Wai Kai Lagoon Water Quality Report: to July 31, 2023

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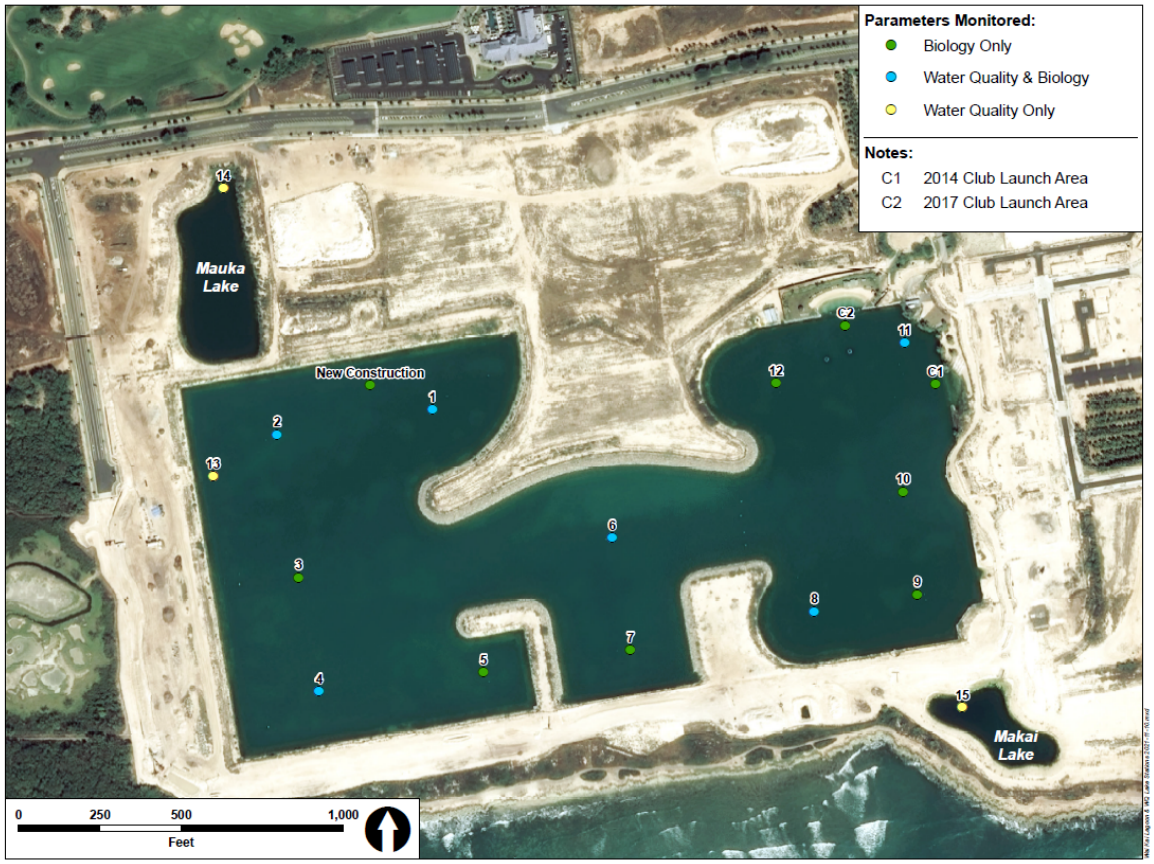
Introduction

Excavation of the Wai Kai Lagoon began late in 2003 and was completed in August 2008. Monitoring of the water quality in the Lagoon began in January 2005, in accordance with the methodology approved by the State of Hawai`i Department of Health and pursuant to Haseko's Department of the Army Water Quality Certification (WQC 137) for the original marina project. Preliminary biological monitoring of the Lagoon flora and fauna began in 2012. Results of this work are summarized in the environmental impact statement published for Haseko's zone change application.[1] In mid-2014, Haseko initiated monthly biological surveying in the Lagoon to complement ongoing monthly water quality monitoring. This work continues, with results shown to July 31, 2023. The available results for this water quality and biological monitoring program from 2015 to present are summarized here graphically after a description of the methods used. Sample station locations used for routine monitoring are shown below.

Monitoring Station Locations. Prepared by Planning Solutions, Inc.



[1] http://oeqc.doh.hawaii.gov/Shared%20Documents/EA_and_EIS_Online_Library/Oahu/2010s/2014-11-23-OA-5E-FEIS-Hoakalei-Master-Plan-Update-Volume-I.pdf and http://oeqc.doh.hawaii.gov/Shared%20Documents/EA_and_EIS_Online_Library/Oahu/2010s/2014-11-23-OA-5E-FEIS-Hoakalei-Master-Plan-Update-Volume-II.pdf

Water Quality Measurements

Lagoon water samples are collected from surface water (within 6 inches of the surface) and near-bottom water (within 1 foot of the Lagoon floor). Stations 1-12 in the Lagoon have been sampled for water quality since 2006. Sampling at Stations 14 and 15, which are the Mauka and Makai water quality lakes, began in April 2019.

All Lagoon samples are collected from a small, inflatable boat. Surface samples in the Lagoon are collected by filling bottles by hand over the side of the boat. Near-bottom samples are collected using a 2L Niskin oceanographic sampling bottle, which is lowered to the desired sampling depth with spring-loaded end-caps held open so water can pass freely through the bottle. A weight hung below the bottle signals the designated sampling depth above the bottom. At the desired sampling depth, a weighted messenger released from the surface triggers closure of the end caps, isolating a volume of water from depth. Upon retrieval, water from the Niskin bottle is poured into 250 ml, acid washed and triple-rinsed polyethylene bottles.

Samples from the water quality lakes are collected only from the near-surface. This is done using a sample bottle attached at the end of a long pole to minimize the possibility of contaminating the sample with material dislodged from the lake edges. At times, surface samples are collected from the middle of the water quality lakes off the side of an inflatable stand up paddleboard.

Water quality parameters evaluated for the Lagoon include all of those for which Chapter 11-54 of the State of Hawai`i Department of Health (DOH) Water Quality Standards establish specific criteria. These parameters include: total nitrogen (TN), nitrate + nitrite nitrogen (NO_3 + NO_2), hereinafter referred to as NO_3, ammonium nitrogen (NH_4), total phosphorus (TP), chlorophyll-a (Chl-a), turbidity, pH and salinity. In addition, ortho-phosphate (PO_4) and silica (SiO_2) are measured, because these parameters are sensitive indicators of biological activity and the degree of groundwater mixing.

Following collection, samples for nutrient analysis are immediately stored on ice. Analyses for NH_4, PO_4, Si and NO_3 are performed with a Seal Analytical segmented flow autoanalyzer (AA3) using EPA approved standard methods for seawater analysis (Strickland and Parsons 1968, Grasshoff 1983). TN and TP are analyzed in a similar fashion following oxidative and UV digestion. Total organic nitrogen (TON) and total organic phosphorus (TOP) are calculated as the difference between TN and dissolved inorganic N and between TP and dissolved inorganic P, respectively.

Water for additional testing is subsampled from the polyethylene bottles and kept chilled until analysis. Chl-a is measured by filtering 150 ml of water through glass-fiber filters (Whatman GFF); pigments on filters are extracted in 90% acetone in the dark at 20° C for 24 hours. Chlorophyll concentration is determined using the modified fluorometric technique (EPA Method 445.0 rev 1.2) and a Turner Trilogy Laboratory Fluorometer. Salinity is determined using a Mettler Toledo InLab-731 ISM conductivity probe and pH is measured using a Mettler Toledo InLab Expert Pro-ISM probe. Turbidity is measured on 20 ml subsamples using a Hanna Instruments HI88703 Turbidimeter. Laboratory testing for water quality variables was conducted by Marine Consulting and Analytical Resources, LLC.

In situ field measurements of water temperature, dissolved oxygen, pH and salinity are acquired using an RBR Maestro^3 CTD (Conductivity, Temperature, Depth) profiling instrument, calibrated to factory specifications. The CTD has a readability of 0.001°C, 0.001 pH units, 0.001% oxygen saturation, and 0.001 parts per thousand (salinity). The instrument is lowered slowly through the water column and automatically records data eight times per second.

Prior to December 2019, screening for *Enterococci* bacteria as a fecal indicator was conducted using the membrane filtration EPA Method 1600[3]. Since late 2019, the Enterolert® method for *Enterococci* is run concurrent with the membrane filtration method. For both analytical methods, water samples are

collected from just under the surface directly into a sterile container. Collected samples are placed in a cooler containing an ice pack and then transported to the lab for immediate processing.

For EPA Method 1600, Standard Method 9230C, membrane filtration procedure (mE1 Agar, 24-hour incubation at 41°C) was used for the detection and enumeration of *Enterococci* bacteria in water as described in *Standard Methods for the Examination of Water and Wastewater*.[2] The units for the EPA 1600 Method are "colony forming units" (CFU) per 100 ml.

The Enterolert® test employs a proprietary nutrient indicator to detect *Enterococci*. It does not require bacterial culturing of the water sample to estimate *Enterococci*, but instead relies on colorimetric tagging to detect the active enzymes that indicate the presence of these bacteria (24-hour incubation at 41°C). The units for the Enterolert® method are "most probable number" (MPN) per 100 ml.

Enterocci data are compared with the Beach Action Value (BAV). A BAV of 130 CFU or MPN per 100 ml is the HDOH Clean Water Branch equivalent of the EPA recommended threshold value and triggers a resampling the next workday and issuance of an advisory until testing indicates action is no longer needed (https://health.hawaii.gov/cwb/fi les/2020/09/Hawaii-Beach-Monitoring-Program-FINAL_9-1-20.pdf).

Chara **Percent Coverage and Canopy Height**

The canopy-forming macroalga *Chara zeylanica* (*Chara*) covers most of the Lagoon bottom. Estimates of percent *Chara* coverage on the Lagoon bottom and average canopy height above the bottom are made monthly by Aquatic Research Consultants LLC at designated stations using SCUBA diving transects 50 meters (~165 feet) in length, starting from each station marker buoys and continued along fixed, predetermined headings. At each site, the GPS location is noted at the beginning and end of each transect. The percent cover of *Chara* is determined using the point contact method. The presence/absence of *Chara* is measured at every 1-meter increment, for a total of 50 points sampled. The percent cover of *Chara* is calculated as the percentage of the points sampled where *Chara* is present. For example, if a diver noted that *Chara* is present at 14 of 50 points sampled along the transect, then the coverage equals 28%. The *Chara* canopy height is measured every 5 meters, if present, along the transect.

Chara **Nitrogen Stable Isotope Ratios**

The ratio found in *Chara* tissue between the stable heavy isotope of nitrogen ($_{15}$N) and the more commonly occurring isotope ($_{14}$N) is related to the potential sources of the nitrogen nutrients assimilated into the alga from the ambient water. The indicator variable used, δ_{15}N, is normalized to the ratio of these two isotopes found in the atmosphere.[3] The apical, new growth of the alga (upper 3-5 cm) was used for analyses. Samples were processed according to Strait and Spalding (2021)[4] and left calcified to limit nitrogen degradation resulting from the acidification process. The δ_{15}N values for this monitoring effort are determined at the Biogeochemical Stable Isotope Facility for Stable Isotopes at the University of Hawai`i.[5]

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[2] Clesceri, L. S., A. E. Greenberg, and D.A. Eaton. 1998. Standard Methods for the Examination of Water and Wastewater. American Public Health Association. Washington, DC), EPA Method 1600.

