



Mountain Ponds and Lakes Monitoring

2016 Results from Lassen Volcanic National Park, Crater Lake National Park, and Redwood National Park

Natural Resource Data Series NPS/KLMN/NRDS—2019/1208



**ON THIS PAGE**

Unknown Darner Dragonfly perched on ground near Widow Lake, Lassen Volcanic National Park.
Photograph by Patrick Graves, KLMN Lakes Crew Lead.

ON THE COVER

Summit Lake, Lassen Volcanic National Park
Photograph by Elliot Hendry, KLMN Lakes Crew Technician.

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Contents

	Page
Figures.....	v
Tables	vi
Appendices.....	viii
Abstract	ix
Acknowledgments.....	x
1.0 Introduction.....	1
2.0 Methods.....	2
2.1 Implementation Schedule	2
2.2 Site Selection and Lake Identifiers	2
2.2.1 Judgment Sites.....	2
2.2.2 Non-Judgment Sites.....	2
2.3 Site Set-up and Sampling Scheme.....	3
2.4 Water Chemistry and Water Quality Profile	5
2.5 Aquatic Communities	6
2.5.1 Zooplankton.....	6
2.5.2 Littoral Macroinvertebrates	6
2.5.3 Fish	7
2.5.4 Zooplankton and Macroinvertebrate reporting.....	8
2.6 Physical Habitat and Lake Morphometrics	8
3.0 Results.....	9
3.1 Lassen Volcanic National Park	9
3.1.1 Physical substrate	17
3.1.2 Water Chemistry.....	17
3.1.3 Water Quality	17
3.1.4 Zooplankton.....	26
3.1.5 Littoral Zone Macroinvertebrates	26

Contents (continued)

	Page
3.1.6 Vertebrates.....	26
3.2 Crater Lake National Park	34
3.2.1 Physical Substrate.....	37
3.2.2 Water Chemistry.....	37
3.2.3 Water Quality	37
3.3.4 Zooplankton.....	37
3.3.5 Littoral Zone Macroinvertebrates.....	42
3.3.6 Vertebrates.....	42
3.3 Redwood National Park.....	44
3.3.1 Physical Substrate.....	44
3.3.2 Water Chemistry.....	44
3.3.3 Water Quality	48
3.3.4 Zooplankton and Littoral Zone Macroinvertebrates.....	48
3.3.5 Vertebrates.....	51
4.0 Conclusion	53
5.0 Literature Cited	54

Figures

	Page
Figure 1. Layout schematic of a pond-lake showing the location and type of sampling completed during each site visit.	4
Figure 2. 2013 Field Crew Lead Kirsten Underwood finishing horizontal zooplankton tow sampling at Lily Pond, Lake 10430 (from 2013 field season).	6
Figure 3. 2013 Crew Leader Kirsten Underwood sampling littoral zone macroinvertebrates in Summit Lake (10793) (left) and Lily Pond (10430) (right) (from 2013 field season).	7
Figure 4. Deployment of gill net at Lily Pond (10430).	7
Figure 5. Locations of ponds and lakes sampled in Lassen Volcanic National Park, 2016.	10
Figure 6. View of Lake 10950 from Lake 10968 from 2013 field crew (looking north).	13
Figure 7. Looking south from Lake 10950 towards Lake 10968 from 2016 field crew.	14
Figure 8. Looking north from Lake 10807 towards Lake 10804 from 2013 field crew, field crew leader Kirsten Underwood in foreground.	14
Figure 9. Looking south from Lake 10804, 21 meters away from the proper Lake 10807 by the 2016 field crew.	15
Figure 10. Examples of the variety of Lassen Volcanic National Park ponds and lakes.	16
Figure 11. Lahontan Redside (<i>Richardsonius egregius</i>) from Widow Lake, 10455.	34
Figure 12. Locations of ponds sampled in Crater Lake National Park, 2016.	35
Figure 13. Three characteristic ponds sampled in Crater Lake National Park, 2016.	36
Figure 14. Cascades Frog, <i>Rana cascadae</i> , at Spruce Lake (CRLAWQL04).	44
Figure 15. Location of Freshwater Lagoon in the southern portion of Redwood National Park, sampled in 2016.	45
Figure 16. Freshwater Lagoon at Redwood National Park, showing abundance of inundated grasses along the shoreline.	46
Figure 17. Asian clam (<i>Corbicula</i>), left, and Chinese Mystery Snail (<i>Cipangopaludina chinensis</i>), right, from Freshwater Lagoon, 2016.	50
Figure 18. Japanese Pond Smelt (<i>Hypomesus olidus</i>) (top), Three Spine Stickleback (<i>Gasterosteus aculeatus</i>) (middle), and Prickly Sculpin (<i>Cottus asper</i>) (bottom) from Freshwater Lagoon, Redwood National Park, 2016.	52

