000	8.000	9.000
Aug	89–03	21	4.157	0.489	2.240	1.000	2.500	4.000	5.900	9.000
Sept	89–03	11	6.291	0.846	2.804	1.100	4.000	6.200	8.000	11.500
June	06–14	13	7.408	0.605	2.182	4.700	5.650	7.300	8.000	13.200
July	06–14	11	6.864	0.688	2.280	3.000	5.100	6.100	9.200	10.000
Aug	06–14	16	4.594	0.421	1.683	2.250	2.938	4.450	6.175	7.800
Sept	06–14	15	6.700	0.515	1.995	4.300	4.500	6.200	8.200	9.900

Table B-10. Total nitrogen in nearshore waters of Lake Pend Oreille by lake location and by time period.

Lake Location	Time Period	N	Mean	SE Mean	StDev	Min	Q1	Median	Q3	Max
North	89–90	39	0.110	0.008	0.050	0.030	0.080	0.100	0.130	0.230
North	03–08	22	0.076	0.012	0.056	0.034	0.055	0.055	0.067	0.260
North	09–14	33	0.116	0.005	0.028	0.050	0.104	0.117	0.128	0.179
Mid	89–90	20	0.093	0.013	0.058	0.010	0.042	0.090	0.137	0.193
Mid	03–08	24	0.068	0.006	0.030	0.034	0.055	0.055	0.055	0.151
Mid	09–14	32	0.120	0.004	0.021	0.088	0.104	0.114	0.135	0.174
South	89–90	12	0.088	0.013	0.046	0.031	0.060	0.082	0.098	0.213
South	03–08	24	0.086	0.011	0.053	0.000	0.055	0.055	0.114	0.233
South	09–14	23	0.118	0.005	0.023	0.090	0.102	0.112	0.136	0.188

Table B-11. Total nitrogen concentrations (µg/L) in nearshore waters of the northern end of Lake Pend Oreille by month.

Month	Year	N	Mean	SE Mean	StDev	Min	Q1	Median	Q3	Max
July	89–90	14	0.124	0.017	0.062	0.030	0.080	0.105	0.170	0.230
Aug	89–90	14	0.089	0.013	0.048	0.030	0.060	0.080	0.102	0.230
Sept	89–90	11	0.117	0.007	0.025	0.080	0.100	0.110	0.141	0.161
June	03–08	6	0.051	0.003	0.008	0.034	0.046	0.055	0.055	0.055
July	03–08	6	0.051	0.003	0.008	0.034	0.046	0.055	0.055	0.055
Aug	03–08	4	0.146	0.054	0.107	0.055	0.055	0.135	0.245	0.260
Sept	03–08	6	0.081	0.012	0.029	0.055	0.055	0.078	0.109	0.113
June	09–14	7	0.142	0.014	0.036	0.089	0.117	0.136	0.178	0.179
July	09–14	6	0.120	0.003	0.007	0.113	0.114	0.119	0.127	0.131
Aug	09–14	11	0.097	0.007	0.024	0.050	0.077	0.104	0.114	0.125
Sept	09–14	6	0.127	0.005	0.011	0.111	0.117	0.129	0.136	0.137

Table B-12. Total nitrogen concentrations (µg/L) in nearshore waters of the mid/southern end of Lake Pend Oreille by month.

Month	Year	N	Mean	SE Mean	StDev	Min	Q1	Median	Q3	Max
July	89–90	14	0.113	0.018	0.068	0.010	0.053	0.123	0.172	0.213
Aug	89–90	14	0.067	0.007	0.028	0.019	0.054	0.060	0.090	0.123
Sept	89–90	4	0.097	0.010	0.020	0.080	0.081	0.092	0.117	0.123
June	03–08	12	0.076	0.012	0.041	0.055	0.055	0.055	0.105	0.173
July	03–08	12	0.080	0.015	0.052	0.000	0.055	0.055	0.140	0.168
Aug	03–08	12	0.082	0.016	0.055	0.034	0.055	0.055	0.111	0.233
Sept	03–08	12	0.067	0.007	0.023	0.050	0.055	0.055	0.090	0.112
June	09–14	16	0.133	0.007	0.028	0.093	0.106	0.137	0.146	0.188
July	09–14	8	0.113	0.003	0.009	0.104	0.108	0.112	0.115	0.132
Aug	09–14	13	0.122	0.006	0.021	0.097	0.105	0.117	0.139	0.165
Sept	09–14	8	0.114	0.004	0.012	0.097	0.105	0.113	0.120	0.136

Table B-13. Chlorophyll *a* in nearshore waters of Lake Pend Oreille by lake location and by time period.

Lake Location	Time Period	N	Mean	SE Mean	StDev	Min	Q1	Median	Q3	Max
North	06–08	23	1.080	0.123	0.592	0.50	0.500	1.200	1.500	2.300
North	09–14	47	1.213	0.170	1.163	0.225	0.500	0.720	1.970	4.840
Mid	06–08	23	1.395	0.202	0.971	0.500	0.500	1.150	1.700	4.200
Mid	09–14	32	1.344	0.245	1.386	0.030	.0500	0.670	1.905	4.500
South	06–08	22	1.411	.0186	0.871	0.500	0.875	1.280	1.575	4.100
South	09–14	23	1.443	0.241	1.156	0.360	0.540	1.100	2.450	4.300

Appendix C. Periphyton Chlorophyll-a Concentrations

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Date	Bayview Nearshore	Bottle	Camp	Ellisport	Garfield	Glengary	Granite	Idlewilde	Kootenai	Lakeview	Oden	Sunnyside	Talache	Trestle
7/21/2014	0			0			0	0		0				
7/22/2014		0	0		0	0						0	0	
7/23/2014									0		0			0
7/28/2014				0.2162		0.1632						0.1298		0.2294
7/29/2014	0.2254						0.0422	0.0784		0.1622			0.1252	
7/30/2014		0.1738	0.0576		0.0758				0.1476		0.1072			
8/04/2014		0.5102	0.2092	0.5492		0.195			0.4642		0.236	0.9986		0.4548
8/05/2014	0.4462				0.2204		0.1792	0.299		0.2998			0.1858	
8/12/2014									0.5998		0.8198	1.2798		
8/13/2014			0.4838	1.9752	0.194	1.3598								2.733
8/14/2014	1.0778							0.2584		0.8432				
8/18/2014				2.0734		0.9906						2.0192		2.0282
8/19/2014		1.858							2.6192		1.3656			
8/20/2014	1.28						0.9168	0.8614		1.7046				
8/21/2014			0.923		0.1932								0.5544	
8/26/2014				2.9482		1.893			2.3462		1.2678	3.4818		2.323
8/27/2014	0.831		0.5544		0.1956		0.9756	0.9644		1.49			0.3642	
9/02/2014				4.58								3.3022		2.23
9/03/2014	1.5726													
9/04/2014			1.4738		0.3894		1.8642	1.0762		1.179			0.6248	
9/05/2014						3.7088			4.5224		3.5062			

Note: Chlorophyll *a* concentrations in $\mu g/m^2$ as reported by Darren Brandt, Advanced Eco-Solutions.