[3] δ15N = 1000((Rx – Rs)/Rs), where Rx is the 15N:14N ratio in the sample and Rs is the corresponding ratio in air.

[4] Strait NS & Spalding HL (2021). Mind your methods: acidification degrades total nitrogen and stable isotopic values within calcified marine macroalgae. *Phycologia*: 60: 131-134.

[5] https://www.soest.hawaii.edu/GG/isotope_biogeochem/

Chara Tissue Nitrogen Concentration

Dry-weight nitrogen concentrations are analyzed for *Chara* tissue samples by the Biogeochemical Stable Isotope Facility at the University of Hawai'i at Mānoa. Relatively high concentrations suggest plentiful nitrogen nutrient availability. The apical, new growth of the algal thallus (upper 3-5 cm) is used for analyses.

Tilapia Nest Occurrence

During the *Chara* coverage and height surveys, the number of Tilapia (*Oreochromis mossambicus*) nests are counted within a distance of 1 m from the transect along one side of the 50 m transect. Visibility at depth is also noted along the transect line over unvegetated (bare sediment) and vegetated areas.

Irradiance Profiles

Measuring irradiance (µE m^{-1} s^{-1}), or light, in the Lagoon water column allows for the comparison of changes in the attenuation of light in the water over time due to increases or decreases in phytoplankton and other particulate matter in the water. Irradiance profiles are measured mid-day at 0.5 m depth increments from just below the water surface to the Lagoon bottom (or top of the *Chara* canopy, as determined when the profiling line becomes slack). Measurements are only taken when weather conditions are clear and sunny. Profiles are conducted on the sunny side of the boat to minimize the effect of boat shadow. A LI-COR LI-1400 data logger coupled with a LI-COR underwater spherical quantum sensor mounted on a profiling frame with a 10 m LI-COR underwater cable is used to measure irradiance. Depth is measured with a line marked at 0.5 m increments. A spherical sensor is used instead of a cosine sensor because the spherical sensor more accurately measures light in a manner consistent with how *Chara* absorbs light at depth. The Secchi depth is also recorded at each site to compare with the diffuse attenuation coefficient.

Plankton Assemblages

Samples for analysis of the plankton assemblage are collected to evaluate temporal and spatial variability, the stability of the microbial system, and to complement water chemistry measurements. Whole water samples[6] or phytoplankton and zooplankton determinations are collected in 1L dark bottles and 5 x 1-gallon plastic jugs respectively, from the surface waters of each station. Zooplankton samples are filtered onto a 93-µm mesh and preserved on site; phytoplankton samples are immediately taken to the laboratory on ice and preserved within 2 hours for subsequent analysis. Because the size range of the plankton assemblage spans four orders of magnitude (<1 µm to >1 mm), a suite of different preservatives and methods is necessary to address each segment of the population. Detailed descriptions of these methods are available from Marine Consulting and Analytical Resources, LLC[7].

Data and Figures

All data and figures for the described analyses are included in the following Figures 1 – 19 on pages 5 – 23.

[6] Whole water samples are aqueous, non-filtered samples that contain all natural colloidal and suspended particulate matter.

[7] mcarhawaii@gmail.com, 334 Awini Way, Honolulu, HI 96825

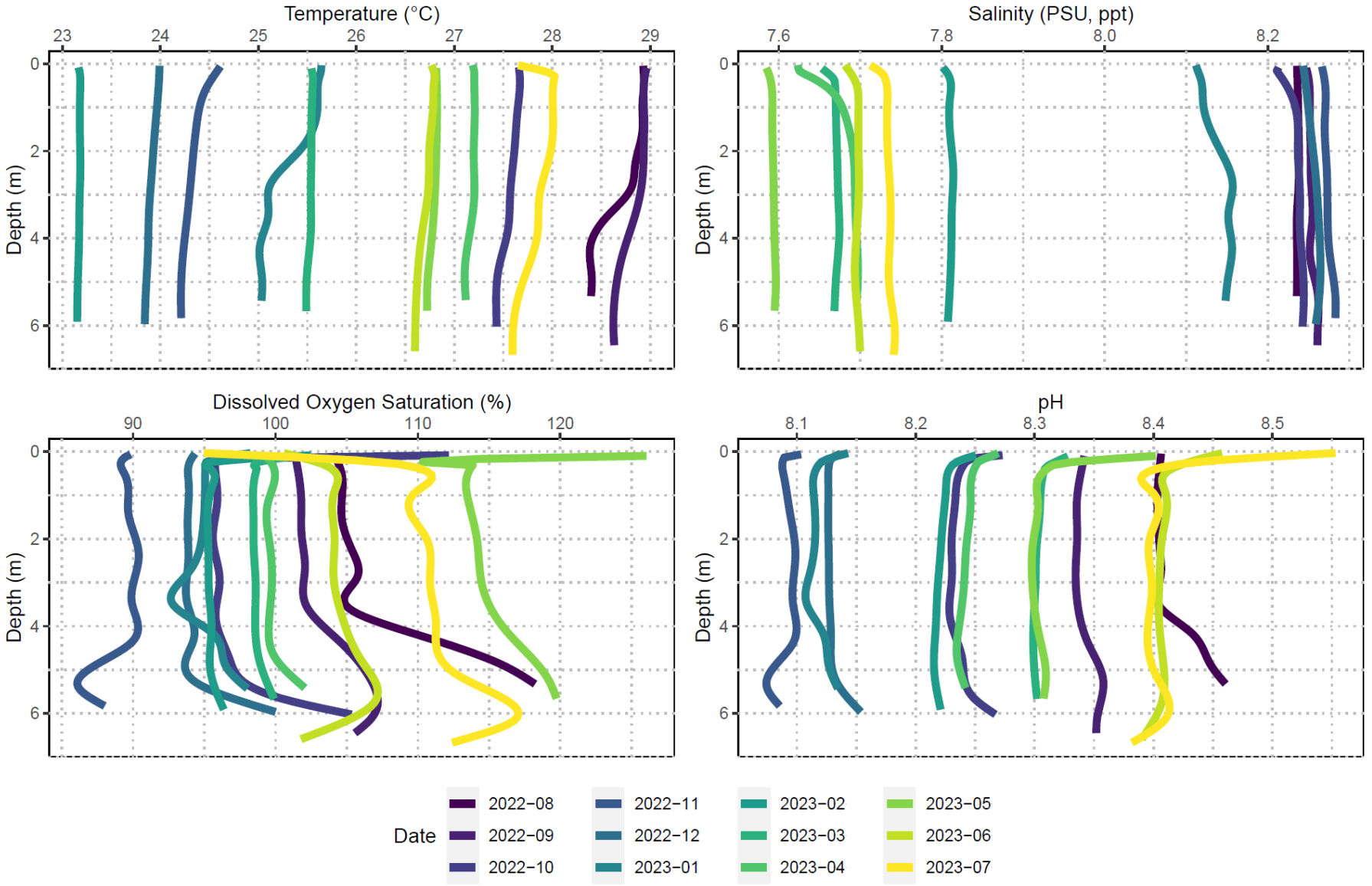

Figure 1. Representative (Station 6) monthly compilation of water column profiles over one year in the Wai Kai Lagoon (Lagoon).

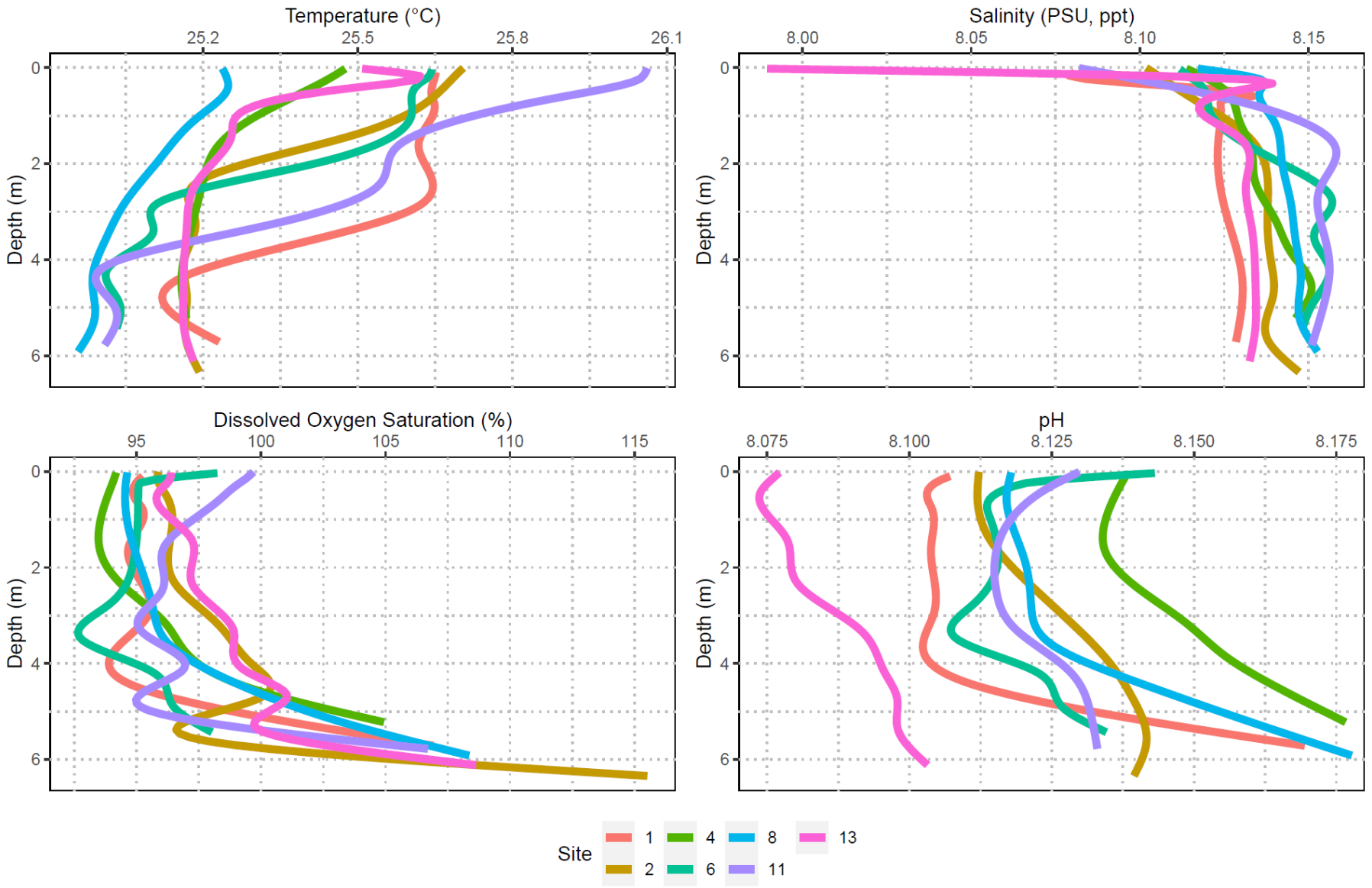

Figure 2. Representative CTD profiles at seven sites in January of 2023 in the Lagoon.

