



Freshwater Quality Monitoring in Pinnacles National Park

2011-2012 Biennial Report

Natural Resource Data Series NPS/PINN/NRDS—2013/472



ON THE COVER

An ephemeral tributary flowing into Chalone Creek site CHA1 during a rain event in March 2011.

Photograph by: Katie Booth

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List of Terms

EPA	(United States) Environmental Protection Agency
MPN	Most Probable Number (of colony-forming units per 100 mL)
MQO	Measurement Quality Objectives
NPS	National Park Service
NPSTORET	National Park Service's version of the EPA STORET database
PINN	Pinnacles National Park
QC	Quality Control
RDL	Reporting Detection Limit
RPD	Relative Percent Difference
RWQCB	Regional Water Quality Control Board
SFAN	San Francisco Bay Area Network (of the National Park Service)
SOP	Standard Operating Procedure
STORET	Storage and Retrieval (EPA's water quality database)
TC/EC	Total coliform and <i>E. coli</i>
TKN	Total Kjeldahl Nitrogen
WY	Water Year

Introduction

Background

National Park Service (NPS) *Management Policies* (NPS 2006) state that the NPS will ‘use qualitative and quantitative techniques to monitor key aspects of resources and processes at regular intervals.’ The Inventory and Monitoring (I&M) program was established to help accomplish those policies. Freshwater quality ranks among the most important vital signs being monitored by the San Francisco Bay Area Network (SFAN) I&M Program (Adams et al. 2006). The SFAN monitors freshwater quality in six national park units including Pinnacles National Park (PINN) (Figure 1). In addition, the NPS has a legal obligation to ensure streams meet minimum water quality standards. The California Environmental Protection Agency regulates water quality through the State Water Resources Control Board, which is divided into nine Regional Water Quality Control Boards (RWQCBs). PINN is within the Central Coast RWQCB area. Through Basin Plans, the RWQCBs have set beneficial uses for water bodies and numerical and narrative objectives (also referred to as standards) to meet the uses. There are specific numerical objectives for pH and dissolved oxygen listed by the Central Coast RWQCB; however, there are no established objectives for nitrate, temperature, specific conductance, or turbidity.

The goal of this report is to present data collected from PINN water quality sites during two consecutive water years (WYs) of monitoring. This report presents ranges and summary statistics of physical, chemical, and biological parameters measured at the PINN water quality sites during WYs 2011-2012 (October 1, 2010 – September 30, 2012). Freshwater quality monitoring is conducted under the SFAN Freshwater Quality Monitoring Protocol, which contains a thorough narrative and twelve standard operating procedures (SOPs) describing sampling locations, quality assurance procedures, field and laboratory methods, and data management procedures (Coopridge and Carson 2006).



Figure 1. Map of the San Francisco Bay Area Inventory and Monitoring Network. Pinnacles National Monument became Pinnacles National Park in January 2013.

PINN Monitoring Sites

Ninety-five percent of PINN is located within the Chalone Creek watershed, which eventually drains into the Salinas River, southwest of the park. The Chalone Creek watershed drainage area is approximately 70 square miles; most of the Creek's headwaters are located outside the park boundary. The majority of Chalone Creek (within the park) is intermittent, commonly exhibiting dry conditions for five to six months per year, although some small reaches have water present year-round.

During WY2011, new pig exclusion fencing was completed with the addition of a nine-mile section in the northeastern portion of the park. The eradication of pigs from within the enclosure expansion is expected to provide great benefits to the health of the Chalone Creek watershed, due to the reduction of erosion and trampling, as well as an increase in plant cover. During WY2012, watershed improvements were made to the West Fork of Chalone Creek; multiple structures were removed from the floodplain, the area was restored, and the new West Side Visitor Contact Station facilities were relocated outside of the floodplain. The mainstem of Chalone Creek was monitored during WYs 2011-2012, along with the Bear Gulch, McCabe Canyon, and Sandy Creek tributaries (Table 1 and Figure 2).

Table 1. Freshwater quality monitoring sites within Pinnacles National Park.

Site	Site Type	Flow Regime	Site Description
BG2	Primary	Perennial	Bear Gulch: directly upstream of footbridge, below Resource Management Office Building
CHA3	Secondary	Intermittent	North Fork Chalone Creek: upstream of North Wilderness Trail & Old Pinnacles Trail junction
CHA2	Primary	Perennial	Chalone Creek: upstream of Hwy146 Road bridge
CHA1	Primary	Perennial	Chalone Creek: off of the South Wilderness Trail
SC1	Primary	Intermittent	Sandy Creek: opposite of the weather station pull-out on Hwy 146
SC2	Secondary	Intermittent	Sandy Creek: in Pinnacles Campground, downstream of restrooms, across from campsite #68
SC3	Secondary	Perennial	Sandy Creek: in Pinnacles Campground, down hill from campsite #1 – sampled at left bank
MC1	Primary	Perennial	McCabe Canyon: upstream of Hwy 146, across from the Pinnacles Campground

San Francisco Bay Area Network
Pinnacles Freshwater Quality Monitoring Sites by Watershed

National Park Service
U.S. Department of the Interior

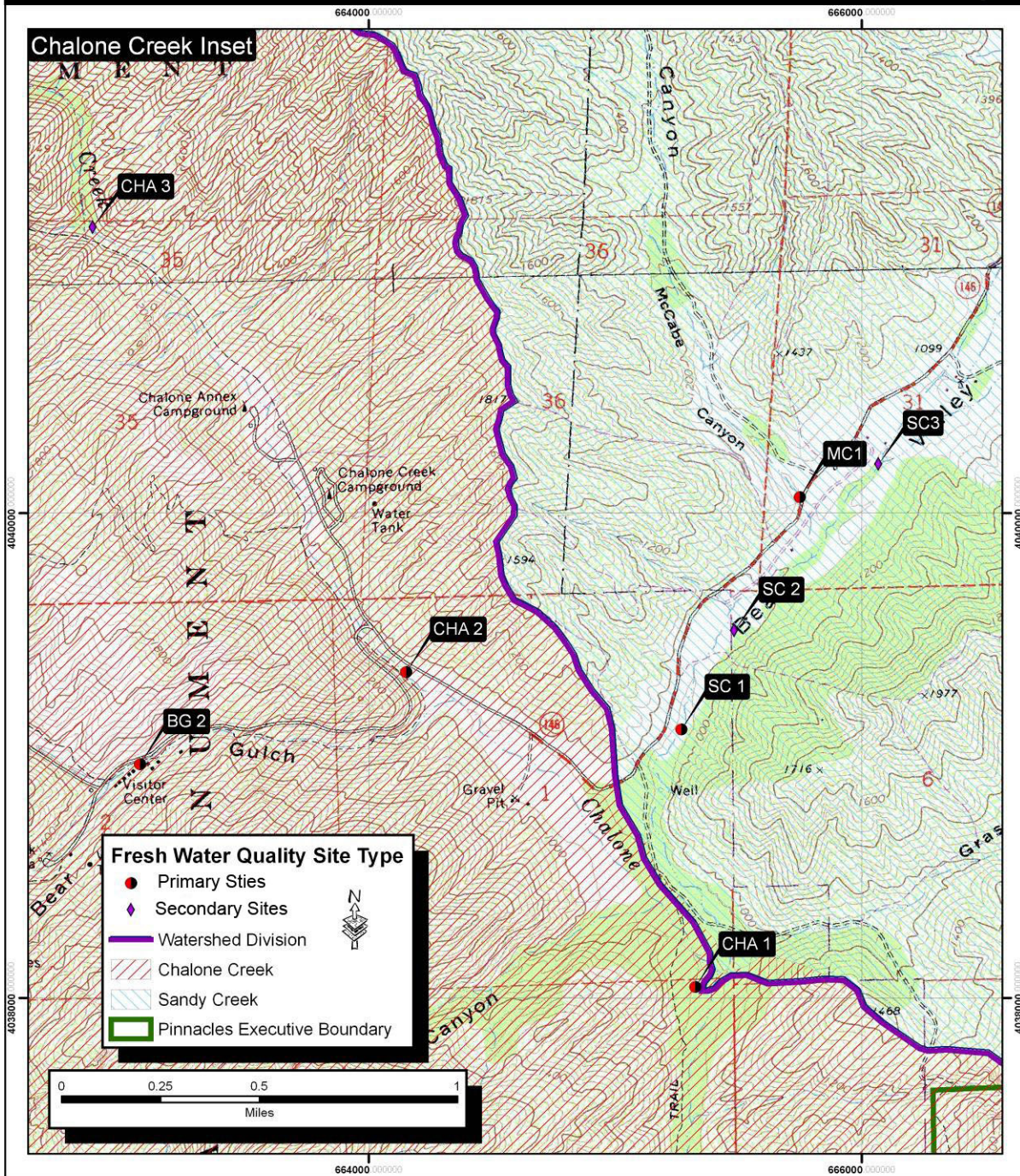


Figure 2. Freshwater quality monitoring sites within Pinnacles National Park.