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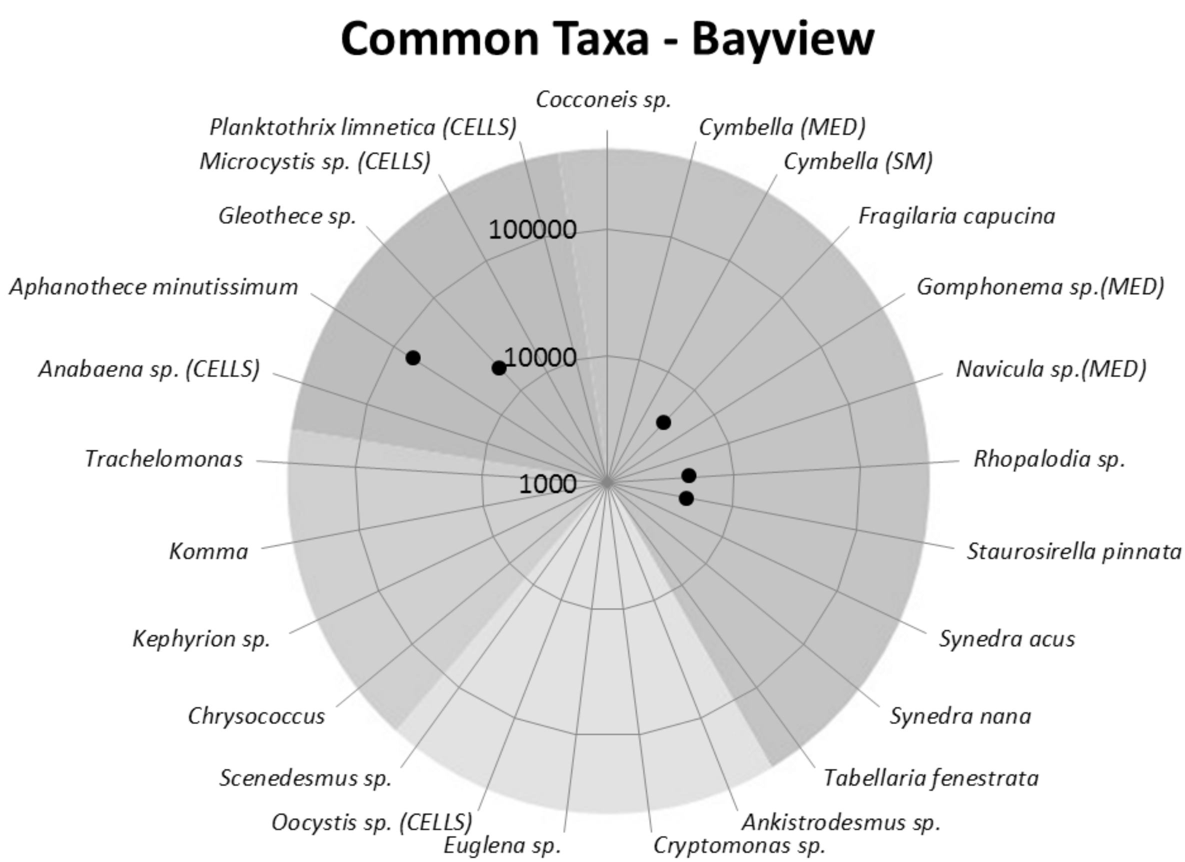
Appendix D. Periphyton Identification and Enumeration

Bayview Nearshore

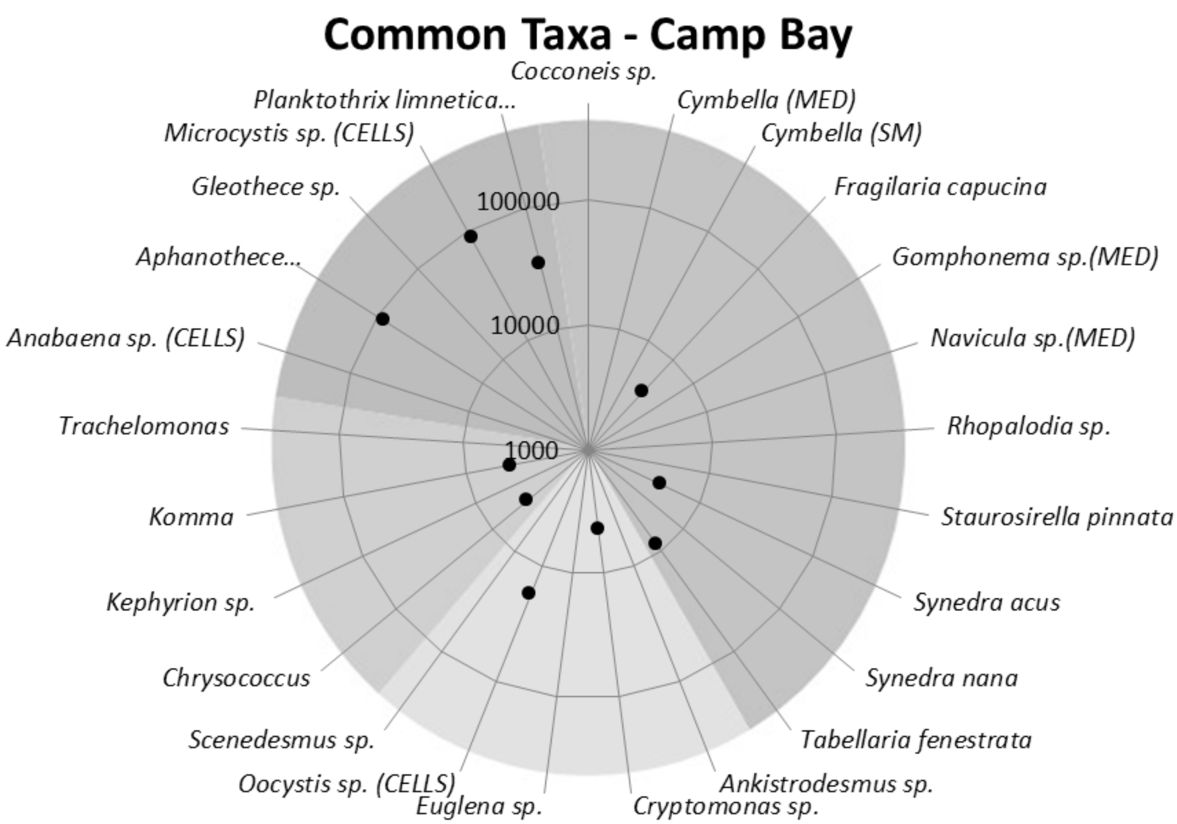
Taxa Name	Class common name	Cells/cm^2	mm^3/m^2	Taxa Frequency
Coccoid Green	Green Algae	190,000	18.93	Widespread
Chroococcus (CELLS)	Cyanobacteria	18,000	22.01	Widespread
Achnanthidium minutissimum	Diatoms	22,000	11.01	Widespread
***Epithemia* sp.**	Diatoms	4,400	15.41	Widespread
Aphanothece minutissimum	Cyanobacteria	66,000	1.32	Widespread
Fragilaria capucina	Diatoms	4,400	3.30	Common
Staurosira construens	Diatoms	13,000	15.85	Widespread
***Gleothece* sp.**	Cyanobacteria	18,000	1.76	Common
micro rods	Green Algae	48,000	9.69	Widespread
***Chroomonas* sp.**	Green Algae	4,400	2.20	Widespread
***Rhopalodia* sp.**	Diatoms	4,400	52.84	Common
Staurosirella pinnata	Diatoms	4,400	2.20	Common
***Tetraedron* sp.**	Green Algae	13,000	6.60	Widespread
***Nostoc* sp.**	Cyanobacteria	35,000	5.28	Widespread

*Widespread = 10–14 stations with taxa present; common = 3–9 stations with taxa present; rare = 1–2 stations with taxa present.