Tables

	Page
Table 1. Location of one dry lake encountered in Lassen Volcanic National Park.	9
Table 2. Morphometric and location data for ponds and lakes sampled at Lassen Volcanic National Park, 2016.	11
Table 3. Physical substrate composition and Secchi Disk depths for ponds and lakes sampled in Lassen Volcanic National Park, 2016.....	18
Table 4. Water chemistry results for ponds and lakes of Lassen Volcanic National Park, 2016.....	21
Table 5. Averaged water quality profiles for ponds and lakes of Lassen Volcanic National Park, 2016.	24
Table 6. Zooplankton metrics for ponds and lakes sampled at Lassen Volcanic National Park, 2016.	27
Table 7. Macroinvertebrate metrics collected in pond and lake littoral zones in Lassen Volcanic National Park, 2016.	29
Table 8. Number of vertebrates encountered at Lassen Volcanic National Park sampling sites during gill netting and visual encounter surveys, 2016.	32
Table 9. Morphometric and location data for ponds sampled in Crater Lake National Park, 2016.	36
Table 10. Physical substrate composition and Secchi Disk depths for ponds sampled in Crater Lake National Park, 2016.....	38
Table 11. Water chemistry results for the ponds of Crater Lake National Park, 2016.	39
Table 12. Averaged water quality probe profiles for ponds of Crater Lake National Park, 2016.....	40
Table 13. Zooplankton metrics for ponds sampled in Crater Lake National Park, 2016.	41
Table 14. Macroinvertebrate metrics collected from ponds in Crater Lake National Park, 2016.....	43
Table 15. Number of vertebrates encountered at Crater Lake National Park sampling sites during visual encounter surveys, 2016.....	43
Table 16. Morphometric and location data for Freshwater Lagoon sampled in Redwood National Park, 2016.	47

Tables (continued)

	Page
Table 17. Physical substrate composition and Secchi Disk depth of Freshwater Lagoon sampled in Redwood National Park, 2016.....	47
Table 18. Water chemistry results for Freshwater Lagoon sampled in Redwood National Park, 2016.	47
Table 19. Averaged water quality profile for Freshwater Lagoon, Redwood National Park, 2016.	49
Table 20. Zooplankton metrics for Freshwater Lagoon, Redwood National Park, 2016.....	49
Table 21. Littoral zone macroinvertebrate metrics for Freshwater Lagoon, Redwood National Park, 2016.	49
Table 22. Number of vertebrates observed and collected at Freshwater Lagoon, Redwood National Park, 2016.	51

Appendices

	Page
Appendix A. Zooplankton Taxa of Lassen Volcanic National Park.....	55
Appendix B. Littoral Zone Macroinvertebrates of Lassen Volcanic National Park	57
Appendix C. Zooplankton Taxa of Crater Lake National Park	62
Appendix D. Littoral Zone Macroinvertebrates of Crater Lake National Park	64
Appendix E. Zooplankton Taxa of Redwood National Park	66
Appendix F. Littoral Zone Macroinvertebrates of Redwood National Park.....	67

Abstract

The Inventory and Monitoring Program of the National Park Service sampled the biotic and abiotic parameters of mountain ponds and lakes of the Klamath Network in three park units: Lassen Volcanic National Park, Crater Lake National Park, and Redwood National Park. Sampling of lentic habitats in these parks occurs every three years (2013, 2016, 2019, etc.). This was the second sample period for this protocol.

The purpose of the Klamath Inventory and Monitoring Network Mountain Ponds and Lakes protocol is to determine status and trends of ecological condition in mountain ponds and lakes. This report serves to report the measured values. Included in the report are measurements of physical habitat, water chemistry and quality, and aquatic communities.