SFAN Monitoring Objectives for PINN

- Determine variability and long-term trends in water quality through summaries of select parameters (water temperature, pH, conductivity, dissolved oxygen, nitrate, total coliform, and *E. coli*) at selected sites.
- Determine the existing ranges and diurnal variability of water temperature, pH, conductivity, and dissolved oxygen at selected sites in priority streams within PINN.
- Determine the extent that selected sites in priority streams within PINN meet federal and state water quality standards for pathogenic indicator bacteria, dissolved oxygen, and pH, through monthly sampling.

Diurnal variability has not been measured because of significant needs for additional funding, staff time, and continuous monitoring equipment. Additionally, long-term trends can not be studied until there is a larger dataset; this will be evaluated by a statistician after 2014 (when there will be four years of data for every site) to determine the feasibility of trends analysis.

Methods

Water Quality Objectives

In California, through Basin Plans, the RWQCBs have set “numerical and narrative objectives for surface waters” (Table 2). Failure to meet water quality objective maximums will be referred to as exceedances throughout this report. Although temperature, conductivity, and some nutrient parameters do not have applicable water quality objectives, they are important indicators of the effects of urbanization, climate change, atmospheric deposition, and ranching impacts on the region’s streams.

Table 2. Numerical objectives for surface waters in Pinnacles National Park, from the Central Coast Region Basin Plan (CA RWQCB 2011).

Parameter	Water Quality Objective
Dissolved Oxygen	5.0 mg/L minimum
pH	Less than 8.5 and greater than 7.0

In order to assist states with the development of nutrient standards, the EPA undertook nationwide sampling of nutrients in rivers and streams, and developed regional reference values (U.S. EPA 2000). The regional reference values can be used to assess whether nutrients in the SFAN are exceeding expected conditions. The EPA regional reference values for the sub-ecoregion encompassing the SFAN are 0.36 mg/L for total Kjeldahl nitrogen (TKN) and 0.16 mg/L for nitrate (Table 3).

Table 3. Ecoregion III reference values for nutrients (U.S. EPA 2000).

Parameter	Regional Reference Value
Nitrate (NO ₃)	0.16 mg/L
Total Kjeldahl nitrogen	0.36 mg/L

Site Selection

Detailed information about the process used to select SFAN monitoring locations is documented in the SFAN Freshwater Quality Monitoring Protocol (Coopridge and Carson 2006).

Sampling Regime

The sampling design for the SFAN Freshwater Quality Monitoring Program involves a rotating basin approach in which each watershed is monitored monthly for a two-year period. This approach allows the SFAN to collect sufficient samples for each site and watershed, in order to perform statistical analyses, while allowing for sufficient funds to perform laboratory analyses and provide representative data for each site. There are two groups of basins in this design, meaning that every four years, each site and each watershed group will have two years of data

available for analysis. This design is intended to allow for the detection of both short- and long-term trends in all monitored watersheds.

Primary sites ranked as a higher priority during site selection in the protocol development process, while secondary sites were identified to be of a slightly lower priority and could be integrated into the sampling regime only if funding and time allowed. An effort is made to visit each site at approximately the same time of day, once per month, and attempt to capture one storm event per year.

Sample Parameters

The NPS I&M Program calls for required monitoring of all basic level 1 water quality parameters. Required level 1 parameters include a qualitative description of flow, as well as the core parameters (water temperature, dissolved oxygen, pH, and specific conductance) (NPS 2002).

SFAN site visits included the measurement of core parameters and the collection of grab samples for laboratory processing, as well as documentation of air temperature, weather, flow severity, number of days since last rain, and photo monitoring (Table 4). Additionally, a quantitative discharge measurement was made at select sites (established stream gaging stations) when site conditions allowed. All instantaneous measurements and grab samples were collected in the centroid of flow. Samples were analyzed for nutrients (nitrate as nitrogen [as N] and TKN at primary sites only), turbidity, and pathogenic indicator bacteria (total coliform and *Escherichia coli* [*E. coli*]). All water quality sampling followed the methods laid out in the SFAN Freshwater Quality Monitoring Protocol (Coopridge and Carson 2006), manufacturer's equipment manuals, and U.S. Geological Survey guidance.

Table 4. SFAN water quality monitoring parameters.

Parameter Group	Specific Parameters
Core	Water temperature, dissolved oxygen, pH, and specific conductance
Bacteria	Total coliform & <i>E. coli</i> at all sites, fecal coliform at Olema Creek sites only
Sediment	Turbidity
Nutrients	Total Kjeldahl nitrogen (TKN) and nitrate (as N)
Discharge	Qualitative flow description (& quantitative stream discharge at select sites)

Table 5 lists the processing methods used for all parameters. Core parameter data were collected in-situ, using a YSI ProPlus (Professional Series) multiprobe sonde. The IDEXX Quanti-Tray system was installed at PORE's Pacific Coast Science and Learning Center in January 2007; all total coliform, *E. coli*, and turbidity samples were processed by SFAN staff at this location. All nutrient samples were processed by Analytical Sciences LLC, in Petaluma, CA.

Table 5. Water quality testing methods used in the SFAN.

Parameter	Method
Core parameters	Instantaneous readings collected in the centroid of flow with a multiprobe sonde
Total coliform bacteria	Enzyme substrate coliform test: standard method 9223B using IDEXX Quanti-Tray 2000 with colilert reagent
<i>E. coli</i> bacteria	Enzyme substrate coliform test: standard method 9223B using IDEXX Quanti-Tray 2000 with colilert reagent
Nitrate (as N)	EPA method 300 [detection limit: 0.15 mg/L]
TKN	Standard method 4500-Norg C [detection limit: 0.25 mg/L]
Turbidity	Hach 2100P portable turbidimeter
Discharge	Methods from the SFAN Streamflow Monitoring Protocol, using a SonTek FlowTracker ADV, Marsh-McBirney Flowmate, or volumetric discharge method (Fong et al, 2011).

Data Handling and Analysis

All data were entered into NPSTORET (housed at PORE), which is the database created and provided by the NPS Water Resources Division. These data are periodically uploaded to the EPA STORET database that allows for public access.

Water quality data contain many values that can not be quantified, but are known to be above or below a certain threshold (e.g., reporting limit, detection limit, quantification limit, etc.); these data are considered censored during statistical analysis (Helsel 2005). The SFAN nutrient results are often reported as ‘ND’ (non-detect), meaning that the value is not defined as zero, but is only known to be less than the reporting detection limit of that particular method. The SFAN bacteria results can be censored on either end (producing results above or below the quantifiable range), which further complicates data analysis. A study by the USGS (Antweiler and Taylor 2008) evaluated the main classes of statistical treatment of censored environmental data, and found that the nonparametric Kaplan-Meier method was the most effective technique for overall determination of summary statistics for datasets with less than 70% censoring; the Kaplan-Meier statistical method was used (through the NPSTORET database) to create summary statistics and figures for all censored SFAN data.