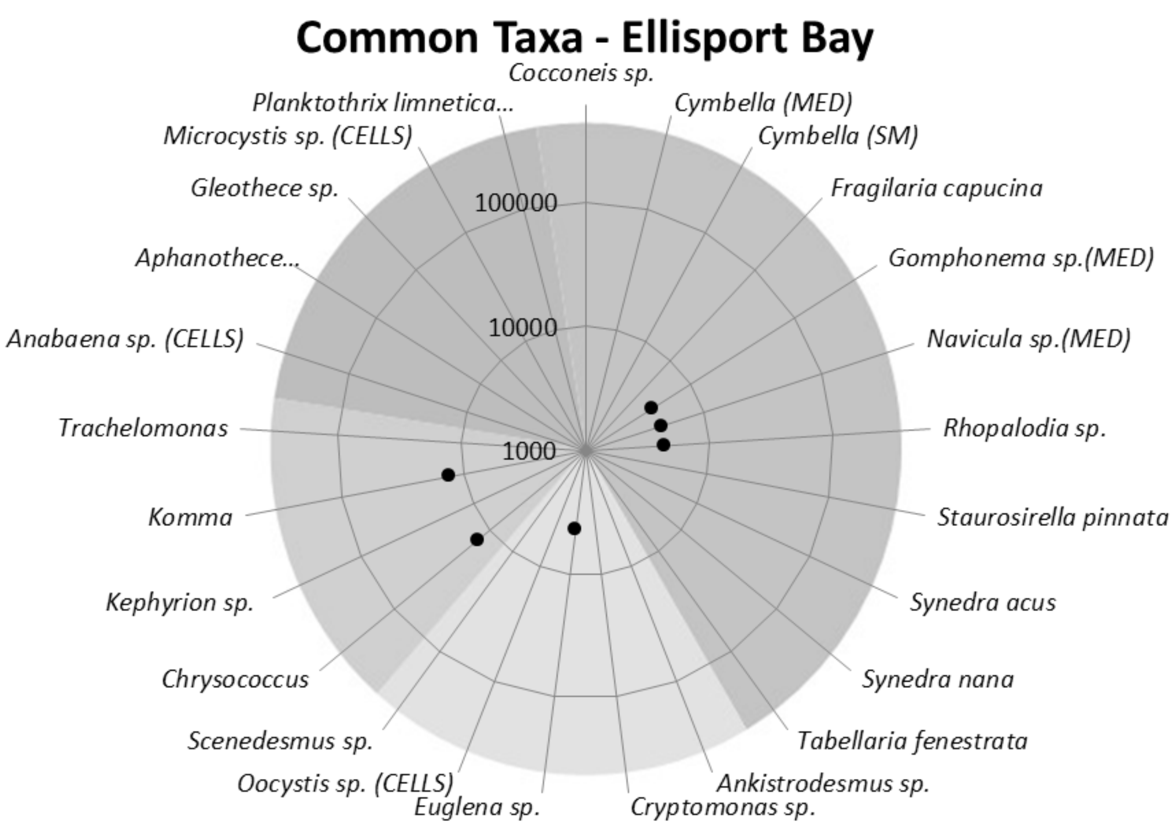
Camp

Taxa Name	Class common name	Cells/cm^2	mm^3/m^2	Taxa Frequency
Aphanothece minutissimum	Cyanobacteria	88,000	1.76	Widespread
Chrysococcus	Green Algae	4,400	3.30	Common
***Cryptomonas* sp.**	Green Algae	4,400	7.71	Common
Coccoid Green	Green Algae	300,000	30.38	Widespread
Chroococcus (CELLS)	Cyanobacteria	8,800	11.01	Widespread
Fragilaria capucina	Diatoms	4,400	3.30	Common
Komma	Green Algae	4,400	4.40	Common
Achnanthidium minutissimum	Diatoms	4,400	2.20	Widespread
***Epithemia* sp.**	Diatoms	4,400	15.41	Widespread
Microcystis* sp. *(CELLS)	Cyanobacteria	88,000	1.76	Common
Staurosira construens	Diatoms	13,000	15.85	Widespread
Oocystis* sp. *(CELLS)	Green Algae	18,000	22.01	Common
Planktothrix limnetica (CELLS)	Cyanobacteria	35,000	8.81	Common
micro rods	Green Algae	44,000	8.81	Widespread
***Nostoc* sp.**	Cyanobacteria	160,000	23.78	Widespread
***Chroomonas* sp.**	Green Algae	8,800	4.40	Widespread
***Tetraedron* sp.**	Green Algae	18,000	8.81	Widespread
Synedra acus	Diatoms	4,400	4.40	Common
Tabellaria fenestrata	Diatoms	8,800	30.82	Common



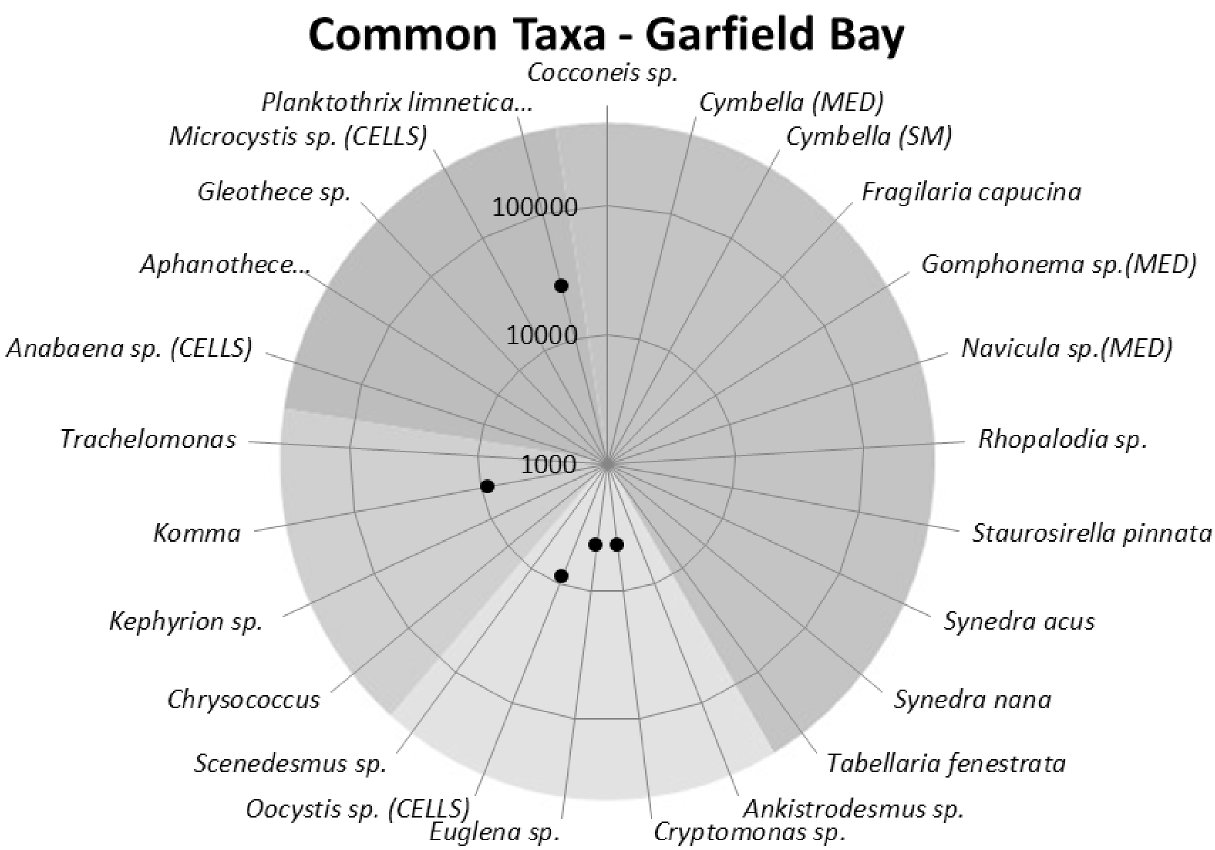
Ellisport

Taxa Name	Class common name	Cells/cm^2	mm^3/m^2	Taxa Frequency
Chrysococcus	Green Algae	13,000	9.91	Common
***Euglena* sp.**	Green Algae	4,400	110.07	Common
Dictyosphaerium (CELLS)	Green Algae	160,000	39.63	Common
Mougeotia (COLONY)	Green Algae	4,400	176.12	Common
Coccoid Green	Green Algae	240,000	24.22	Widespread
Chroococcus (CELLS)	Cyanobacteria	35,000	44.03	Widespread
***Planktolyngbya* sp.**	Cyanobacteria	110,000	11.01	Rare
micro rods	Green Algae	62,000	12.33	Widespread
***Chroomonas* sp.**	Green Algae	22,000	11.01	Widespread
***Scourfieldia* sp.**	Green Algae	8,800	2.64	Common
***Tetraedron* sp.**	Green Algae	4,400	2.20	Widespread
Gomphonema* sp.*(MED)	Diatoms	4,400	22.01	Rare
Achnanthidium minutissimum	Diatoms	57,000	28.62	Widespread
***Epithemia* sp.**	Diatoms	4,400	15.41	Widespread
Komma	Green Algae	13,000	13.21	Common
Navicula* sp.*(MED)	Diatoms	4,400	22.01	Common
***Rhopalodia* sp.**	Diatoms	4,400	52.84	Common
Staurosira construens	Diatoms	18,000	21.13	Widespread