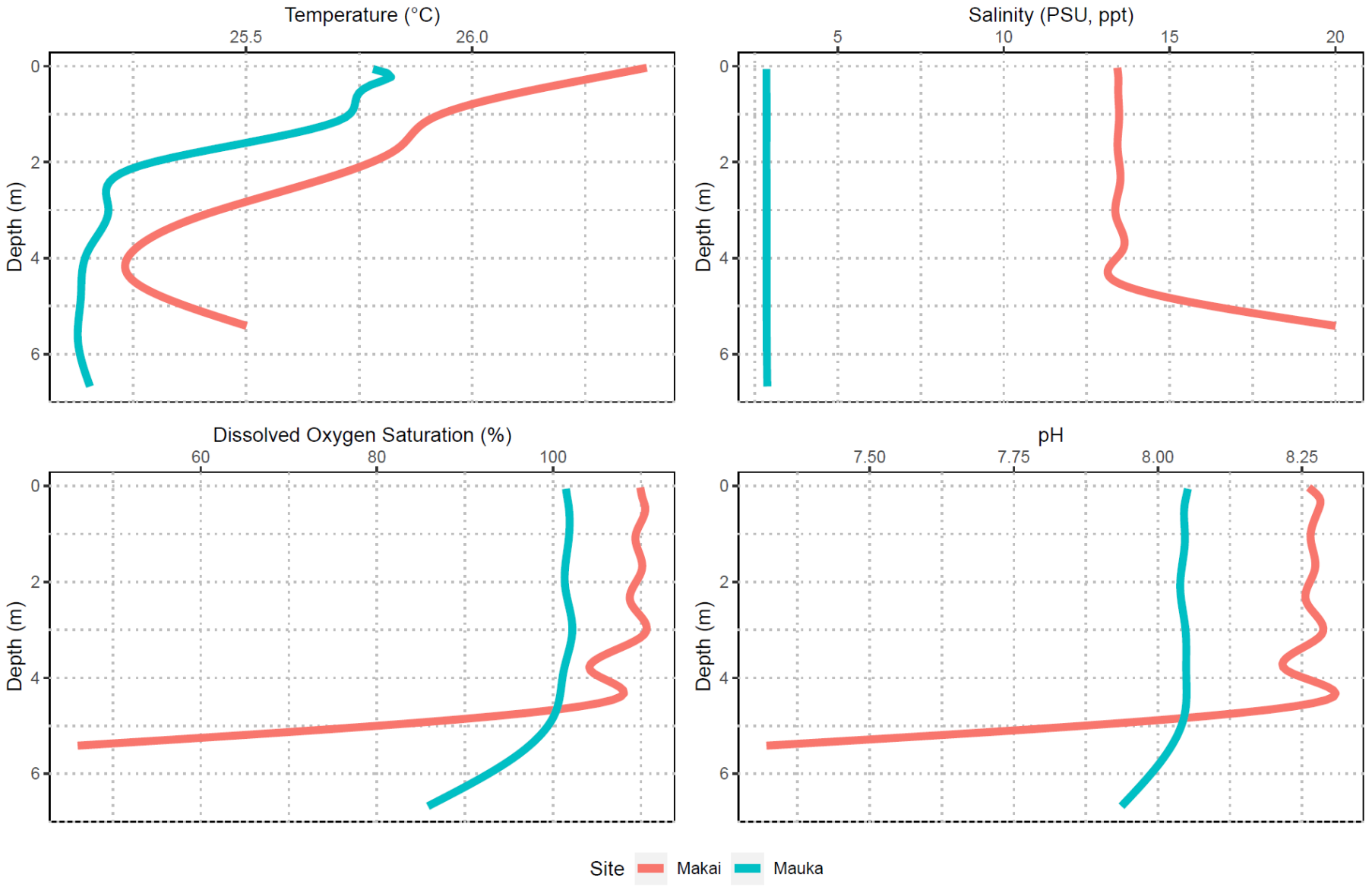

Figure 3. CTD profiles collected from the Mauka and Makai Lakes in January of 2023.

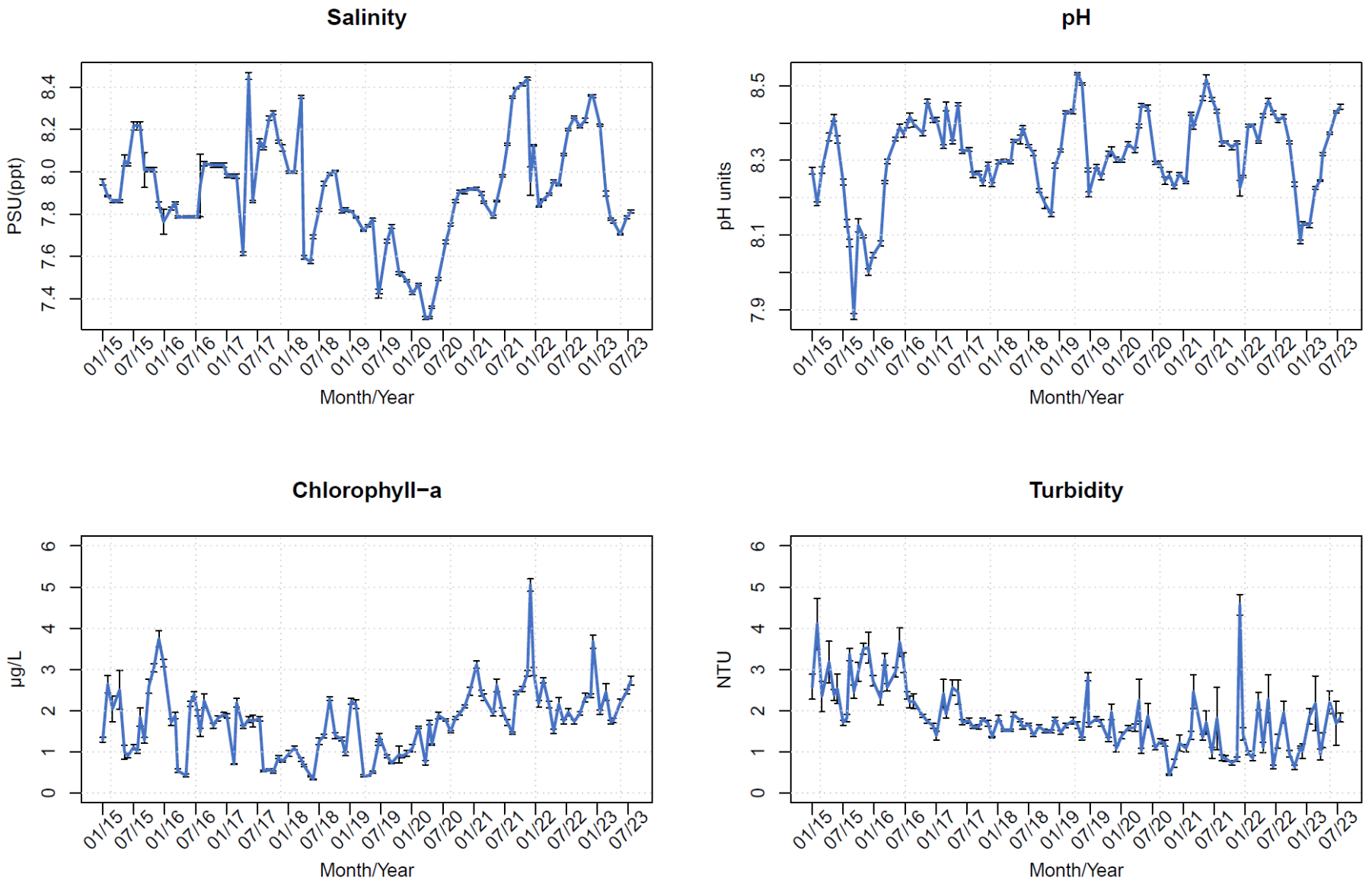

Figure 4. Water quality variables (salinity, pH, Chlorophyll-a, and turbidity) collected from the Lagoon starting in January 2015. Each point represents the average of two depths at six stations. Error bars represent the standard errors.

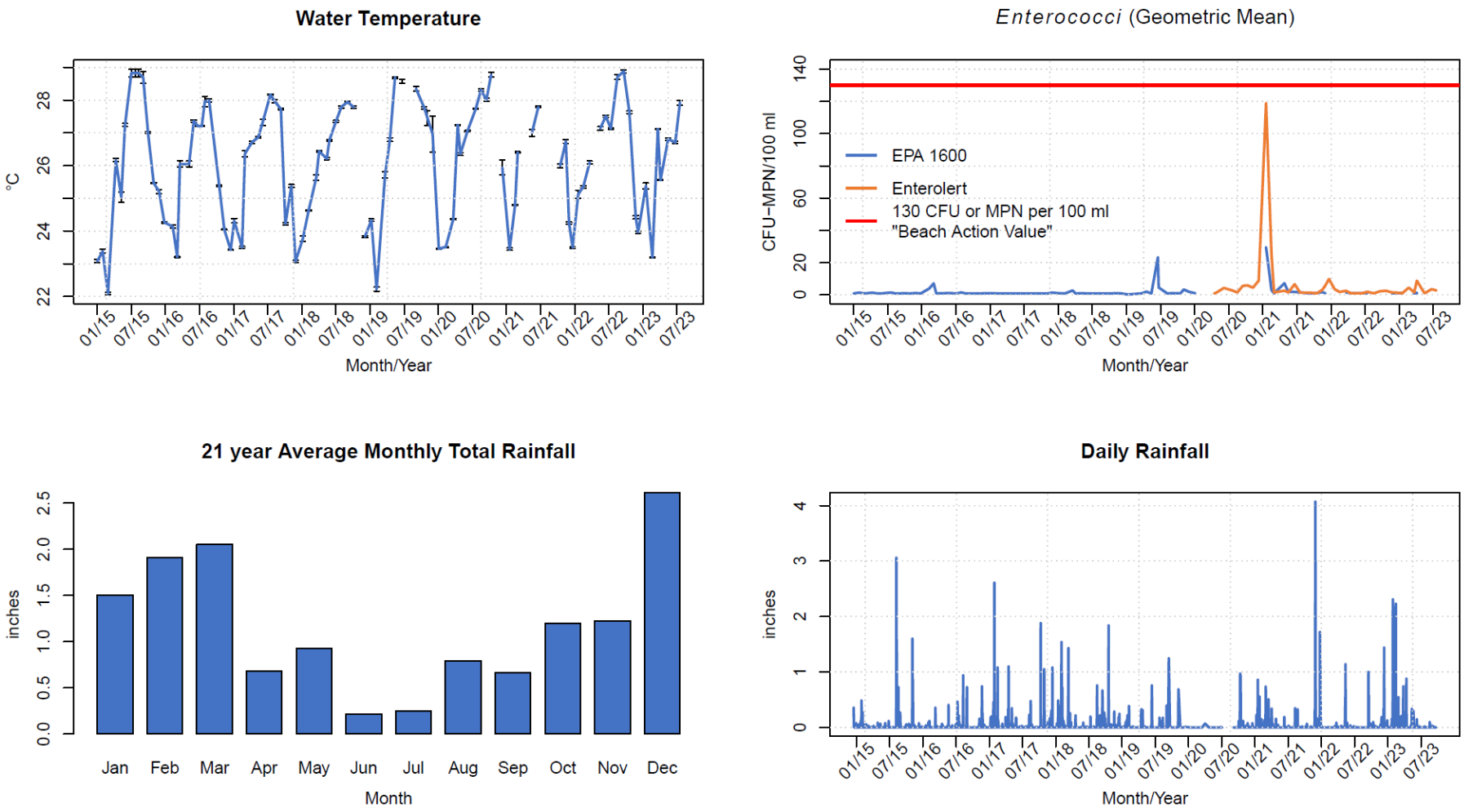

Figure 5. Top Left: Temperature (°C) from CTD profiles at six Lagoon stations. Top Right: *Enterococci* measured with EPA 1600 membrane filtration and Enterolert® methods. The Beach Action Value (BAV) of 130 CFU or MPN per 100 ml is the HDOH Clean Water Branch equivalent of the EPA recommended threshold value and triggers a resampling the next workday and issuance of an advisory until testing indicates action is no longer needed. Bottom: The average rainfall calculated by month over the past 20 years and the daily rainfall since January 2015. Rainfall data from https://www.ncdc.noaa.gov/cdo-web/search for the Kalaeloa airport site.