Quality Control

Field equipment was calibrated at the beginning of each sampling day: a three-point calibration was performed for all pH sensors, a one-point calibration was performed for specific conductance, and dissolved oxygen was calibrated with the water-saturated air method (one-point). Calibration checks were performed immediately following each calibration, and again at the end of the field day, in order to monitor for fouling and drift, and to ensure that the instruments stayed within the calibration acceptance criteria of each parameter. If any parameter failed a post-field drift check, all corresponding results from that entire field day were thrown out.

In order to assess precision, 10% of all samples were collected in duplicate. Additionally, trip blanks (distilled water) were collected and submitted for laboratory analysis, in order to detect

and locate possible sources of contamination. Laboratory quality control (QC) measures included matrix spikes, method blanks, laboratory control spikes and use of a variety of calibration standards. All data that were entered into NPSTORET were verified by an alternate staff person.

Measurement Quality Objectives

The SFAN has established measurement quality objectives (MQOs) for all monitored parameters. There are MQOs for calibration acceptance, precision, and systematic error (percent recovery). Measurement of systematic error (reported as percent recovery) represents the accuracy of the laboratory procedures and equipment, which is determined by conducting matrix spikes or laboratory control spikes, to test a known value of a particular analyte. The MQO for systematic error (percent recovery) is 70-130% for TKN, and 75-125% for nitrate (as N). The professional laboratory contracted by the SFAN did not report any QC results that were outside of these acceptable ranges.

The MQOs for precision are defined in the SFAN Freshwater Quality Monitoring Protocol as the acceptable thresholds of relative percent difference (RPD), calculated from the duplicated QC sample sets. The precision MQO for nitrate (as N) and TKN is +/- 30% (RPD), while the MQO for total coliform and fecal coliform is +/- 60% (RPD); an MQO was not established for *E. coli*, but it can be assumed to be 60% as well. A precision analysis will be presented in the SFAN Freshwater Quality WY 2011-2012 Biennial Report.

Results and Discussion

This report includes results collected from PINN during WYs 2011 and 2012, the fifth and sixth years of protocol implementation. Due to the two-year rotating basin design of this protocol, the WY 2011 and 2012 data represent the third and fourth years of monitoring this specific rotation for the network. While it is not yet possible to observe long-term trends, the data can be viewed in the context of established water quality objectives, ecological objectives, and regional reference values established by the EPA.

Routine monitoring visits took place monthly, at approximately the same time of day, and an effort was made to collect storm samples from every site during each water year. One storm sampling event was conducted in PINN during WY 2011. Three sites in PINN (CHA3, SC2, and SC1) were too low for sampling at least once during the dry season, so the summary statistics are computed from smaller datasets.

Summary statistics for WYs 2011-2012 are presented in the following sections, organized by parameter. All calculations, results, and statistics discussed in this report are from these two water years as a whole, not individually. All means and standard deviations presented in tables are rounded to one more decimal place than the least precise value (least number of decimal places) of each corresponding dataset (Sullivan 2011).

Core Parameters

Water temperature, dissolved oxygen, pH, and specific conductance are defined as core parameters in the SFAN Freshwater Quality Monitoring Protocol; these are all interrelated, and describe the most basic level of water chemistry. Thorough knowledge of these parameters is needed in order to better understand the nutrient and bacteria data collected. Core parameters are measured in-situ during every site visit, alongside each grab sample collection.

Summary statistics of all PINN core parameter results from WYs 2011-2012 are displayed in detail in Table 6; however, box and whiskers plots of these data are displayed separately (sorted by parameter) for simplified viewing. Turbidity data are included at the end of this section, although not defined as a core parameter in the SFAN Protocol.

All summary statistics are based on instantaneous measurements routinely collected at approximately the same time of day on each visit; therefore, the data in the tables and figures presented do not reflect the true minimum and maximum values of diurnal variation.

Table 6. Core parameter results from Pinnacles National Park (water years 2011-2012). (Std. dev. = standard deviation. N of obs. = number of observations.) All means and standard deviations are rounded to one more decimal place than the least precise value (least number of decimal places) of each corresponding dataset.

Parameter	Statistic	BG2	CHA3	CHA2	CHA1	MC1	SC3	SC2	SC1
Water temperature (°C)	Mean	12.26	10.61	12.22	14.33	15.18	13.72	10.78	12.86
	Median	11.7	10.0	11.3	14.8	15.2	15.0	10.5	13.8
	Minimum	7.0	6.1	5.3	10.7	7.7	6.8	3.1	4.6
	Maximum	16.3	17.0	16.1	16.9	21.7	18.7	18.1	19.6
	Std. dev.	2.69	3.13	2.74	1.78	3.97	3.32	3.98	4.21
	N of obs.	24	13	24	24	24	24	19	18
Dissolved oxygen (mg/L)	Mean	7.071	6.743	7.854	4.605	9.182	9.172	3.753	10.510
	Median	7.43	7.22	7.55	4.20	9.06	9.19	3.67	10.29
	Minimum	3.39	0.84	6.74	0.80	7.56	7.46	0.90	8.01
	Maximum	11.66	12.14	11.35	11.05	10.99	10.75	6.75	14.15
	Std. dev.	2.105	3.739	1.139	2.589	0.975	0.781	1.685	1.887
	N of obs.	24	13	24	24	24	24	19	18
pH (pH units)	Mean	7.258	7.316	7.394	7.050	7.838	8.088	7.341	8.215
	Median	7.24	7.31	7.38	7.04	7.82	8.08	7.39	8.27
	Minimum	6.73	6.84	7.21	6.82	7.67	7.93	7.04	7.59
	Maximum	7.63	7.85	7.68	7.50	8.35	8.19	7.77	8.60
	Std. dev.	0.219	0.267	0.111	0.150	0.155	0.062	0.187	0.241
	N of obs.	21	10	21	21	21	21	16	15
Specific conductance (µS/cm)	Mean	258.50	355.40	324.20	502.00	217.60	794.20	952.30	717.50
	Median	303.4	353.4	340.4	510.3	209.9	815.0	967.0	780.0
	Minimum	36.0	167.0	69.6	92.0	140.1	343.0	395.0	285.0
	Maximum	365.1	434.9	511.2	700.0	344.9	1033.0	1198.0	953.0
	Std. dev.	93.30	68.87	118.60	153.40	60.65	177.90	181.80	215.80
	N of obs.	23	12	23	23	23	23	18	17
Turbidity (NTU)	Mean	3.25	3.14	1.48	5.63	83.5	2.070	3.69	27.91
	Median	1.26	1.27	0.66	1.65	80.3	1.89	2.34	20.9
	Minimum	0.31	0.52	0.22	0.50	55.4	0.41	1.05	2.05
	Maximum	25.7	15.4	14.6	40.5	145	5.93	11.5	72.6
	Std. dev.	5.30	4.20	2.90	9.36	23.4	1.299	3.05	16.36
	N of obs.	24	13	24	24	24	24	19	17

Water Temperature

There is not an established water quality objective for water temperature in SFAN streams. During WYs 2011-2012, six of the seven highest mean temperatures in the SFAN were found at PINN sites. The PINN sites exhibited the widest range of results and the majority of the highest water temperature recordings in the SFAN (Figure 3). After 2014, these results will be compared with data from other water years, in an attempt to identify any trends in water temperature at PINN.