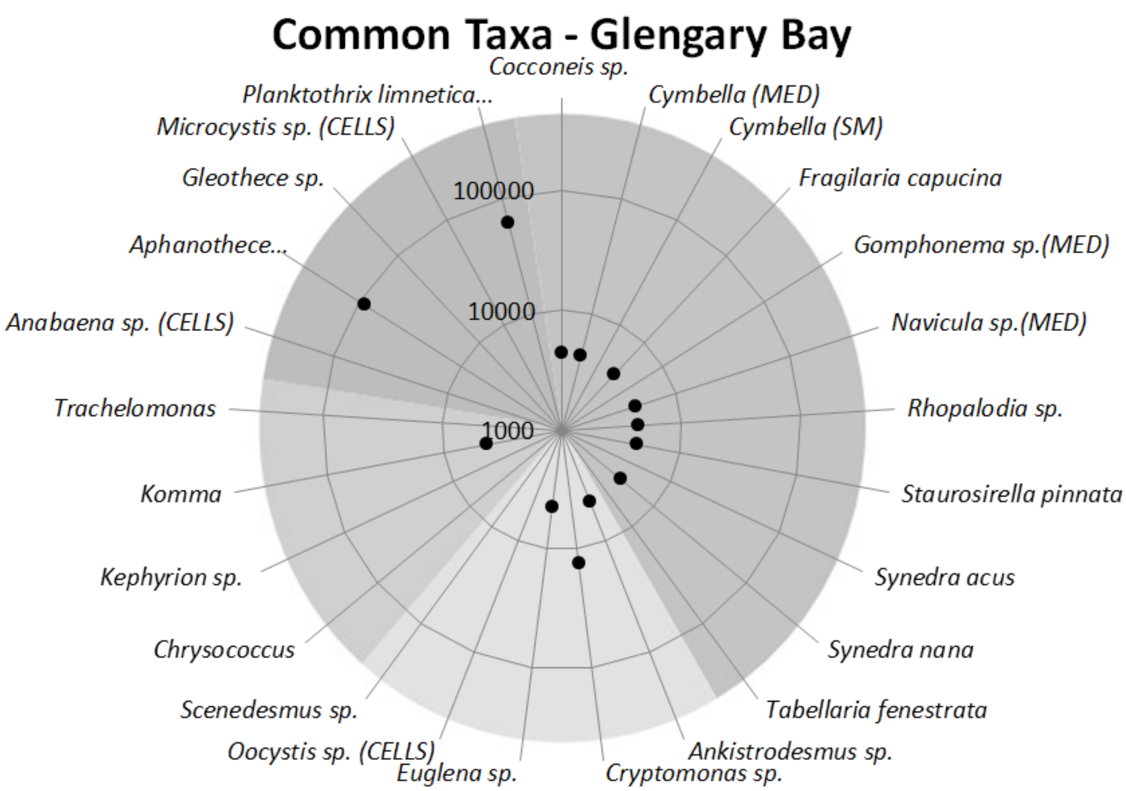
Garfield

Taxa Name	Class common name	Cells/cm^2	mm^3/m^2	Taxa Frequency
***Cryptomonas* sp.**	Green Algae	4,400	7.71	Common
Mougeotia (MEDIUM-CELLS)	Green Algae	4,400	13.21	Rare
***Euglena* sp.**	Green Algae	4,400	110.07	Common
Coccoid Green	Green Algae	160,000	16.29	Widespread
Chroococcus (CELLS)	Cyanobacteria	18,000	22.01	Widespread
Komma	Green Algae	8,800	8.81	Common
***Epithemia* sp.**	Diatoms	4,400	15.41	Widespread
Gomphonema* sp.*(SM)	Diatoms	4,400	11.01	Rare
Navicula* sp.*(SM)	Diatoms	4,400	6.60	Rare
Achnanthidium minutissimum	Diatoms	18,000	8.81	Widespread
micro rods	Green Algae	31,000	6.16	Widespread
Oocystis* sp. *(CELLS)	Green Algae	8,800	11.01	Common
Planktothrix limnetica (CELLS)	Cyanobacteria	26,000	6.60	Common
***Chroomonas* sp.**	Green Algae	22,000	11.01	Widespread
***Nostoc* sp.**	Cyanobacteria	18,000	2.64	Widespread