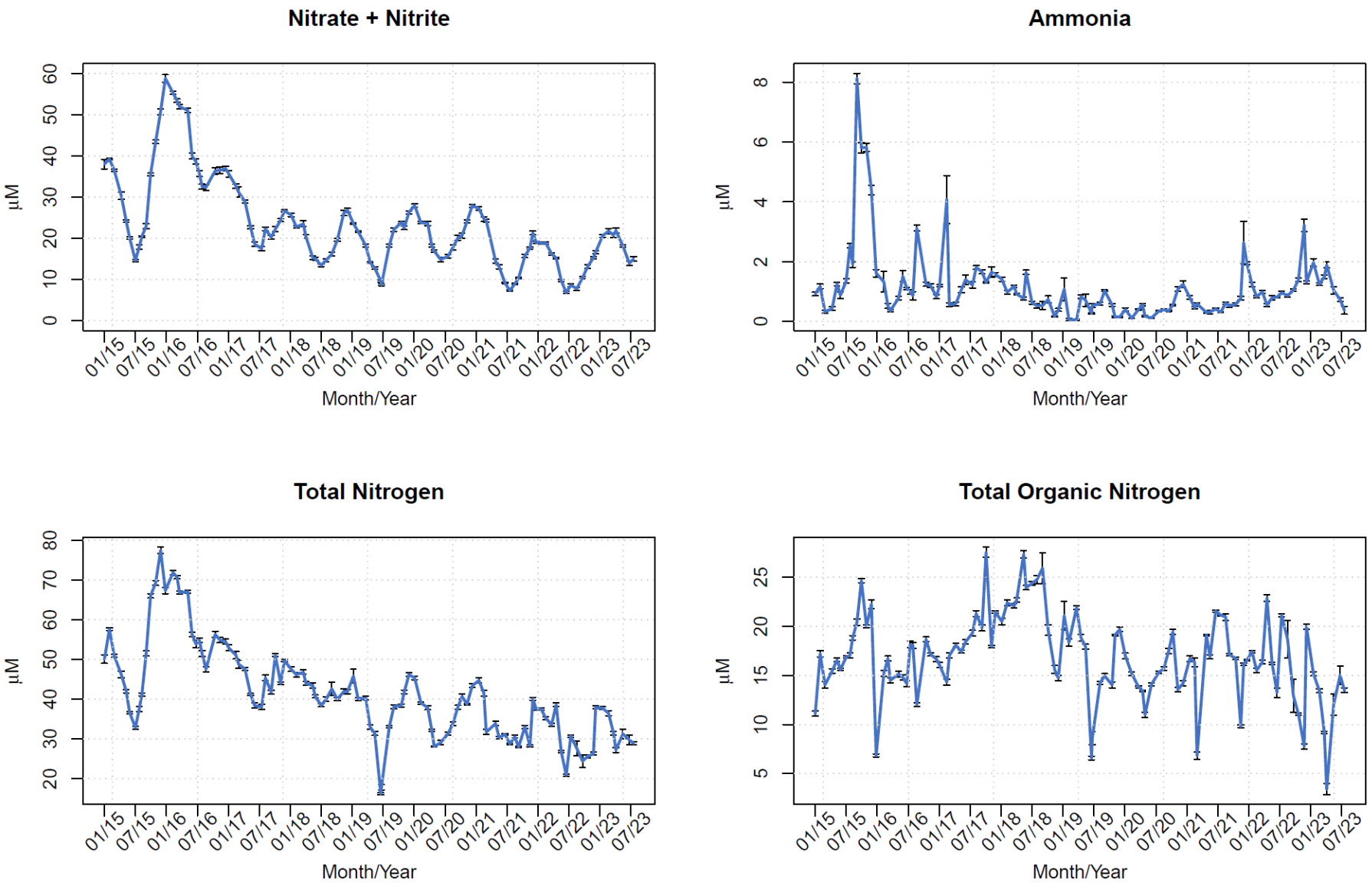

Figure 6: Nitrogen values from the Lagoon starting in January 2015. Each point represents the lagoon average of two depths at six stations. Error bars are standard errors.

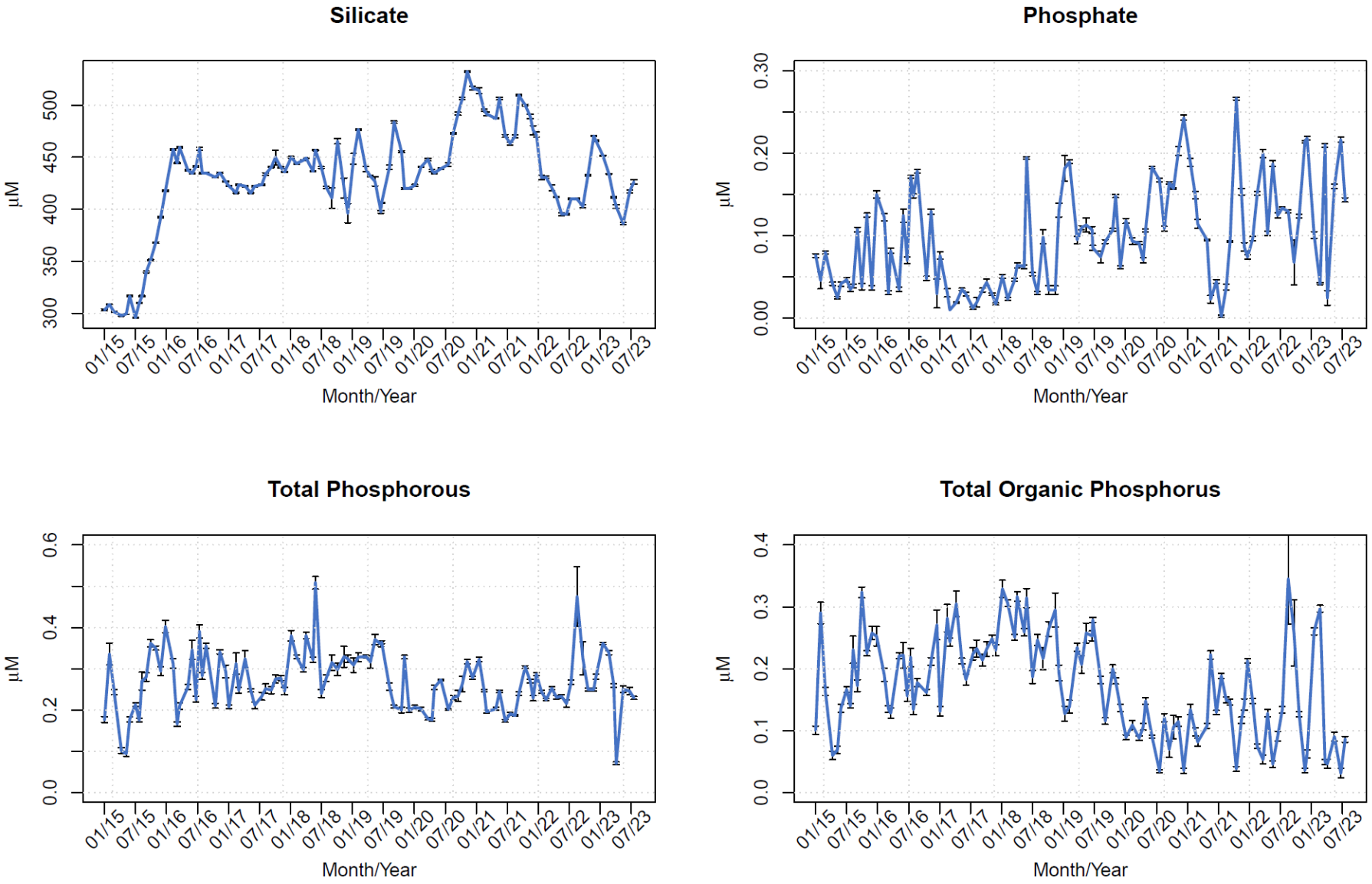

Figure 7: Phosphorus and silicate concentrations from the Lagoon starting in January 2015. Each point represents the average of two depths at six stations. Error bars are standard errors.

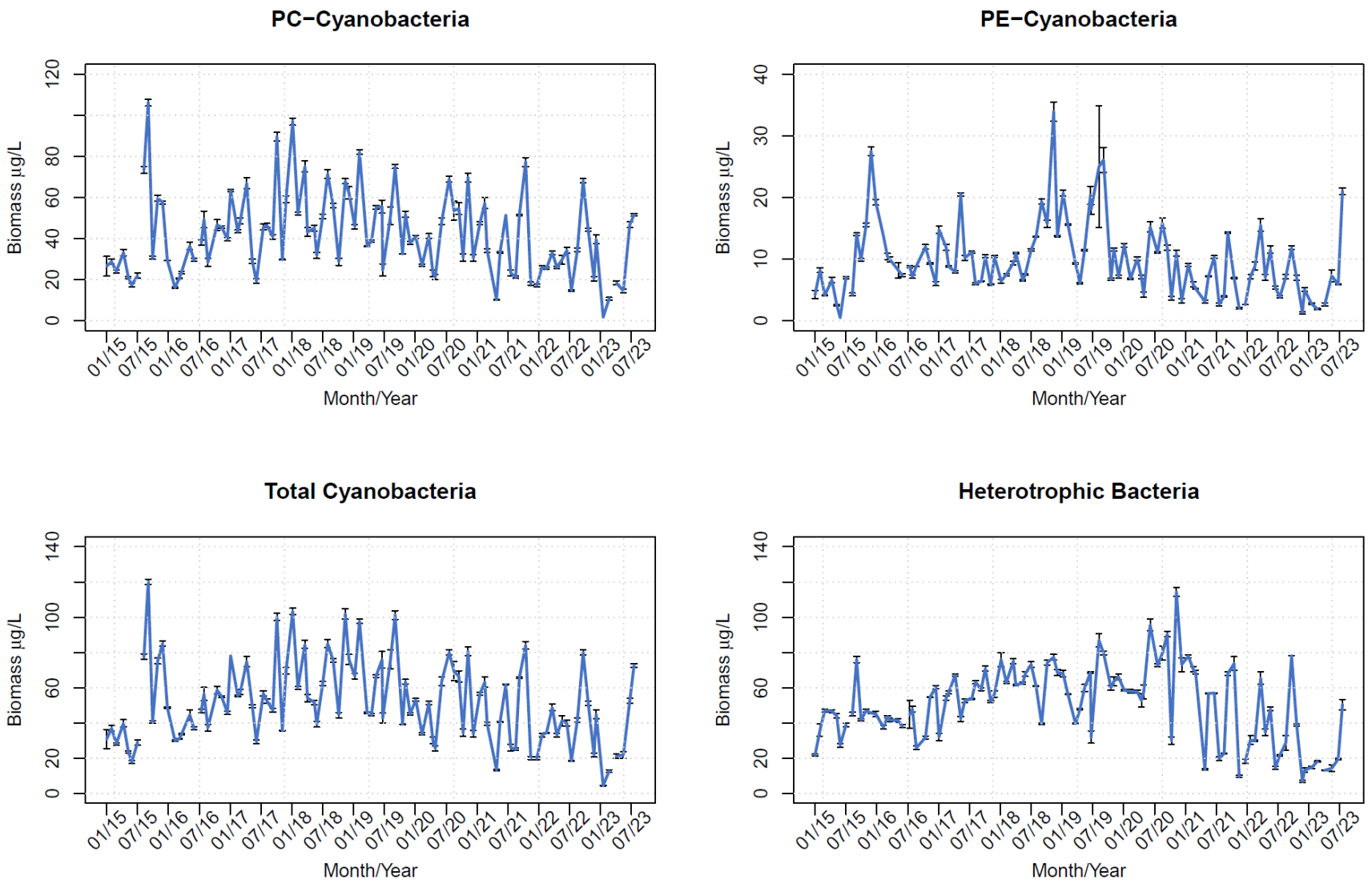

Figure 8: The biomass of picoplankton (< 2 µm) bacterial populations in the Lagoon, both photosynthetic and heterotrophic. Phycocyanin containing cyanobacteria (PC-cyanobacteria) are distinguished from phycoerythrin containing cyanobacteria (PE-cyanobacteria) based on different pigment fluorescence. Bacterial populations are enumerated via flow cytometry at the UH SOEST Flow Cytometry Facility http://www.soest.hawaii.edu/ sfcf/index.htm. Points represent the average of triplicate samples at three stations in the Lagoon. Error bars are standard errors.