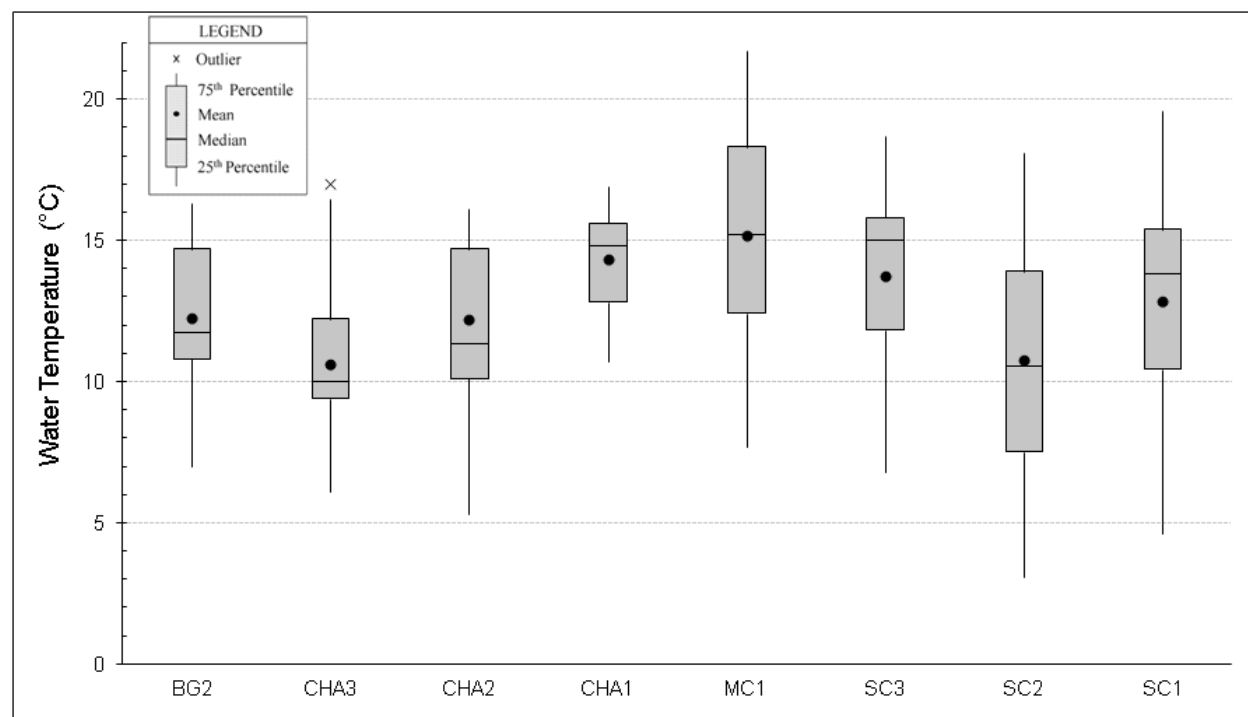


Figure 3. Water temperature results from Pinnacles National Park (water years 2011-2012). Boxplots present the interquartile range of each dataset; whiskers are drawn to 1.5 times the interquartile range.

Dissolved Oxygen

The Central Coast RWQCB established a dissolved oxygen minimum of 5 mg/L, which applies to the eight PINN sites. During WYs 2011-2012, 14% of all SFAN dissolved oxygen results (91 of 652) failed to meet their respective objectives; the majority of these failures were from PINN sites. Dissolved oxygen means were above the water quality objectives for every SFAN site, except for SC2 and CHA1 (PINN sites).

The PINN dataset had the highest failure rate in the SFAN (when compared to the minimum objective of 5 mg/L). Twenty-four percent of the PINN results (41 of 170) failed to meet this objective during WYs 2011-2012; however, all of these low levels were found at four sites, while the other half of the sites (CHA2, MC1, SC3, and SC1) exhibited consistently high dissolved oxygen readings during each monthly visit of WYs 2011-2012 (Figure 4).

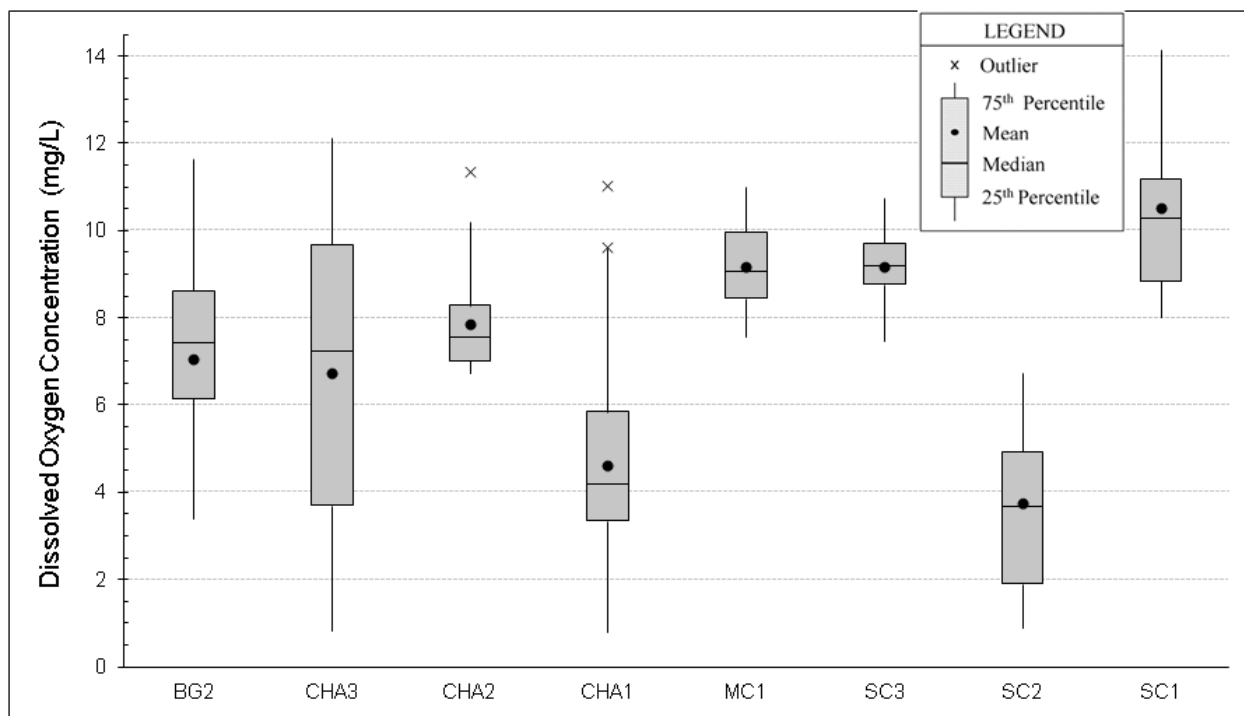


Figure 4. Dissolved oxygen results from Pinnacles National Park (water years 2011-2012). Boxplots present the interquartile range of each dataset; whiskers are drawn to 1.5 times the interquartile range.

pH

The pH water quality objective range for surface waters in PINN is 7.0 to 8.5 pH units (CA RWQCB 2011). During WYs 2011-2012, 98% of all SFAN pH results fell within their objective range. Nine percent of the PINN pH results (13 of 146) failed to meet the water quality objective of 7.0 to 8.5 pH units; most of these (12 results) were below the objective range, while only one result exceeded the high end of the objective range (Figure 5). This single result (8.60 pH units at site SC1) was the only exceedance in the SFAN; this site also produced most of the highest pH results in PINN (11 of the 12 highest), as well as the highest mean in the SFAN (8.215 pH units).