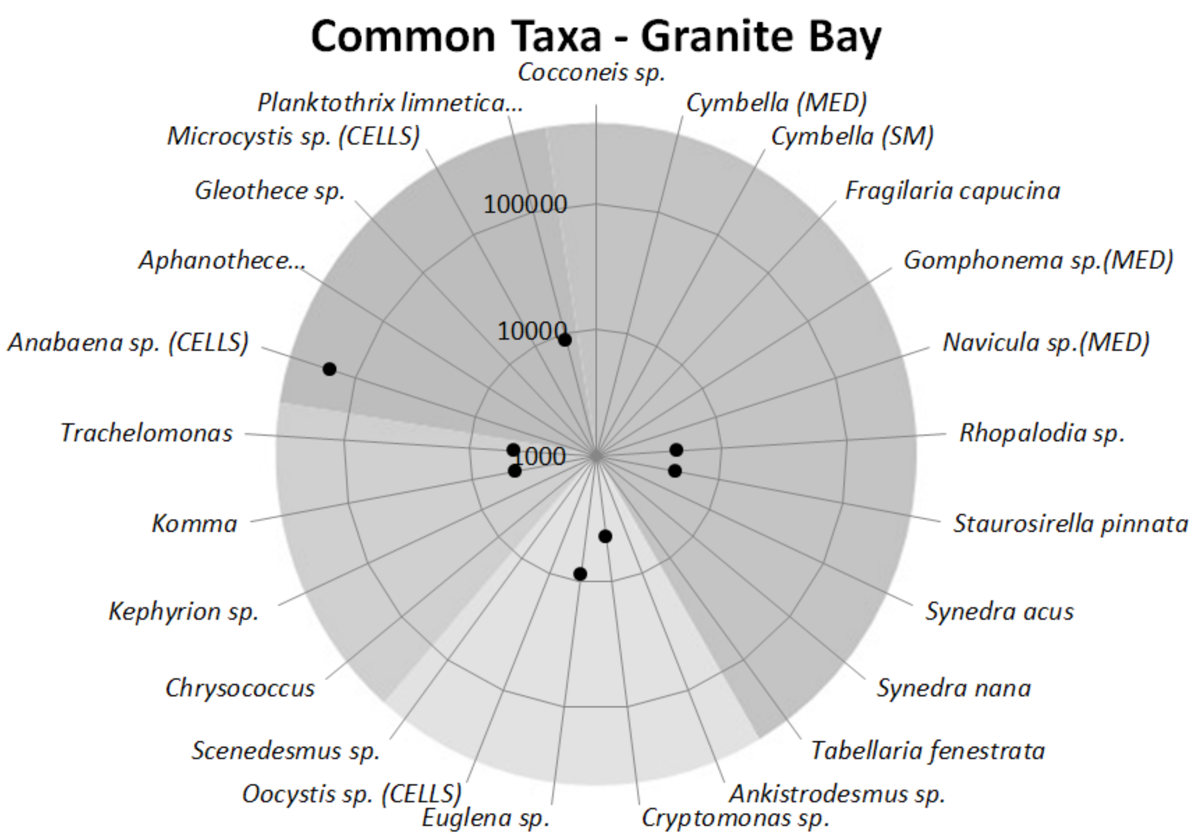
Glengary

Taxa Name	Class common name	Cells/cm^2	mm^3/m^2	Taxa Frequency
***Ankistrodesmus* sp.**	Green Algae	4,400	3.52	Common
Gymnodinium* sp. *(MEDIUM)	Dinoflagellates	4,400	17.61	Rare
Coccoid Green	Green Algae	330,000	33.46	Widespread
Chroococcus (CELLS)	Cyanobacteria	35,000	44.03	Widespread
Aphanothece minutissimum	Cyanobacteria	88,000	1.76	Widespread
Achnanthidium minutissimum	Diatoms	18,000	8.81	Widespread
***Cocconeis* sp.**	Diatoms	4,400	8.81	Common
***Cryptomonas* sp.**	Green Algae	13,000	23.12	Common
***Epithemia* sp.**	Diatoms	8,800	30.82	Widespread
Cymbella (MED)	Diatoms	4,400	11.01	Common
***Euglena* sp.**	Green Algae	4,400	110.07	Common
Fragilaria capucina	Diatoms	4,400	3.30	Common
Staurosira construens	Diatoms	35,000	42.27	Widespread
Komma	Green Algae	4,400	4.40	Common
Navicula* sp.*(MED)	Diatoms	4,400	22.01	Common
micro rods	Green Algae	44,000	8.81	Widespread
Planktothrix limnetica (CELLS)	Cyanobacteria	62,000	15.41	Common
***Nostoc* sp.**	Cyanobacteria	84,000	12.55	Widespread
***Chroomonas* sp.**	Green Algae	31,000	15.41	Widespread
***Rhopalodia* sp.**	Diatoms	4,400	52.84	Common
Staurosirella pinnata	Diatoms	4,400	2.20	Common
Synedra nana	Diatoms	4,400	3.08	Common



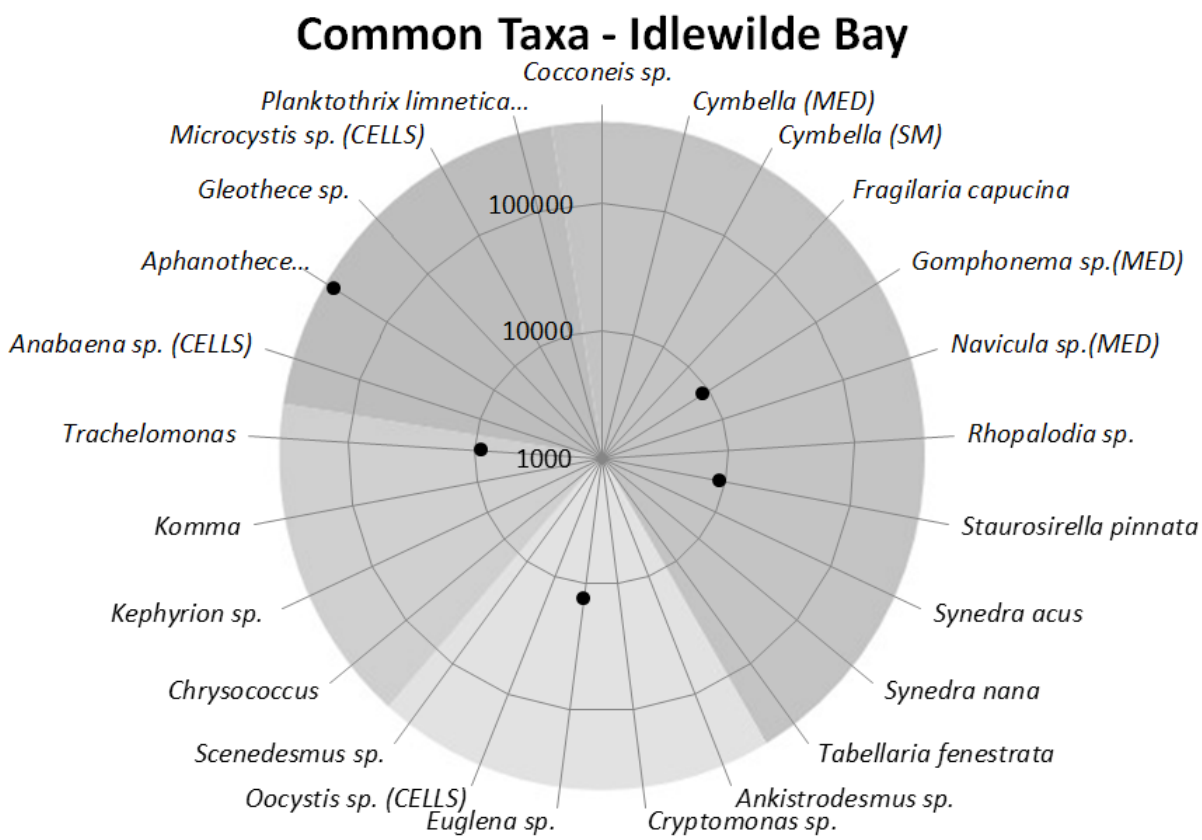
Granite

Taxa Name	Class common name	Cells/cm²	mm³/m²	Taxa Frequency
Anabaena* sp. *(CELLS)	Cyanobacteria	160,000	81.45	Common
***Cryptomonas* sp.**	Green Algae	4,400	7.71	Common
Coccoid Green	Green Algae	150,000	14.53	Widespread
***Euglena* sp.**	Green Algae	8,800	220.15	Common
Chroococcus (CELLS)	Cyanobacteria	18,000	22.01	Widespread
Komma	Green Algae	4,400	4.40	Common
Achnanthidium minutissimum	Diatoms	13,000	6.60	Widespread
***Epithemia* sp.**	Diatoms	4,400	15.41	Widespread
Planktothrix limnetica (CELLS)	Cyanobacteria	8,800	2.20	Common
Staurosira construens	Diatoms	8,800	10.57	Widespread
***Rhopalodia* sp.**	Diatoms	4,400	52.84	Common
micro rods	Green Algae	57,000	11.45	Widespread
Staurosirella pinnata	Diatoms	4,400	2.20	Common
***Chroomonas* sp.**	Green Algae	8,800	4.40	Widespread
Trachelomonas	Green Algae	4,400	6.60	Common
***Tetraedron* sp.**	Green Algae	4,400	2.20	Widespread
***Nostoc* sp.**	Cyanobacteria	26,000	3.96	Widespread
micro rods	Green Algae	57,000	11.45	Widespread