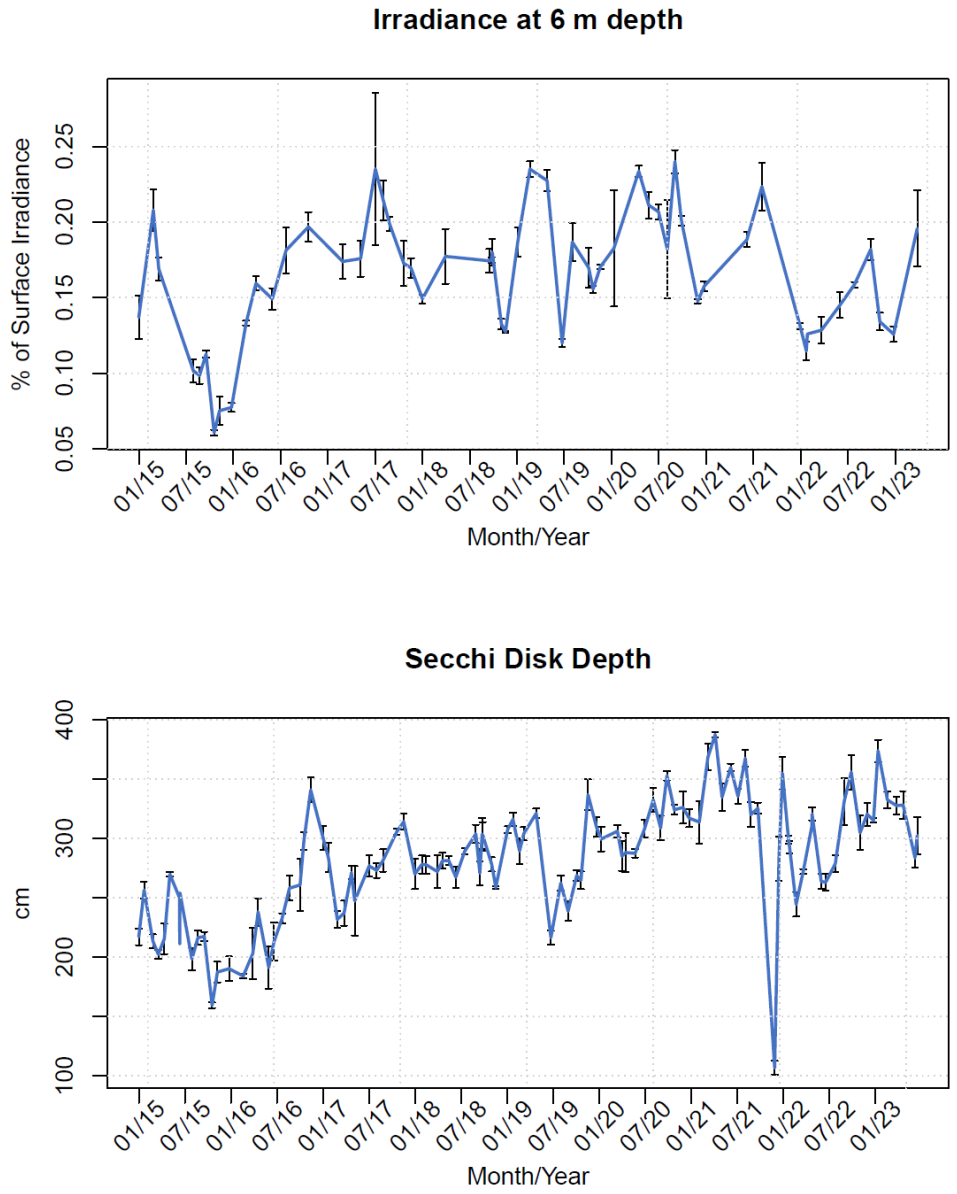

Figure 9: Water clarity in the Lagoon starting in January 2015 as assessed by the percentage of surface irradiance (from 0.01 m) at 6 meters depth and the secchi depth from the surface in cm. Error bars are standard error from 3 sites.

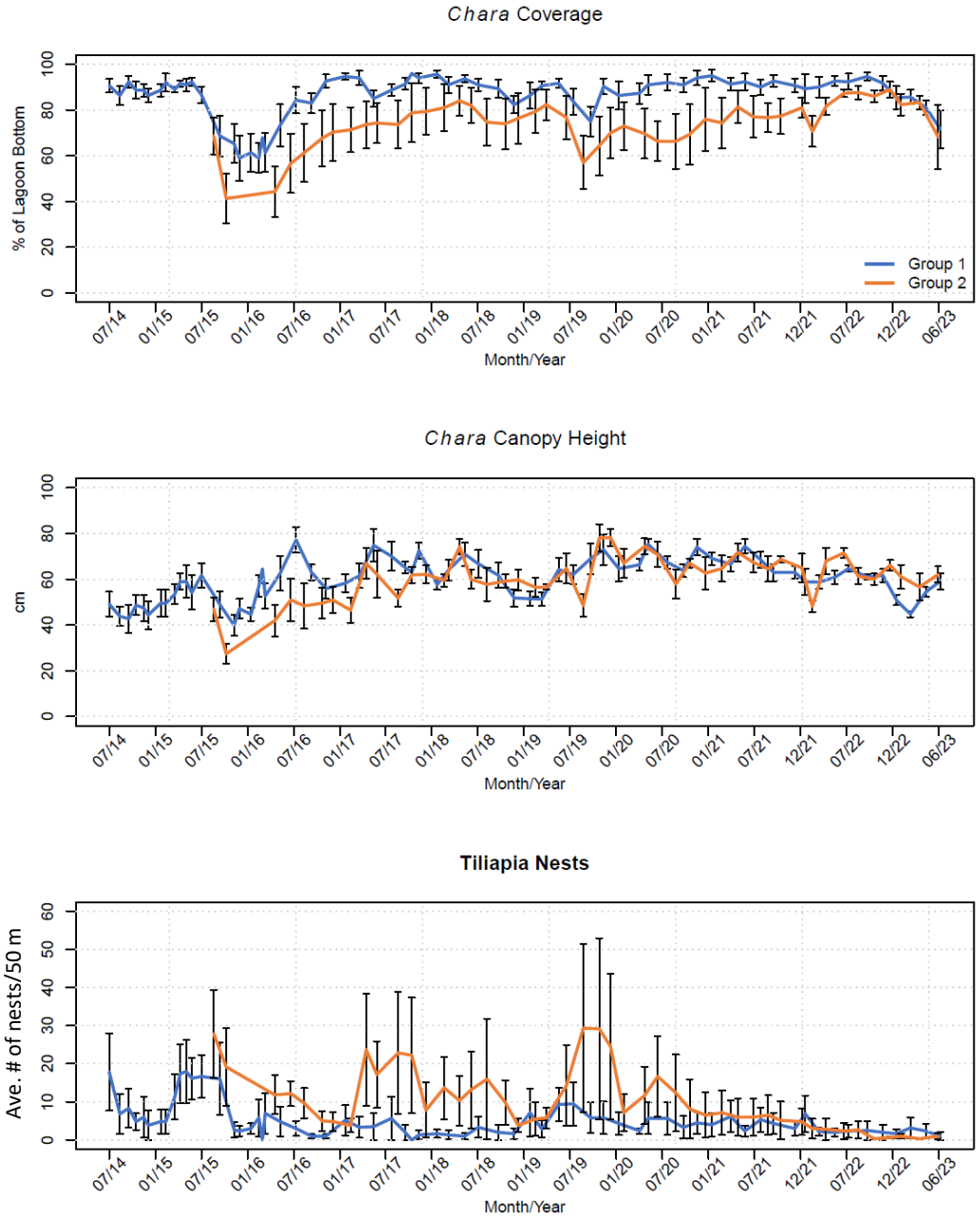

Figure 10: Top: The percentage of the Lagoon bottom covered by *Chara* and the average canopy height of the *Chara* at stations 1, 2, 4, 6, 8, 11 (Group 1) and stations 3, 5, 7, 9, 10, 12 (Group 2). Bottom: The average number of observed tilapia nests in a 1 x 50 m area for the same two groups of stations. Error bars are standard errors.