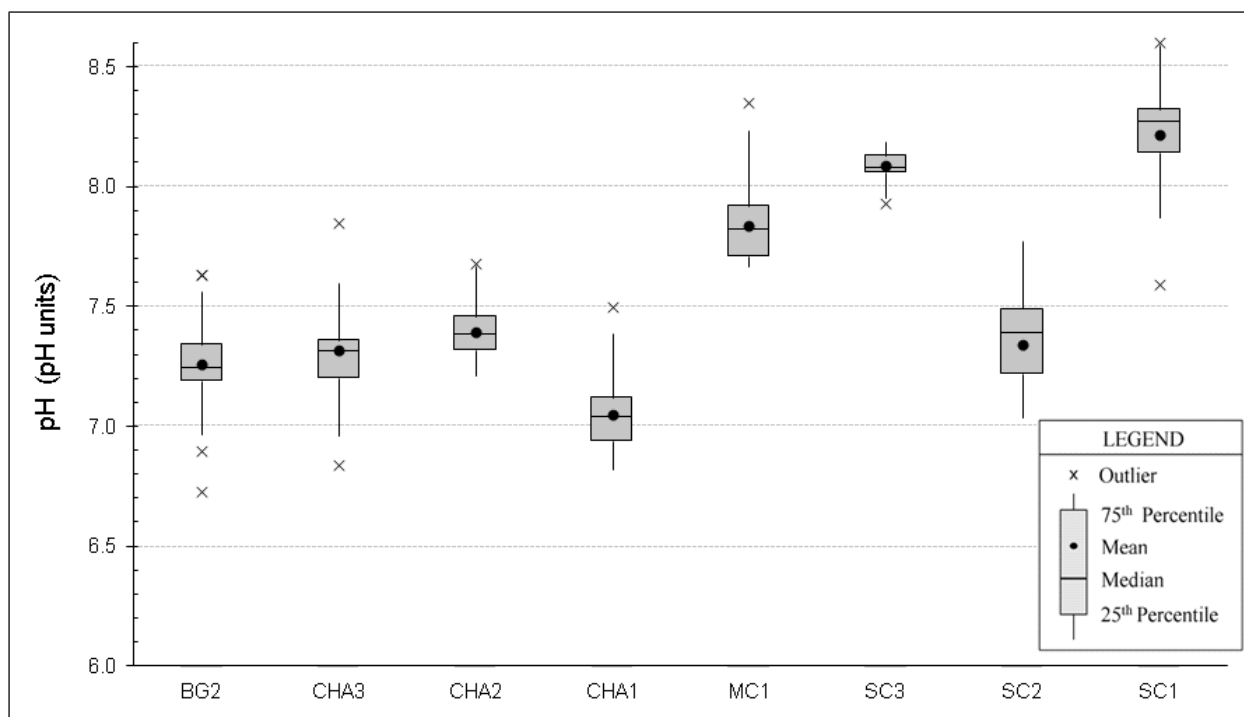


Figure 5. pH results from Pinnacles National Park (water years 2011-2012). Boxplots present the interquartile range of each dataset; whiskers are drawn to 1.5 times the interquartile range.

Specific Conductance

Conductivity (the ability of a solution to conduct an electrical current) is an indicator of the presence of dissolved solids, and is influenced by local geology as well as urban runoff and other anthropogenic inputs. Since conductivity fluctuates with temperature, a value of 'specific conductance' is calculated in-situ using the simultaneously-measured water temperature value, in order to yield a value that is corrected to 25°C. The RWQCB Basin Plans do not provide established water quality objectives for specific conductance. Ideally, freshwater streams should have specific conductance levels below 500 $\mu\text{S}/\text{cm}$ in order to support diverse aquatic life; this level is used as an ecological objective in this report, in order to give context to the results (Behar 1997).

During WYs 2011-2012, 85% of all SFAN specific conductance results (532 of 624) fell below the ecological objective of 500 $\mu\text{S}/\text{cm}$. Of those that exceeded the objective, 71% were results from PINN sites. Forty percent of all PINN results (65 of 162) exceeded this value, and the majority of these (80%) were from the three Sandy Creek sites (SC1, SC2, and SC3); the other 20% were all from site CHA1 in Chalone Creek (Figure 6). These four sites produced the highest means of all the PINN sites. The lowest individual specific conductance result in the SFAN was also from PINN; site BG2 in Bear Gulch measured 36 $\mu\text{S}/\text{cm}$ after a rain event in March of 2011.

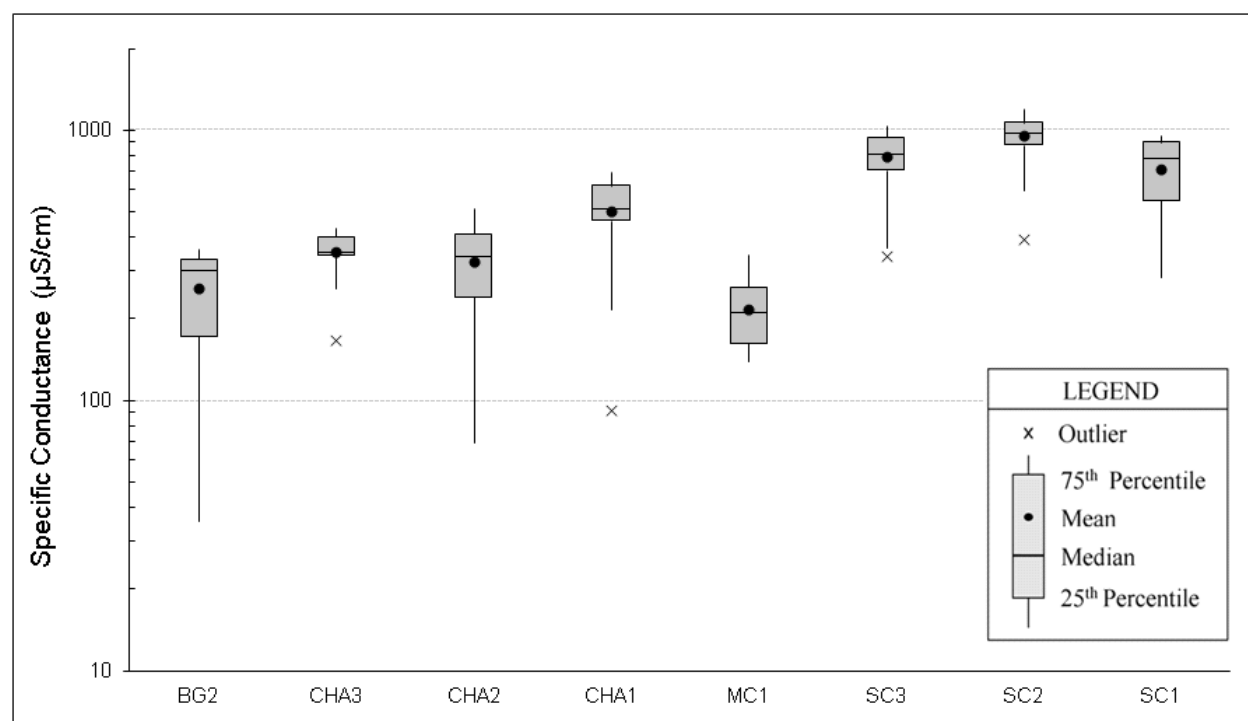


Figure 6. Specific conductance results from Pinnacles National Park (water years 2011-2012). Boxplots present the interquartile range of each dataset; whiskers are drawn to 1.5 times the interquartile range.

Turbidity

Turbidity is the capacity of suspended sediment (including clay, silt, fine organic and inorganic matter, and microscopic organisms) in water to scatter light (American Public Health Association et al. 1998). Inputs of such solids occur because of erosion from stream banks, runoff from various source areas within a watershed, and re-suspension from the streambed during storm events. While erosion and sedimentation are natural processes, agriculture and land development can accelerate these means and result in an imbalance in the amount of sediment in a stream system (Coopridge and Carson 2006). Turbidity is often measured in nephelometric turbidity units (NTU). A level of turbidity greater than 5 NTU is considered visible turbidity, and turbidity levels above 25 NTU have been shown to cause reductions in salmonid growth (Sigler et al. 1984). There is not an established objective for turbidity levels in SFAN streams, but the ecological objective maximum of 25 NTU is kept in mind when looking at these results. Additionally, the NPS Water Resource Division uses a “screening criteria” of 50 NTU to determine water quality exceedances in its Baseline Water Quality Inventory and Analysis Reports (NPS 2003). Although these objectives are important to keep in mind, it is often not the peak levels that determine negative ecological consequences, but the persistence of high levels after storm events; longer durations of high turbidity levels are more likely to cause damage to fish and other aquatic organisms (Newcombe and MacDonald 1991). This program captures single turbidity samples during site visits, and does not conduct continuous monitoring or turbidity threshold sampling.