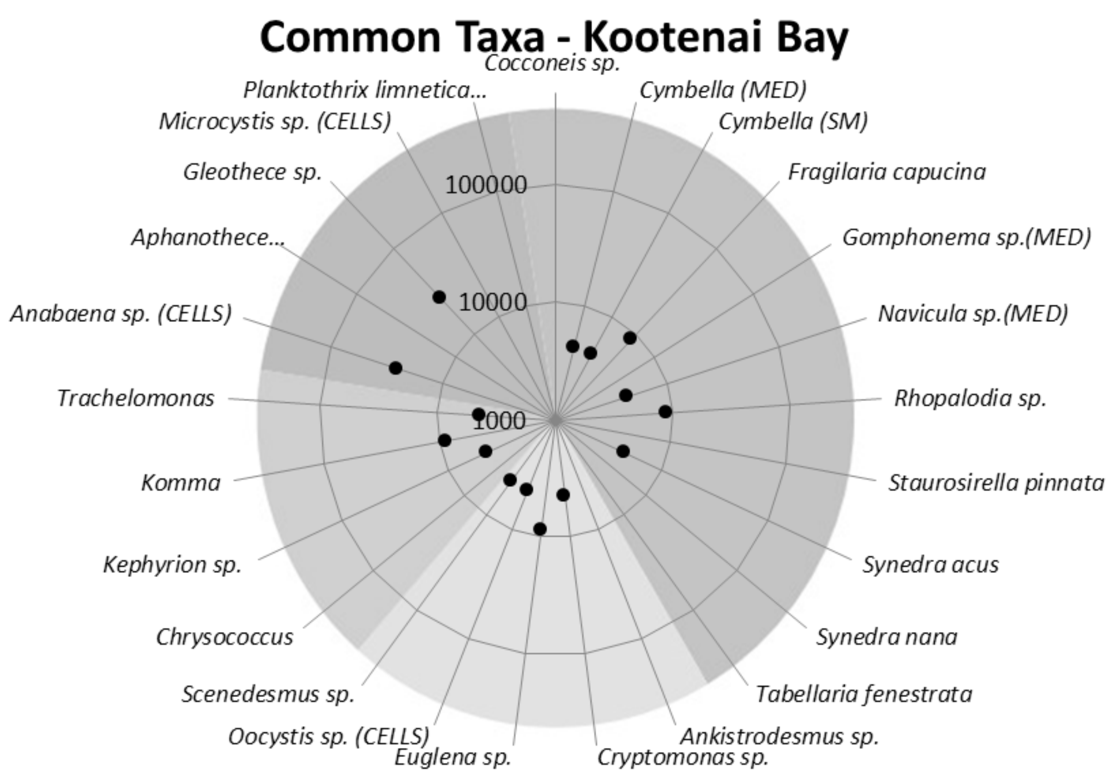
Idlewilde

Taxa Name	Class common name	Cells/cm^2	mm^3/m^2	Taxa Frequency
Aphanothece minutissimum	Cyanobacteria	310,000	6.16	Widespread
Coccoid Green	Green Algae	210,000	21.13	Widespread
Chroococcus (CELLS)	Cyanobacteria	8,800	11.01	Widespread
Achnanthidium minutissimum	Diatoms	4,400	2.20	Widespread
Didymosphenia geminata	Diatoms	4,400	55.04	Rare
***Euglena* sp.**	Green Algae	13,000	330.22	Common
Staurosira construens	Diatoms	8,800	10.57	Widespread
Gomphonema* sp.*(MED)	Diatoms	8,800	44.03	Rare
micro rods	Green Algae	18,000	3.52	Widespread
***Tetraedron* sp.**	Green Algae	13,000	6.60	Widespread
Staurosirella pinnata	Diatoms	8,800	4.40	Common
Trachelomonas	Green Algae	8,800	13.21	Common
***Chroomonas* sp.**	Green Algae	13,000	6.60	Widespread



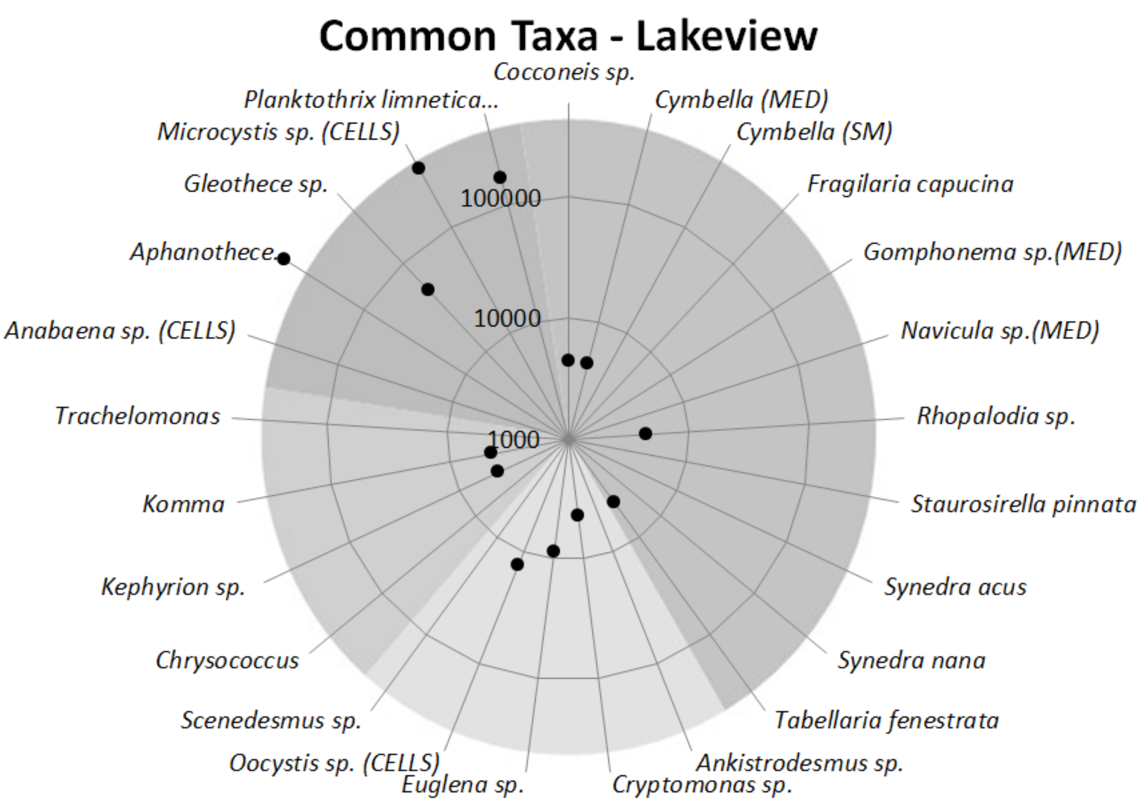
Kootenai

Taxa Name	Class common name	Cells/cm^2	mm^3/m^2	Taxa Frequency
Anabaena* sp. *(CELLS)	Cyanobacteria	26,000	13.21	Common
***Cryptomonas* sp.**	Green Algae	4,400	7.71	Common
Cymbella (MED)	Diatoms	4,400	11.01	Common
Cymbella (SM)	Diatoms	4,400	4.40	Common
Coccoid Green	Green Algae	510,000	51.07	Widespread
***Euglena* sp.**	Green Algae	8,800	220.15	Common
Chroococcus (CELLS)	Cyanobacteria	44,000	55.04	Widespread
Achnanthidium minutissimum	Diatoms	8,800	4.40	Widespread
Fragilaria capucina	Diatoms	8,800	6.60	Common
***Gleothece* sp.**	Cyanobacteria	26,000	2.64	Common
***Epithemia* sp.**	Diatoms	4,400	15.41	Widespread
***Kephyrion* sp.**	Green Algae	4,400	2.20	Common
Fragilaria crotonensis	Diatoms	13,000	9.25	Rare
Komma	Green Algae	8,800	8.81	Common
Navicula* sp.*(MED)	Diatoms	4,400	22.01	Common
Oocystis* sp. *(CELLS)	Green Algae	4,400	5.50	Common
micro rods	Green Algae	40,000	7.93	Widespread
***Rhopalodia* sp.**	Diatoms	8,800	105.67	Common
***Scenedesmus* sp.**	Green Algae	4,400	2.64	Common
***Tetraedron* sp.**	Green Algae	22,000	11.01	Widespread
***Chroomonas* sp.**	Green Algae	26,000	13.21	Widespread
Synedra acus	Diatoms	4,400	4.40	Common
Trachelomonas	Green Algae	4,400	6.60	Common
***Nostoc* sp.**	Cyanobacteria	170,000	25.10	Widespread