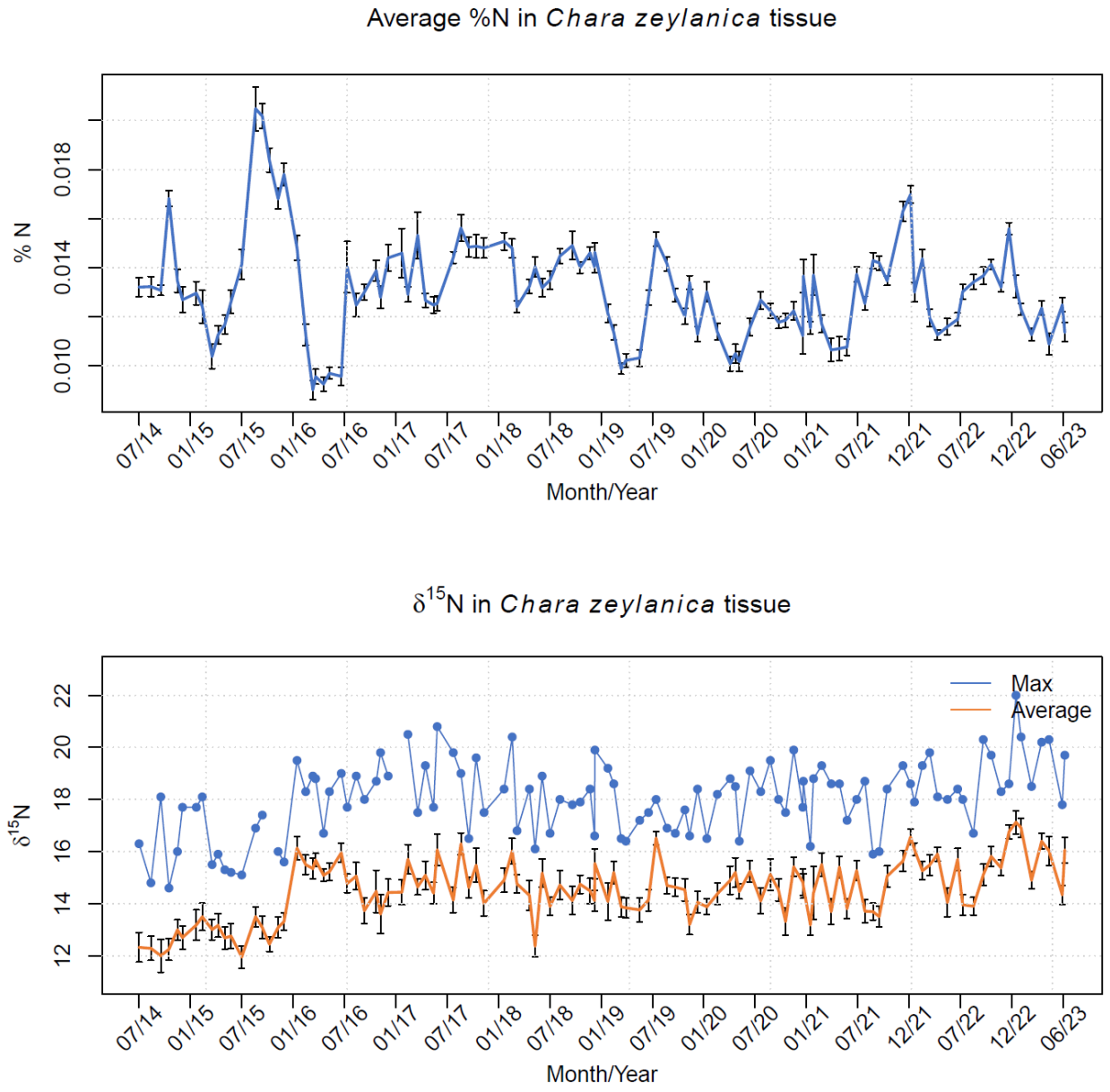

Figure 11: The average percent nitrogen and the maximum and average $\delta^{15}N$ in *Chara* tissue. Error bars are standard errors.

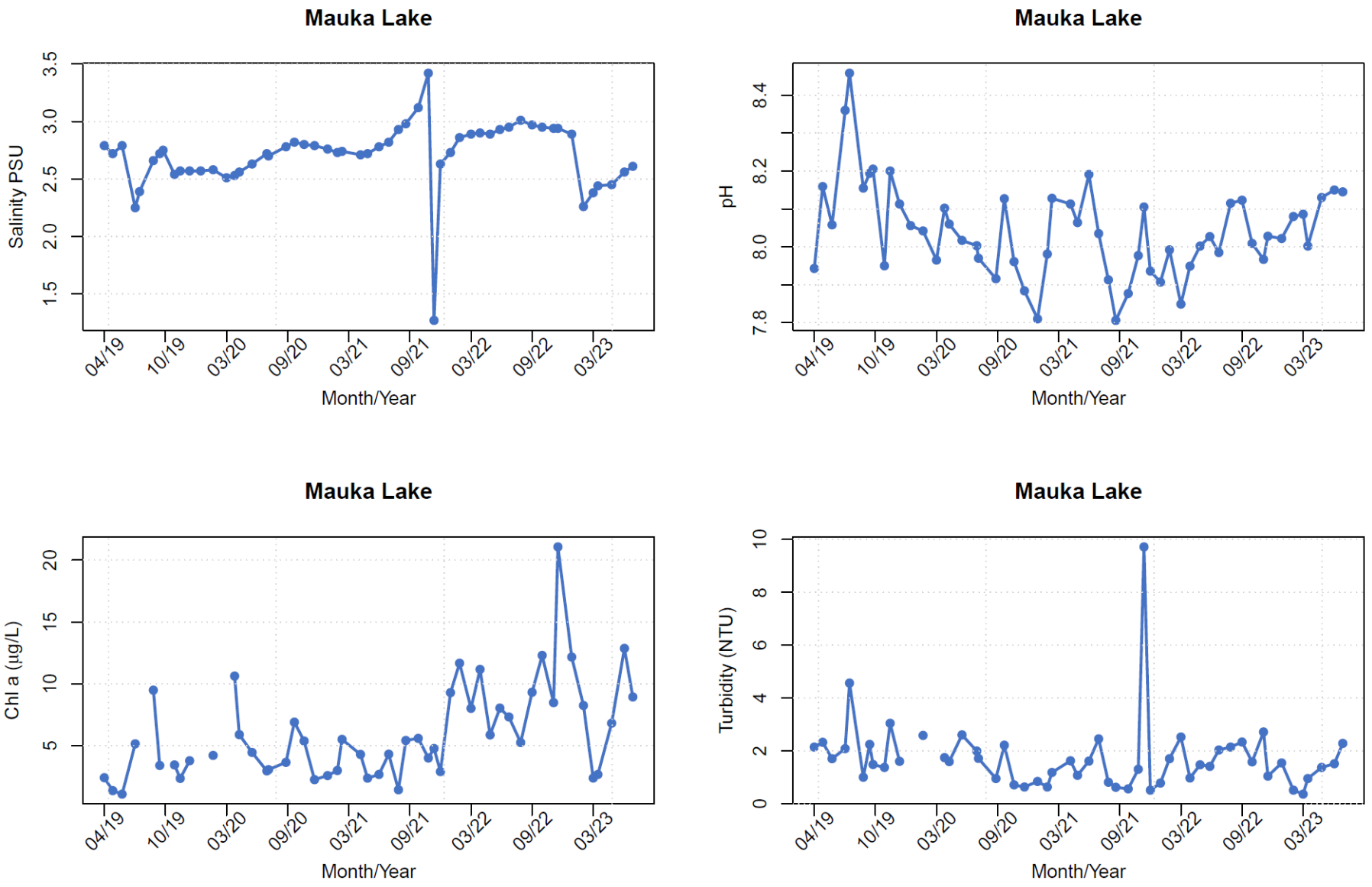

Figure 12: Water quality parameters in the Mauka Lake starting in April 2019. Breaks in the lines reflect gaps in the temporal data.

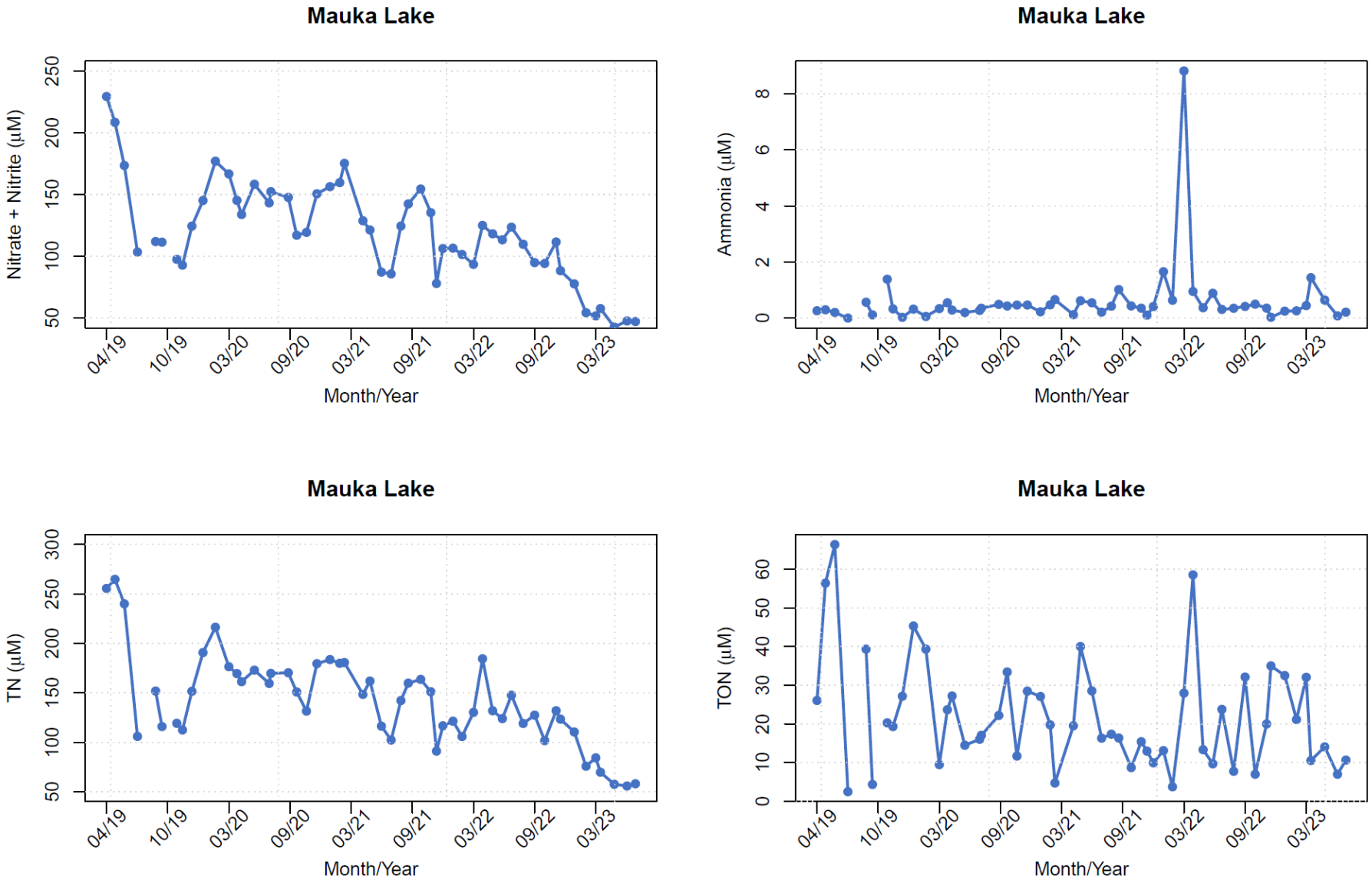

Figure 13: Nutrients in the Mauka Lake starting in April 2019. Breaks in the lines reflect gaps in the temporal data.