During WYs 2011-2012, the turbidity results from the PINN sites were highly varied; the highest mean turbidity (for a single site) was found here, as well as the two lowest means in the SFAN. Twenty-one percent of the PINN results (35 of 169) exceeded the ecological objective of 25 NTU, and the majority of these (25 of 35) were from site MC1 in McCabe Canyon. Although many SFAN sites had high turbidity spikes, MC1 had the most consistently high turbidity values compared to all program sites; the mean was 83.5 NTU, higher than any other in the SFAN, yet it also exhibited the narrowest range in results (Figure 7). All 25 samples from site MC1 were above the ecological objective of 25 NTU, and the lowest value recorded was 55.4 NTU. Site SC1 in Sandy Creek also produced a relatively high mean (27.91 NTU), while sites SC3 and CHA2 produced the lowest means in the SFAN (2.070 and 1.48 NTU, respectively).

Data is displayed in Figure 7 on the following page.

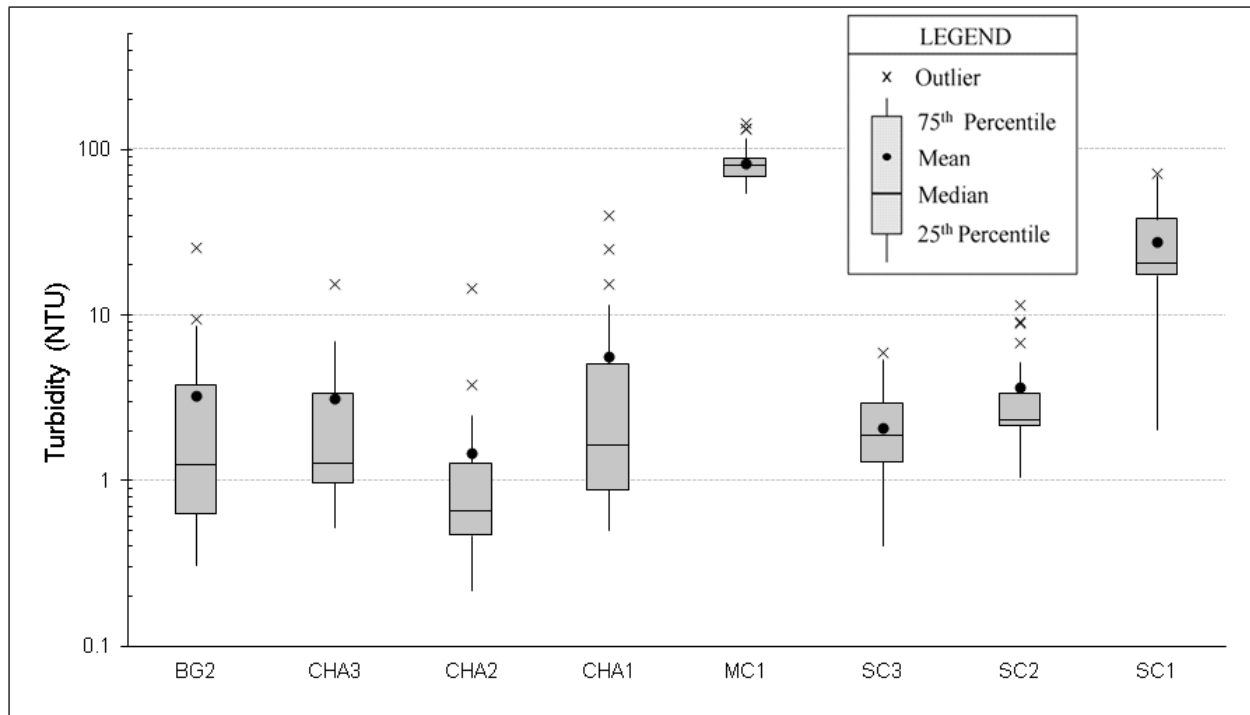


Figure 7. Turbidity results from Pinnacles National Park (water years 2011-2012). Boxplots present the interquartile range of each dataset; whiskers are drawn to 1.5 times the interquartile range.

Nutrient Parameters

All nutrient samples were collected in sterile, laboratory-issued bottles during each site visit, and stored immediately on ice until transferred to a professional laboratory for processing. During WYs 2011-2012, nitrate (as N) and TKN were sampled on a monthly basis at five primary PINN water quality sites. Three PINN sites (CHA3, SC3, and SC2) were established as secondary monitoring locations in the SFAN Protocol which excludes collection of nutrient samples.

Summary statistics of all nutrient data collected from PINN during WYs 2011-2012 are displayed in detail in Table 7; however, a box and whiskers plot of TKN data is displayed separately for simplified viewing. Due to relatively low nutrient levels in the SFAN streams, many results were reported as non-detect, which means that the analyte was not detected at or above the laboratory's reporting detection limit (RDL). These results were considered censored and required the use of the nonparametric Kaplan-Meier method (through the NPSTORET database) for analysis of all nutrient results (see Data Handling and Analysis in the Methods section for a description). All summary statistics are based on instantaneous measurements routinely collected at approximately the same time of day on each visit; therefore, the data in the tables and figures presented do not reflect the true minimum and maximum values of diurnal variation.

Table 7. Nutrient results from Pinnacles National Park (water years 2011-2012). (Std. dev. = standard deviation.) All means and standard deviations are rounded to one more decimal place than the least precise value (least number of decimal places) of each corresponding dataset.

Parameter	Statistic	BG2	CHA2	CHA1	MC1	SC1
Nitrate as nitrogen (mg/L)	Mean	-	-	-	0.249	-
	Median	-	-	-	-	-
	Minimum	<0.15	<0.15	<0.15	<0.15	<0.15
	Maximum	0.39	<0.15	0.23	0.83	0.19
	Std. dev.	-	-	-	0.195	-
	# NDs/ # Results ¹	19/24	24/24	22/24	12/24	17/18
Total Kjeldahl nitrogen (mg/L)	Mean	0.48	0.44	0.44	1.65	0.83
	Median	0.46	0.41	0.44	1.5	0.75
	Minimum	0.25	0.27	0.25	0.82	0.53
	Maximum	1.0	1.1	1.0	4.1	1.5
	Std. dev.	0.17	0.17	0.15	0.80	0.26
	# NDs/ # Results ¹	0/24	0/24	0/24	0/24	0/18

¹ The number of results that were reported as 'ND' (not detected at or above the reporting detection limit) are shown above, as a ratio over the total number of results from that site.

- Dashes are inserted where there is a lack of data or a high percentage of censoring that prevents calculation.

Nitrate as Nitrogen

Neither the state of California nor the Central Coast RWQCB has set objectives for nitrates, however, there is a national drinking water objective of 10 mg/L nitrate as nitrogen (as N) established by the EPA, as well as a regional reference value of 0.16 mg/L (U.S. EPA 2000). Additionally, a study by R. Crunkilton (2000) found that a level of 1.1 mg/L nitrate (as N) can be toxic to aquatic life, especially fish and amphibian eggs. For this report, SFAN nitrate results are compared to the ecological threshold of 1.1 mg/L nitrate (as N) (Crunkilton 2000). The RDL for all nitrate (as N) samples processed during WYs 2011-2012 was 0.15 mg/L (utilizing EPA Method 300).

Every water quality sample collected in PINN registered below the ecological objective for nitrate (as N), and 83% (95 of 115) were reported as non-detect. Because of the high percentage of censored data, figures can not be created for PINN nitrate (as N) results.

Total Kjeldahl Nitrogen (TKN)

Combined ammonia-nitrogen and organic nitrogen are referred to as TKN. Different forms of nitrogen can exist in streams as a result of both natural and anthropogenic sources. Monitoring TKN, in addition to nitrate and ammonia, can create a clearer understanding of what forms of nitrogen (organic or inorganic) are available at different times of the year. The Central Coast RWQCB's Basin Plan does not currently have an established criterion for TKN; however, the EPA encouraged the establishment of regulatory objectives for nutrients by conducting a large scale survey to provide states with regional reference values. The regional reference value for SFAN streams is 0.36 mg/L TKN (U.S. EPA 2000).