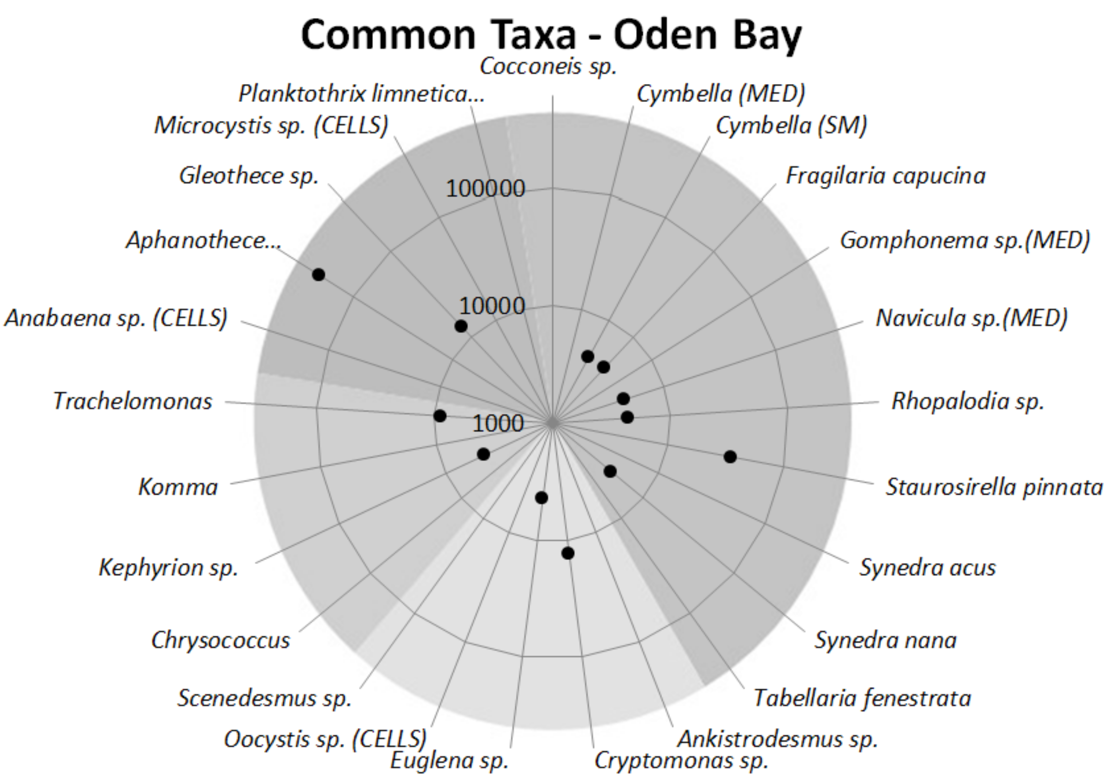
Lakeview

Taxa Name	Class common name	Cells/cm^2	mm^3/m^2	Taxa Frequency
Aphanothece minutissimum	Cyanobacteria	590,000	11.89	Widespread
***Cocconeis* sp.**	Diatoms	4,400	8.81	Common
***Cryptomonas* sp.**	Green Algae	4,400	7.71	Common
Coccoid Green	Green Algae	400,000	39.63	Widespread
Chroococcus (CELLS)	Cyanobacteria	150,000	187.13	Widespread
Cymbella (MED)	Diatoms	4,400	11.01	Common
***Euglena* sp.**	Green Algae	8,800	220.15	Common
***Nostoc* sp.**	Cyanobacteria	97,000	14.53	Widespread
Achnanthidium minutissimum	Diatoms	44,000	22.01	Widespread
***Gleothece* sp.**	Cyanobacteria	48,000	4.84	Common
***Kephyrion* sp.**	Green Algae	4,400	2.20	Common
***Epithemia* sp.**	Diatoms	13,000	46.23	Widespread
Komma	Green Algae	4,400	4.40	Common
Staurosira construens	Diatoms	8,800	10.57	Widespread
Microcystis* sp. *(CELLS)	Cyanobacteria	350,000	7.04	Common
Oocystis* sp. *(CELLS)	Green Algae	13,000	16.51	Common
micro rods	Green Algae	84,000	16.73	Widespread
***Tetraedron* sp.**	Green Algae	4,400	2.20	Widespread
Planktothrix limnetica (CELLS)	Cyanobacteria	170,000	42.93	Common
***Chroomonas* sp.**	Green Algae	26,000	13.21	Widespread
***Tetraedron* sp.**	Green Algae	4,400	2.20	Widespread
***Rhopalodia* sp.**	Diatoms	4,400	52.84	Common
Tabellaria fenestrata	Diatoms	4,400	15.41	Common



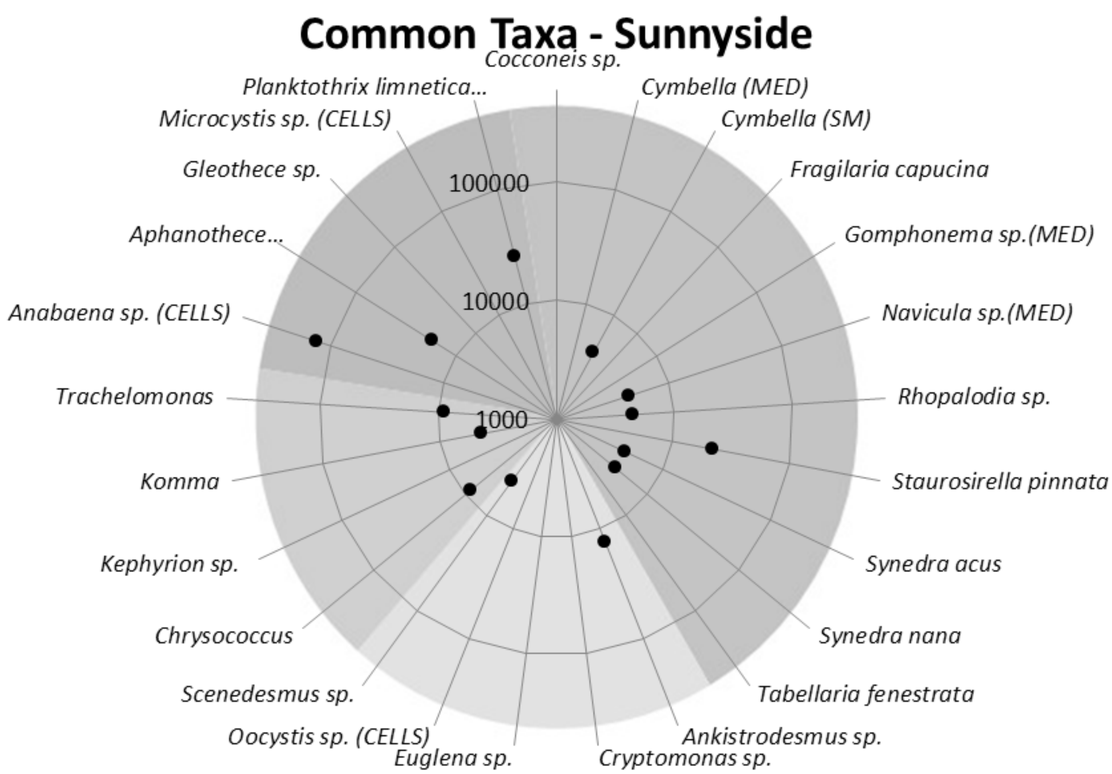
Oden

Taxa Name	Class common name	Cells/cm^2	mm^3/m^2	Taxa Frequency
Aphanothece minutissimum	Cyanobacteria	220,000	4.40	Widespread
***Cryptomonas* sp.**	Green Algae	13,000	23.12	Common
Coccoid Green	Green Algae	460,000	46.23	Widespread
Chroococcus (CELLS)	Cyanobacteria	26,000	33.02	Widespread
***Planktolyngbya* sp.**	Cyanobacteria	92,000	9.25	Rare
***Chroomonas* sp.**	Green Algae	44,000	22.01	Widespread
Cymbella (SM)	Diatoms	4,400	4.40	Common
***Tetraedron* sp.**	Green Algae	18,000	8.81	Widespread
***Euglena* sp.**	Green Algae	4,400	110.07	Common
micro rods	Green Algae	57,000	11.45	Widespread
Fragilaria capucina	Diatoms	4,400	3.30	Common
***Gleothece* sp.**	Cyanobacteria	13,000	1.32	Common
***Nostoc* sp.**	Cyanobacteria	26,000	3.96	Widespread
Achnanthidium minutissimum	Diatoms	8,800	4.40	Widespread
***Kephyrion* sp.**	Green Algae	4,400	2.20	Common
***Epithemia* sp.**	Diatoms	4,400	15.41	Widespread
Navicula* sp.*(MED)	Diatoms	4,400	22.01	Common
***Rhopalodia* sp.**	Diatoms	4,400	52.84	Common
Staurosirella pinnata	Diatoms	35,000	17.61	Common
Staurosira construens	Diatoms	8,800	10.57	Widespread
Synedra nana	Diatoms	4,400	3.08	Common
Trachelomonas	Green Algae	8,800	13.21	Common