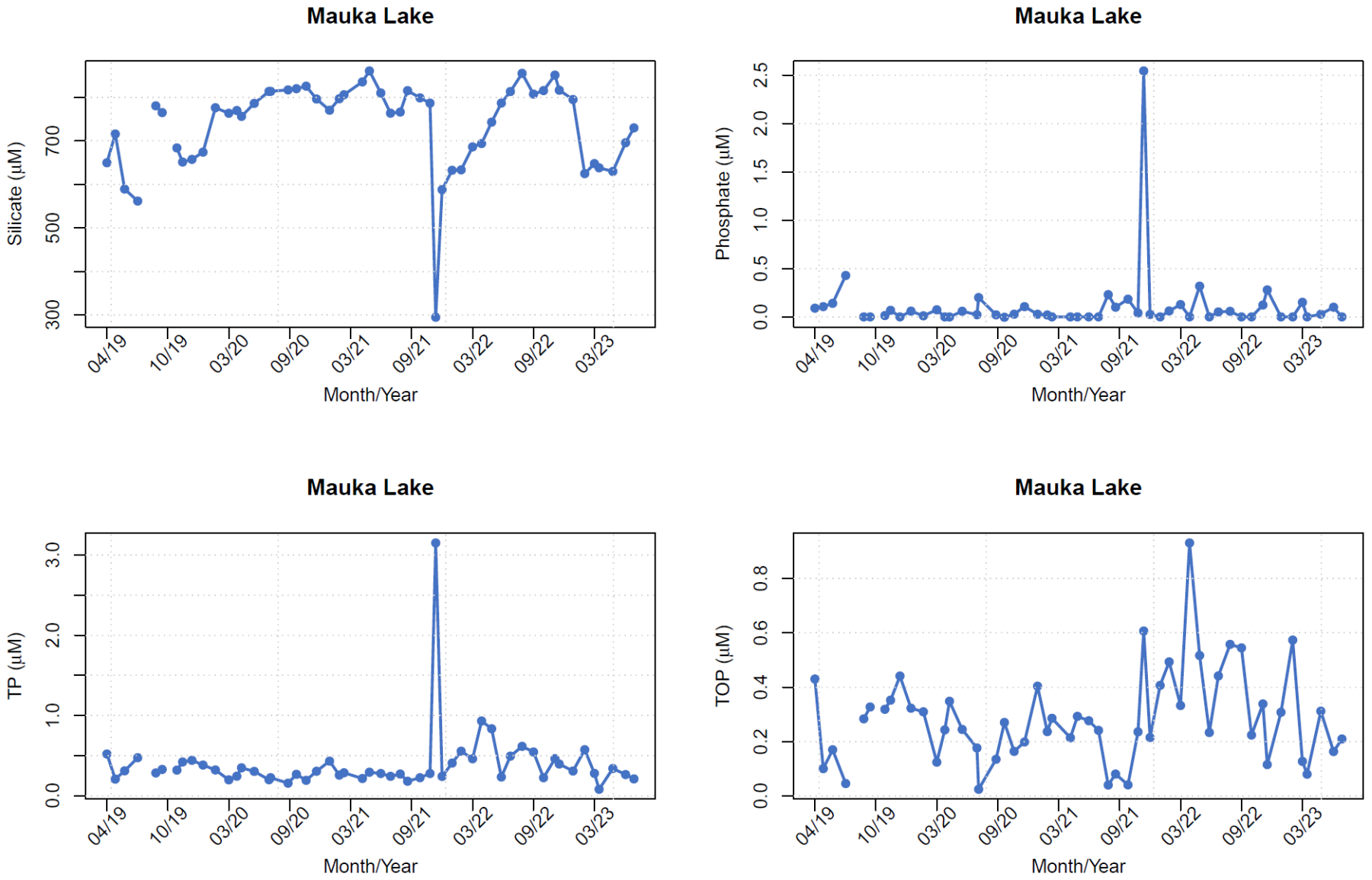

Figure 14: Nutrients and silicate in the Mauka water quality lake starting in April 2019. Breaks in the lines reflect gaps in the temporal data.

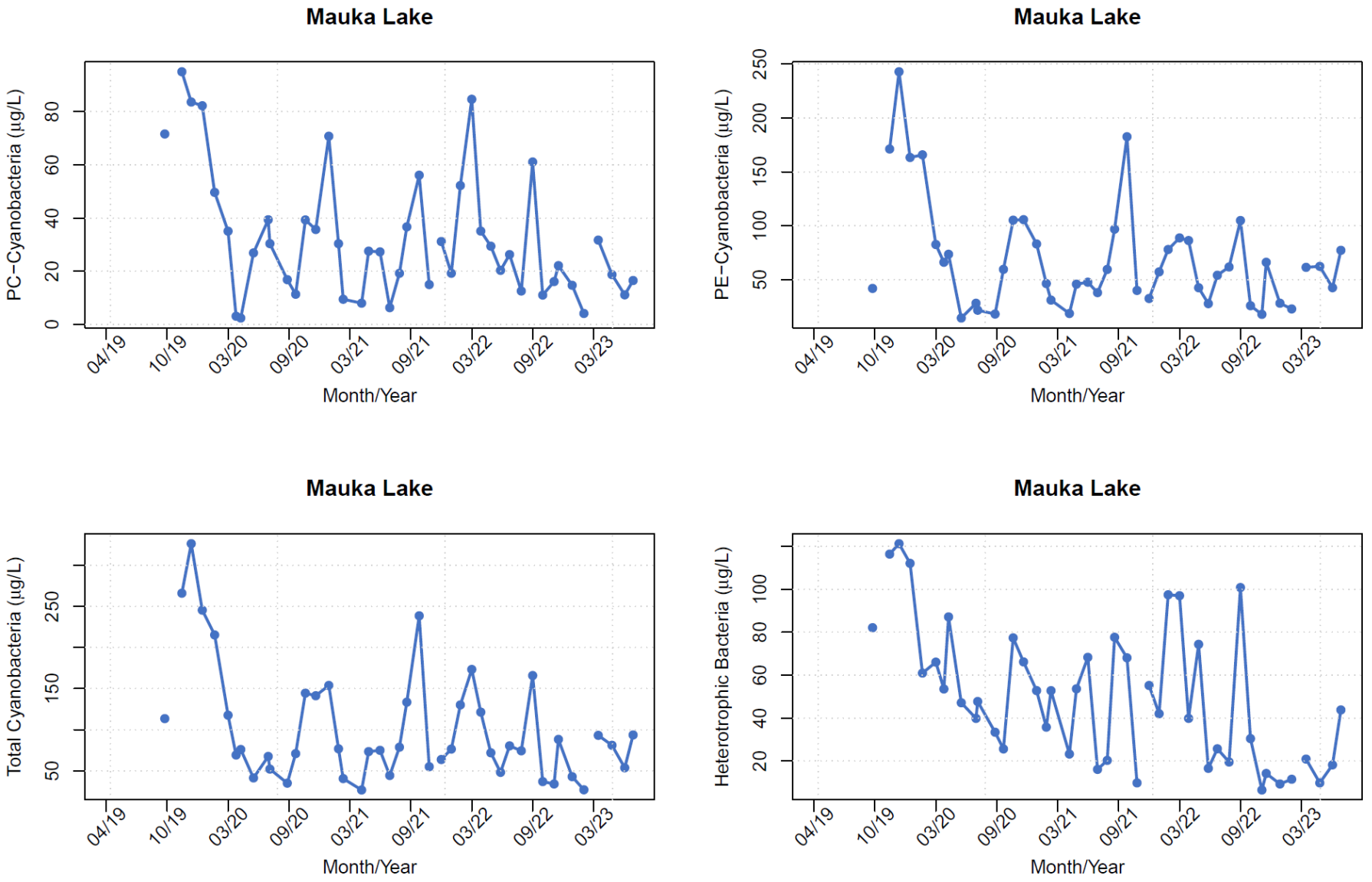

Figure 15: Phytoplankton in the Mauka Lake starting in April 2019. Breaks in the lines reflect gaps in the temporal data.

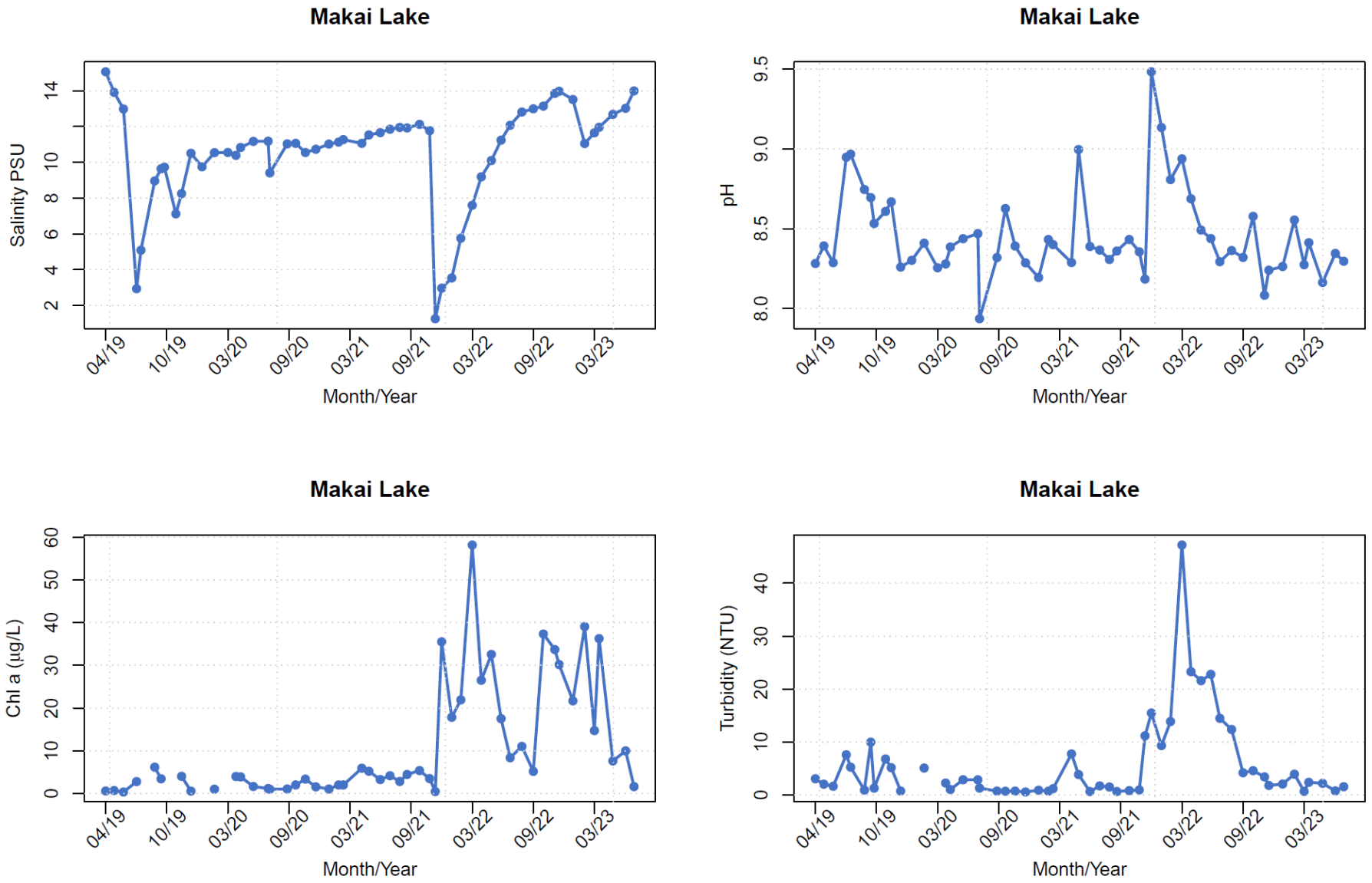

Figure 16: Water quality parameters in the Makai Lake starting in April 2019. Breaks in the lines reflect gaps in the temporal data.