During WYs 2011-2012, the laboratory's RDL for all TKN tests (employing Standard Method 4500-Norg C) was 0.25 mg/L; 95% of all SFAN samples (440 of 462) were reported to be above this level. All samples collected from PINN during WYs 2011-2012 had detectable levels of TKN, and 81% of all PINN results (93 of 115) were above the regional reference value of 0.36 mg/L. PINN site MC1, in McCabe Canyon, produced the highest TKN mean in the SFAN and the second highest individual result in the program (4.1 mg/L in July 2012) (Figure 8). Seven out of the eight highest MC1 results were recorded during low flow conditions in the dry season.

Data is displayed in Figure 8 on the following page.

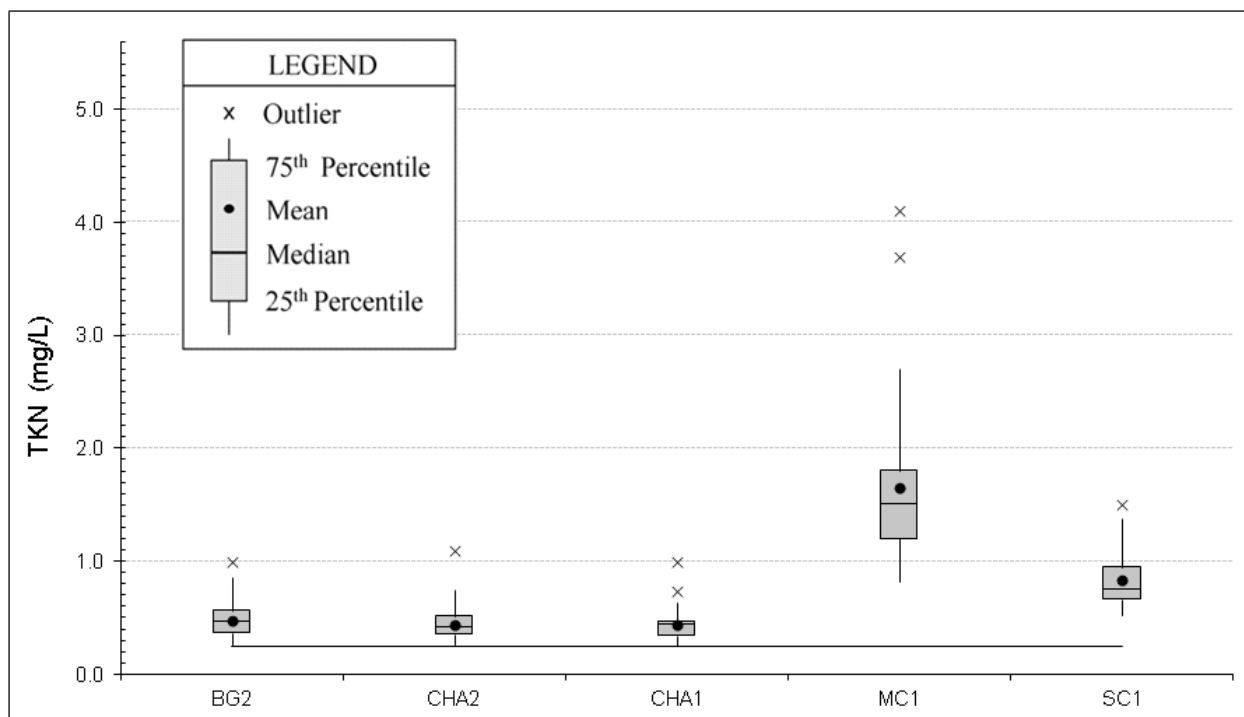


Figure 8. Total Kjeldahl nitrogen (TKN) results from Pinnacles National Park (water years 2011-2012). Boxplots present the interquartile range of each dataset; whiskers are drawn to 1.5 times the interquartile range. The laboratory reporting detection limit (0.25 mg/L) is displayed with a solid line.

Results for Pathogenic Indicator Bacteria begin on the following page.

Pathogenic Indicator Bacteria

Total coliform and *E. coli* bacteria are indicators of pathogens that can be detrimental to human health. Each of these parameters is monitored year-round as part of the SFAN Freshwater Quality Monitoring Program. The results are reported with the units ‘MPN/100mL’ which stands for ‘most probable number of colony-forming units per 100 mL of sample volume.’ These results do not quantify the amount of bacteria in a body of water, but are used to estimate concentrations of bacteria that may indicate the presence of pathogens. Currently the EPA uses *E. coli* as an indicator of risk to human health, and it is the recommended parameter for fresh water. Total coliform bacteria results are automatically reported along with *E. coli*, and although these results may be used to view long-term trends in the future, total coliform is not commonly used as a pathogenic indicator for human health concerns.

All bacteria samples were collected in sterile, factory-sealed bottles and stored immediately on ice. Total coliform and *E. coli* (TC/EC) samples were processed at the in-house laboratory at PORE. In this laboratory, TC/EC results are produced together from a single test. Due to the cost savings of processing these samples in-house, TC/EC samples were collected at every SFAN site visit (at both primary and secondary sites) during WYs 2011-2012. Unlike the nutrient data that are often censored at the lower end (from non-detect results), the TC/EC data can be censored on either end due to the laboratory method used; this makes data analysis more challenging, and requires the use of the Kaplan-Meier statistical method (through the NPSTORET database) to create summary statistics and figures (see Data Handling and Analysis section under Methods). In addition to the complication of censoring on both ends, the TC/EC data also have varying lower and upper quantification limits that differ between sites and seasons. Samples processed at the standard 10x dilution factor have a quantification range of 10 – 24,190 MPN/100 mL. During WYs 2011-2012, two samples were processed at a 100x dilution factor, which resulted in a quantification range of 100 – 241,900 MPN/100 mL.

Summary statistics of all PINN bacteria data collected during WYs 2011-2012 are displayed in detail in Table 8 on the following page; however, box and whiskers plots of these data are displayed separately (sorted by parameter) for simplified viewing. All summary statistics are based on instantaneous measurements routinely collected at approximately the same time of day on each visit; therefore, the data in the tables and figures presented do not reflect the true minimum and maximum values of diurnal variation.

Table 8. Pathogenic indicator bacteria results from Pinnacles National Park (water years 2011-2012). All means and standard deviations are rounded to one more decimal place than the least precise value (least number of decimal places) of each corresponding dataset.

Parameter	Statistic	BG2	CHA3	CHA2	CHA1	MC1	SC3	SC2	SC1
Total coliform (MPN/100 mL)	Mean	2534.0	6084.0	2740.0	1117.0	77354.0	3348.0	1881.0	6682.0
	Median	1700	4100	1600	630	13000	2300	1200	5500
	Minimum	380	260	170	31	990	420	170	640
	Maximum	7300	>24190	16000	8200	>241900	20000	5500	24000
	Std. dev.	2059.0	6792.0	3417.0	1756.0	108875.0	4031.0	1592.0	6600.0
	# censored/ # results ¹	0/24	1/13	0/24	0/24	7/24	0/24	0/19	0/18
<i>E. coli</i> (MPN/100 mL)	Mean	73.1	15.5	124.3	70.4	22636.0	223.6	74.6	384.1
	Median	20	-	31	20	560	160	20	150
	Minimum	<10	<10	<10	<10	31	<10	<10	10
	Maximum	910	62	1800	410	>241900	860	620	1500
	Std. dev.	184.8	14.5	361.7	102.6	67876.0	234.3	141.3	474.0
	# censored/ # results ²	7/24	9/13	5/24	8/24	2/24*	1/24	3/19	0/18

¹ These censored results are '> QL' (above the quantification limit) & are shown as a ratio over the total number of results.

² These censored results are '< QL' (below the quantification limit) & are shown as a ratio over the total number of results.

* MC1 is the only exception – this site produced two censored results above the quantification limit.