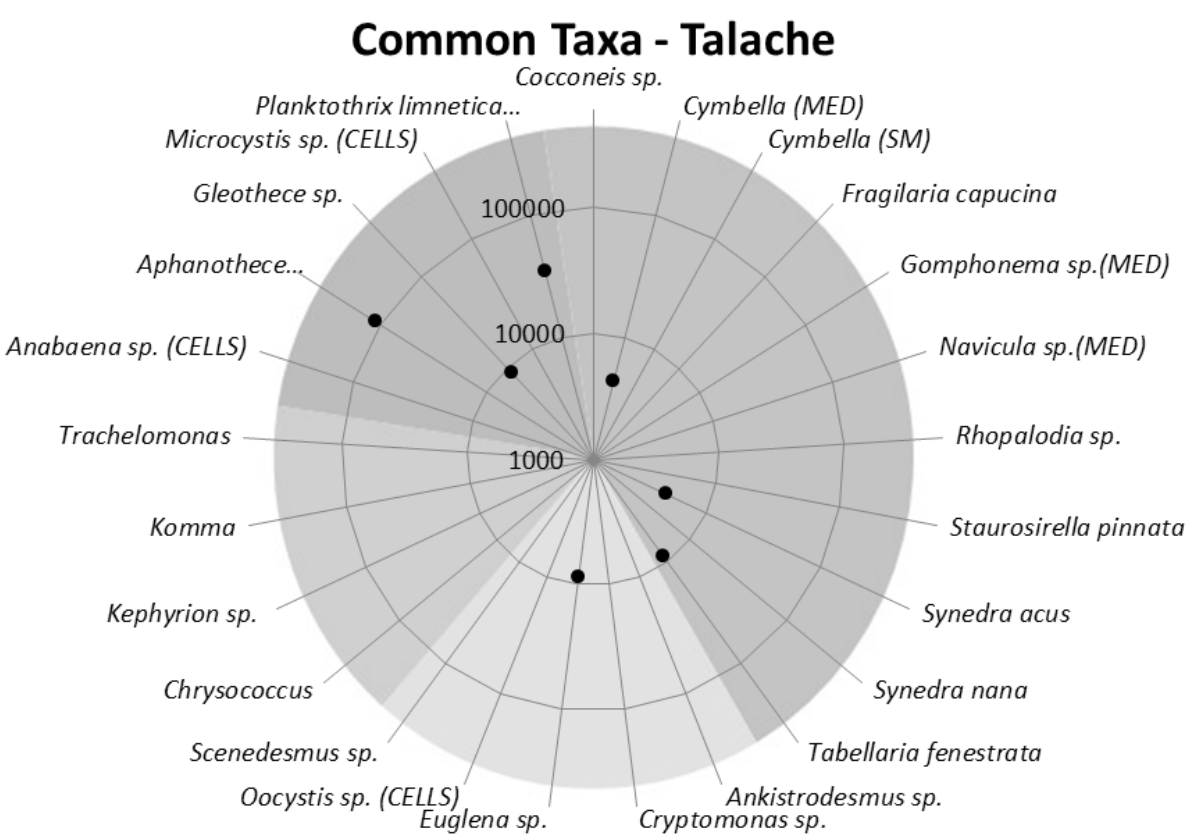
Sunnyside

Taxa Name	Class common name	Cells/cm^2	mm^3/m^2	Taxa Frequency
Anabaena sp. (CELLS)	Cyanobacteria	140,000	68.25	Common
***Ankistrodesmus* sp.**	Green Algae	13,000	10.57	Common
Aphanothece minutissimum	Cyanobacteria	18,000	0.35	Widespread
***Cosmarium* sp.**	Green Algae	4,400	22.01	Rare
Coccoid Green	Green Algae	320,000	32.14	Widespread
Chrysococcus	Green Algae	8,800	6.60	Common
Chroococcus (CELLS)	Cyanobacteria	35,000	44.03	Widespread
Cymbella (SM)	Diatoms	4,400	4.40	Common
Komma	Green Algae	4,400	4.40	Common
***Cyanothece* sp.**	Cyanobacteria	18,000	1.76	Rare
micro rods	Green Algae	44,000	8.81	Widespread
***Chroomonas* sp.**	Green Algae	4,400	2.20	Widespread
***Nostoc* sp.**	Cyanobacteria	110,000	17.17	Widespread
***Tetraedron* sp.**	Green Algae	4,400	2.20	Widespread
Navicula sp.(MED)	Diatoms	4,400	22.01	Common
Planktothrix limnetica (CELLS)	Cyanobacteria	26,000	6.60	Common
Achnanthidium minutissimum	Diatoms	31,000	15.41	Widespread
***Cyclotella* sp.**	Diatoms	4,400	6.60	Rare
***Rhopalodia* sp.**	Diatoms	4,400	52.84	Common
***Epithemia* sp.**	Diatoms	13,000	46.23	Widespread
***Scenedesmus* sp.**	Green Algae	4,400	2.64	Common
Staurosirella pinnata	Diatoms	22,000	11.01	Common
Staurosira construens	Diatoms	26,000	31.70	Widespread
Synedra acus	Diatoms	4,400	4.40	Common
Synedra nana	Diatoms	4,400	3.08	Common
Trachelomonas	Green Algae	8,800	13.21	Common



Talache

Taxa Name	Class common name	Cells/cm^2	mm^3/m^2	Taxa Frequency
Coccoid Green	Green Algae	160,000	16.29	Widespread
Chroococcus (CELLS)	Cyanobacteria	18,000	22.01	Widespread
Aphanothece minutissimum	Cyanobacteria	110,000	2.20	Widespread
Achnanthidium minutissimum	Diatoms	26,000	13.21	Widespread
Cymbella (MED)	Diatoms	4,400	11.01	Common
***Epithemia* sp.**	Diatoms	4,400	15.41	Widespread
***Rhizosolenia* sp.**	Diatoms	4,400	2.20	Rare
***Euglena* sp.**	Green Algae	8,800	220.15	Common
***Gleothece* sp.**	Cyanobacteria	8,800	0.88	Common
micro rods	Green Algae	31,000	6.16	Widespread
***Chroomonas* sp.**	Green Algae	18,000	8.81	Widespread
Planktothrix limnetica (CELLS)	Cyanobacteria	35,000	8.81	Common
***Chroomonas* sp.**	Green Algae	18,000	8.81	Widespread
***Tetraedron* sp.**	Green Algae	13,000	6.60	Widespread
Synedra acus	Diatoms	4,400	4.40	Common
Tabellaria fenestrata	Diatoms	8,800	30.82	Common



Trestle

Taxa Name	Class common name	Cells/cm^2	mm^3/m^2	Taxa Frequency
Chrysococcus	Green Algae	4,400	3.30	Common
Cymbella (MED)	Diatoms	4,400	11.01	Common
Gomphonema* sp.*(MED)	Diatoms	8,800	44.03	Rare
***Kephyrion* sp.**	Green Algae	4,400	2.20	Common
Coccoid Green	Green Algae	600,000	60.32	Widespread
Chroococcus (CELLS)	Cyanobacteria	53,000	66.04	Widespread
Achnanthidium minutissimum	Diatoms	26,000	13.21	Widespread
Komma	Green Algae	4,400	4.40	Common
***Epithemia* sp.**	Diatoms	13,000	46.23	Widespread
Gomphonema* sp.*(SM)	Diatoms	4,400	11.01	Rare
***Rhopalodia* sp.**	Diatoms	4,400	52.84	Common
Staurosirella pinnata	Diatoms	62,000	30.82	Common
Synedra acus	Diatoms	4,400	4.40	Common
Fragilaria crotonensis	Diatoms	18,000	12.33	Rare
Synedra nana	Diatoms	4,400	3.08	Common
Tabellaria fenestrata	Diatoms	4,400	15.41	Common
Trachelomonas	Green Algae	8,800	13.21	Common
micro rods	Green Algae	26,000	5.28	Widespread
***Chroomonas* sp.**	Green Algae	18,000	8.81	Widespread
***Tetraedron* sp.**	Green Algae	8,800	4.40	Widespread
Staurosira construens	Diatoms	62,000	73.97	Widespread
***Coleochaete* sp.**	Green Algae	330,000	495.33	Rare
***Nostoc* sp.**	Cyanobacteria	35,000	5.28	Widespread