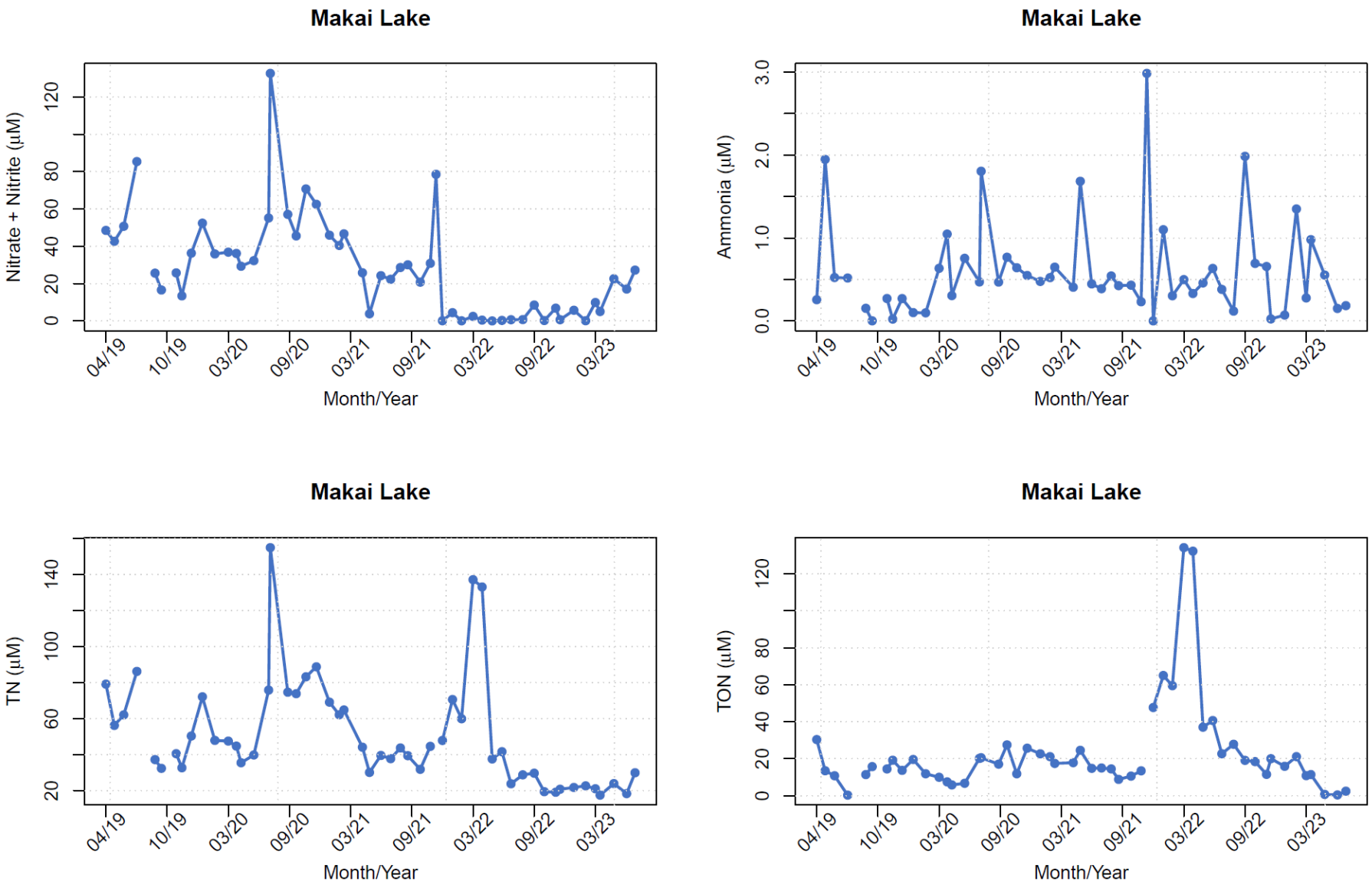

Figure 17: Nutrients in the Makai Lake starting in April 2019. Breaks in the lines reflect gaps in the temporal data.

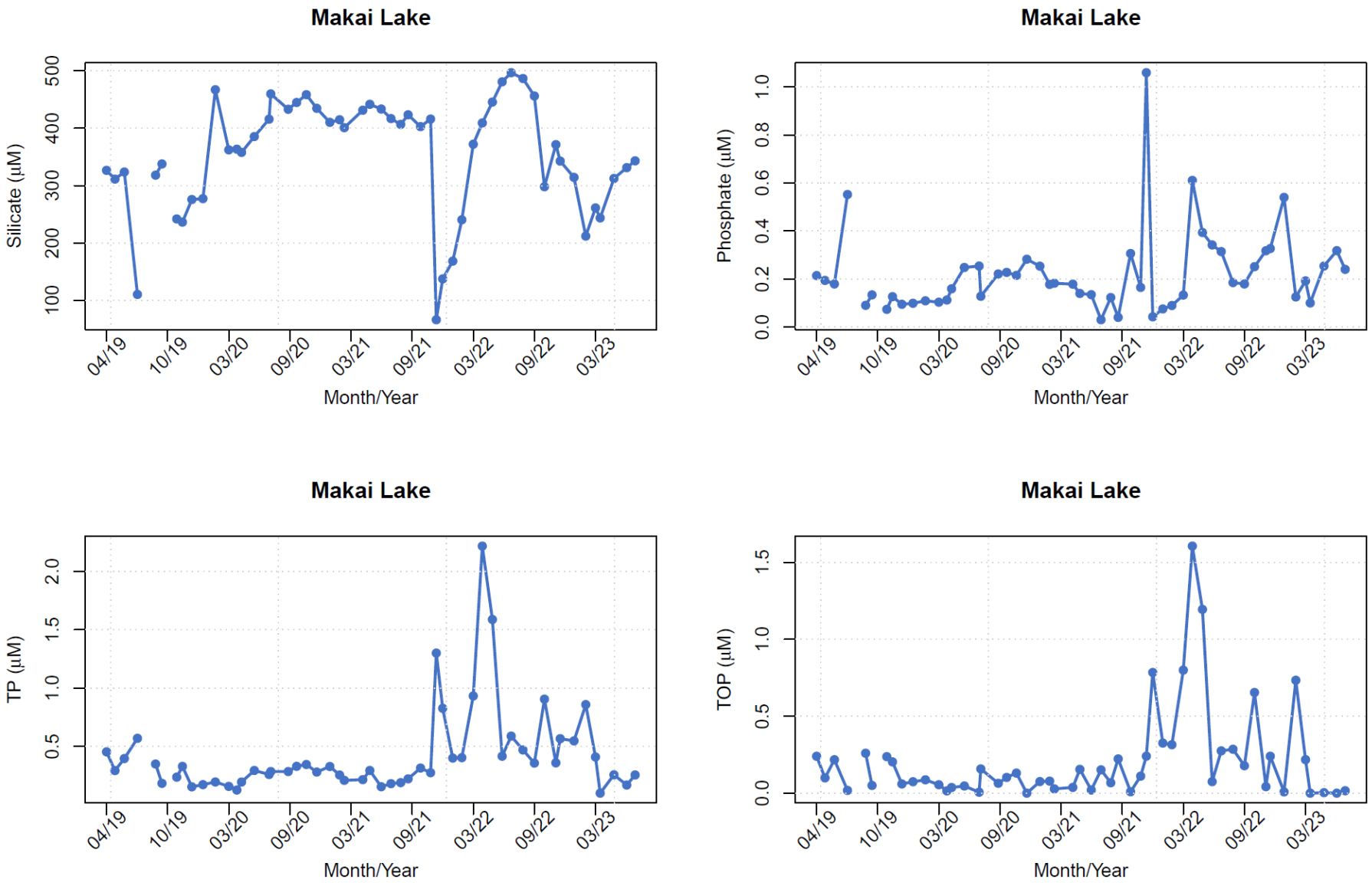

Figure 18: Nutrients and silicate in the Makai Lake starting in April 2019. Breaks in the lines reflect gaps in the temporal data.

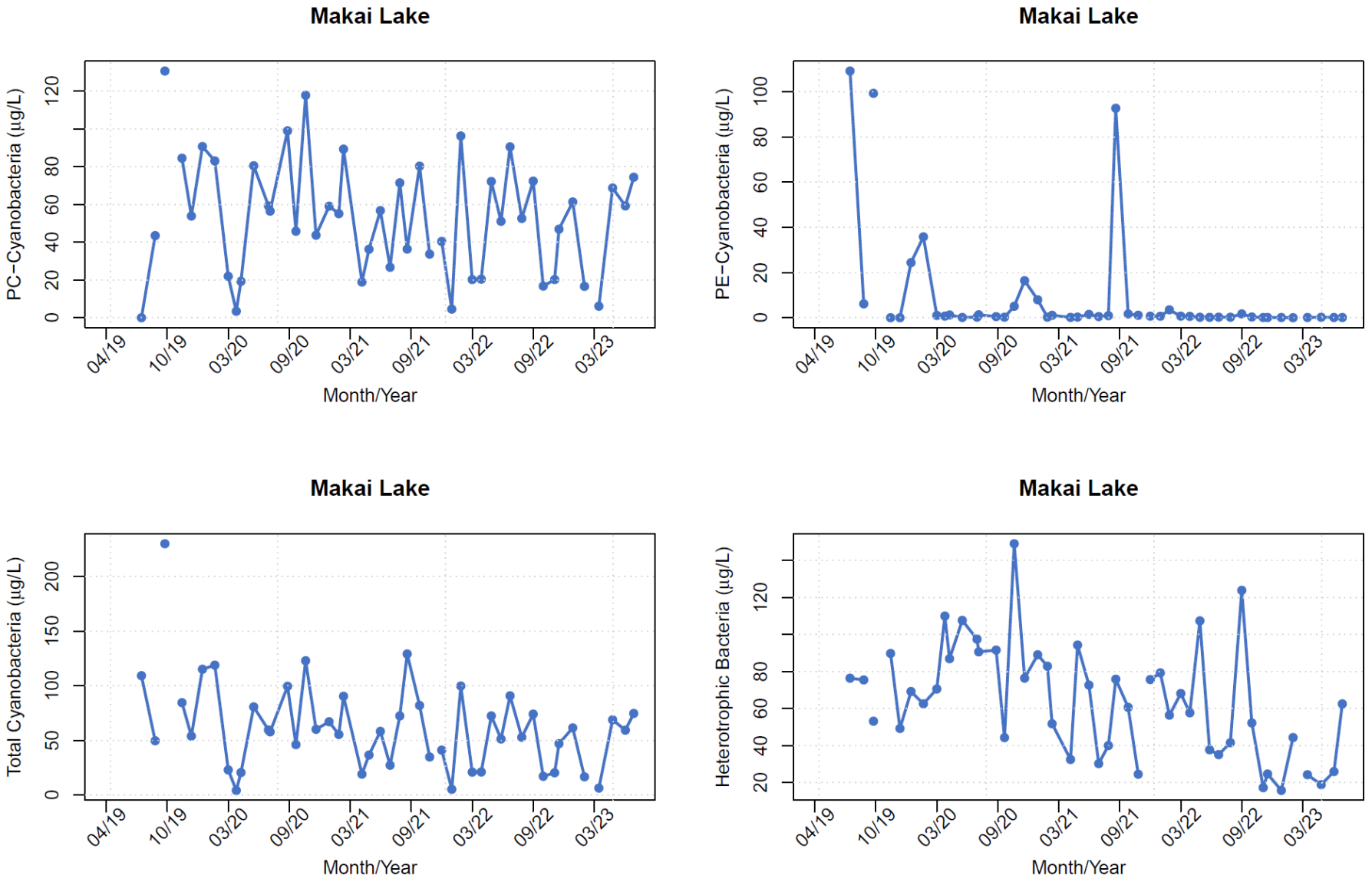

Figure 19: Phytoplankton in the Makai Lake starting in April 2019. Breaks in the lines reflect gaps in the temporal data.