In Lassen Volcanic National Park, a total of 30 probabilistically chosen ponds and lakes were visited along with a single judgment site (Lake Helen). Sampling occurred from 20 July 2016 to 31 August 2016. One of the 30 probabilistic ponds-lakes were found to be dry, for a total of 29 probabilistic ponds and lakes sampled.

In Crater Lake National Park, six ponds outside the Crater Lake caldera were sampled from 13 September 2016 to 16 September 2016, excluding a single site that was inaccessible. Based on visits in prior years and the current visits, it was determined that this constitutes all the known perennial sampleable ponds outside the Crater Lake caldera. There are no judgment sites in Crater Lake National Park.

In Redwood National Park, a single judgment site, Freshwater Lagoon, was sampled on 20 and 21 September 2016.

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1.0 Introduction

The Klamath Network (KLMN) vital signs selection process identified two freshwater vital signs for monitoring: Aquatic Communities and Water Quality (Sarr et al. 2007). Prioritization of these vital signs was driven by potential natural and anthropogenic impacts to freshwater habitats and resources.

During the initial process of selecting Aquatic Communities and Water Quality as vital signs, National Park Service (NPS) staff did not differentiate between lentic (pond and lake) and lotic (stream) habitats. However, fundamental differences in ecosystem structure and process between streams and lakes dictated a basic division in sampling methodology and the development of separate protocols and reporting for each of these habitats. This report covers lentic habitats for the mountain ponds and lakes (Dinger et al. 2012); lotic sampling is covered in separate reports and protocol (Dinger et al. 2013).

Ponds and lakes are integral ecosystems in the landscape of many parks. Not only are lakes attractive visitor destinations, but they also serve as watering holes and habitat for park wildlife. Lake ecosystems have been studied for over a century, both as isolated “mesocosms” (i.e., stand alone, self-contained systems) and as part of a broader landscape, providing a rich context for understanding linkages between natural and anthropogenic stressors and their effects.

The overall aquatic community of a lake serves as an integrated biomonitoring tool, encompassing short-term and long-term responses to impacts (Rosenberg and Resh 1993). Invertebrates (benthic and planktonic) can rapidly respond to impacts, while fish and amphibians (with longer life cycles) will manifest time-integrated responses. Trends in aquatic communities reflect changes in water and habitat quality; therefore, monitoring aquatic communities and associated habitat characteristics will detect changes in ecological integrity over time. We have chosen to monitor multiple indicators of the lake ecosystem, encompassing key attributes of habitat, chemistry, and biology. The use of multiple indicators for measuring potential ecosystem change will provide us with an integrated and robust system for detecting trends and changes over time.

The primary goal of the Mountain Ponds and Lakes protocol is to *determine the status and trends of ecological condition in the mountain lakes of the Klamath Network*. The two Klamath Network parks with substantial pond and lake habitats are Lassen Volcanic and Crater Lake National Parks. An additional park, Redwood National Park has several coastal lagoons, and one freshwater lagoon (named Freshwater Lagoon) is also included in this sampling and report.

Future analysis and reporting on lake ecological condition and trends will be in Analysis and Synthesis Reports to follow, allowing for a more comprehensive interpretation beyond the scope of an annual report. These future reports will focus on identifying pond and lake attributes and trends in resources over time. The purpose of this current report is the quick dissemination of raw data and selected derived response measures for park specialists, managers, scientists, and the public.

2.0 Methods

The methods used for monitoring KLMN mountain ponds and lakes come from three primary sources: (1) USGS protocols for sampling lakes and ponds (Hoffman et al. 2005), (2) Techniques developed by Roland Knapp for sampling Sierra Nevada lakes (Knapp et al. 2005), and (3) USEPA National Lakes Assessment techniques (2011), with modifications to fit KLMN time, logistics, and budgetary constraints. The methods described below are abbreviated descriptions of the methods used in data and sample collection. Full descriptions of methodology are contained in the protocol for Integrated Aquatic Community and Water Quality Monitoring of Mountain Ponds and Lakes in the Klamath Network (Dinger et al. 2012). Additionally, methods are provided for some field sampling that is not analyzed or reported herein—they are included here to provide an overview of the portfolio of data that will be available in future Analysis and Synthesis reports or upon request.

2.1 Implementation Schedule

The KLMN aquatics sampling plan stipulates that mountain pond and lake sampling be implemented one year out of three, alternating with two years of wadeable stream sampling. This report covers data from the second year of implementation of mountain pond and lake sampling (2016). Mountain ponds and lakes will be sampled again in 2019.