Total Coliform

During WYs 2011-2012, a total of 170 total coliform samples were collected from PINN water quality monitoring sites. The six lowest results came from site CHA1 in Chalone Creek; this site also had the lowest mean total coliform value (1,117 MPN/100mL) compared to all other PINN sites (Figure 9). The seven highest results, and the highest mean value in PINN, were found at a single site: MC1 in McCabe Canyon. Each of these seven individual results exceeded the method's quantification limit; six exceeded the upper limit of 24,190 MPN/100mL (processed at a 10x dilution), and one result exceeded the upper limit of 241,900 MPN/100mL (processed at a 100x dilution).

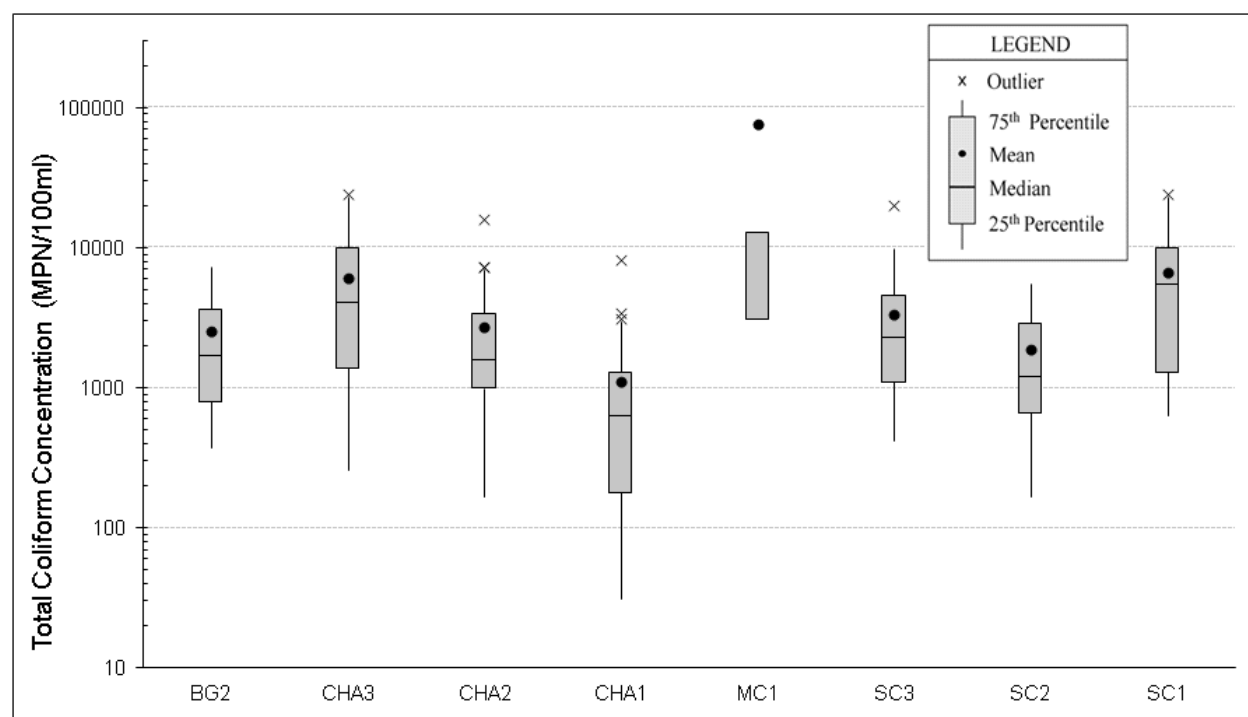


Figure 9. Total coliform results from Pinnacles National Park (water years 2011-2012). Boxplots present the interquartile range of each dataset. Whiskers are drawn to 1.5 times the interquartile range, except for site MC1 (high censoring prevented computation).

***Escherichia coli* (*E. coli*)**

During WYs 2011-2012, a total of 170 *E. coli* samples were collected from PINN water quality monitoring sites. Nineteen percent of these results (33 of 170) were reported to be below the laboratory reporting detection limit of 10 MPN/100mL, and the majority of these non-detects (22 of 33) were from Chalone Creek sites CHA1, CHA2, and CHA3 (Figure 10). Site BG2 in Bear Gulch produced 11 of the lowest results in PINN (seven non-detect and four of 10 MPN/100mL). The six highest results found in PINN during WYs 2011-2012 were from site MC1 in McCabe Canyon; five of these were recorded during consecutive visits, May 2012 through September 2012. The highest individual result recorded in the SFAN program during WYs 2011-2012 was collected from MC1 during August 2012 (an exceedance of the highest quantification limit; above 241,900 MPN/100mL).

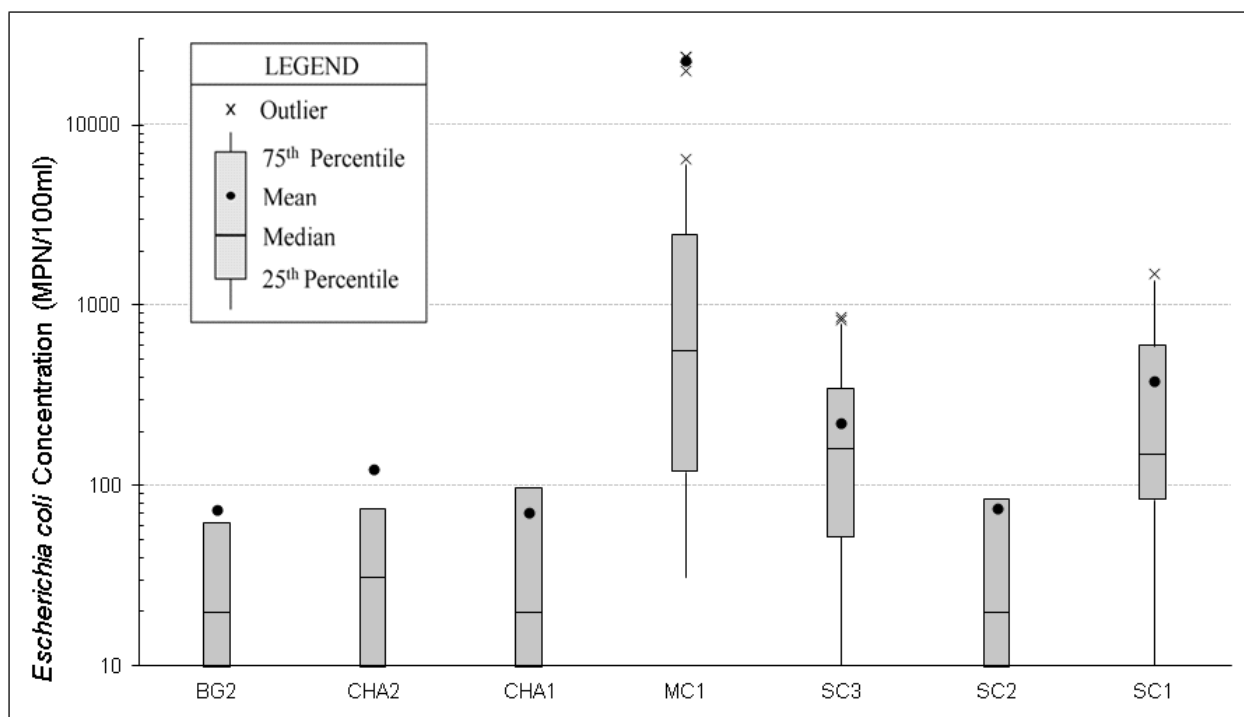


Figure 10. *Escherichia coli* results from Pinnacles National Park (water years 2011-2012). Boxplots present the interquartile range of each dataset. Whiskers are drawn to 1.5 times the interquartile range, except for sites BG2, CHA2, CHA1, and SC2 (high censoring prevented computation). CHA3 was excluded due to its high percentage of censored data.

Summary

During water years 2011 and 2012, this water quality program produced a clear snapshot of watershed health in Pinnacles National Park. A more complete summary and discussion of these data will be included in the SFAN 2011-2012 Biennial Report. Two additional years of monitoring, employing the same methodology, will resume in water years 2015-2016. Continuing with this long-term monitoring program is necessary in order to document seasonal ecological fluctuations, determine trends, guide management decisions, and evaluate the success of restoration projects.

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