2.2 Site Selection and Lake Identifiers

Selection of sites varied by park unit, and included both judgment and probabilistically chosen sites.

2.2.1 Judgment Sites

In Lassen Volcanic National Park, there was a single judgment lake: Lake Helen, selected by park staff due to its high recreation use, proximity to a major park roadway, and low buffering capacity. In Redwood National Park, Freshwater Lagoon was selected by park staff because it is no longer a true lagoon (being cut off by US Highway 101), is partly on park land and partly on state lands, and is stocked extensively with exotic fish.

2.2.2 Non-Judgment Sites

Excluding the judgment sites, the target sample-site population for the Integrated Aquatic Community and Water Quality Monitoring of Mountain Ponds and Lakes protocol is all mountain ponds and lakes that are:

- Perennial – This selection criterion is applied to remove habitats that are influenced by seasonal desiccation which could mask other stressors of interest. It also ensures that data collection can always occur at the sites, assisting in data completion goals.
- <25 m maximum depth – This selection criterion removes large lakes that are characterized by physical and environmental processes that are different from those for smaller lakes and ponds. While monitoring large lakes is valuable, separate methodology would be required to adequately assess them, and they are a numerical minority of sites within the Klamath Network. (Note that a judgment lake, Lake Helen is deeper than 25 m, but limited in surface area ~11 hectares).

- <1000 m from a travelable road or trail – This selection criterion reduces logistical constraints to field crews, such as travel time, to ensure that each site can be sampled in the allotted time frame for achieving sampling objectives.
- Located in topographies with slope <30 degrees – This selection criterion ensures crew safety and that access to lakes is feasible.

Lassen Volcanic National Park

Within Lassen Volcanic National Park there are a total of 239 ponds and lakes. Thirty-six of these ponds and lakes were excluded based on the above criteria. The target sample size for the protocol at Lassen Volcanic National Park was 30 sites, and these sites were chosen from the remaining 203 ponds and lakes using a Generalized Random Tessellation Stratified design (GRTS – pronounced “grits”) (Stevens and Olsen 1999, 2004). This design employs a systematic sampling technique to obtain a spatially balanced probabilistic sample. This procedure also produces a spatially balanced over-sample (i.e., a list of additional sites to sample if sample points need to be replaced or added). Since the GRTS method creates spatially balanced and dispersed sample sites, it minimizes spatial autocorrelation among sites and maximizes the effective sample size for a given number of sample sites, which should help increase statistical power.

Within Lassen Volcanic National Park, many of the ponds and lakes are unnamed waterbodies, complicating the identification and reporting on each. However, the state of California (CA) has assigned a unique number to each water body within the state. Using these numbers, we can track each site, be it named or not. In cases where a pond or lake has a geographical name, we report both the CA code (“Site Code”) and the name.

Crater Lake National Park

Within Crater Lake National Park, outside of the caldera, there were a total of 38 potential sites identified by park staff. Initial site visits in 2008 during protocol development showed that a large majority of these were ephemeral and prone to drying prior to crews being able to sample them (Dinger et al. 2012). After further field verification, we identified a total of six ponds that were perennial and suitable for sampling, and one site that was inaccessible (See Dinger 2016 for more details). Hence, sampling of perennial ponds in Crater Lake constitutes a complete census of known sites fitting the site-selection criteria summarized above.

At Crater Lake National Park, many of the ponds were also unnamed waterbodies. We assigned an arbitrary site code to each water body identifying the park (e.g., CRLA = Crater Lake), type of protocol (e.g., Water Quality = WQ), and habitat type (L = Lake) resulting in: CRLAWQL01 to CRLAWQL38. Both the site code and geographical name, when applicable, are used in reporting.

2.3 Site Set-up and Sampling Scheme

The sampling crew utilizes an arbitrarily selected set-up station, from which sampling occurs at three secondary site types: (1) An index site located at the deepest point of the lake, (2) 15 roughly equally spaced sampling stations around the lake perimeter, and (3) a nearby gill-net deployment station for fish sampling (Figure 1). In addition to these sampling locations, the crew walks the perimeter of the lake, recording the lake outline with a GPS unit and characterizing habitat substrates.

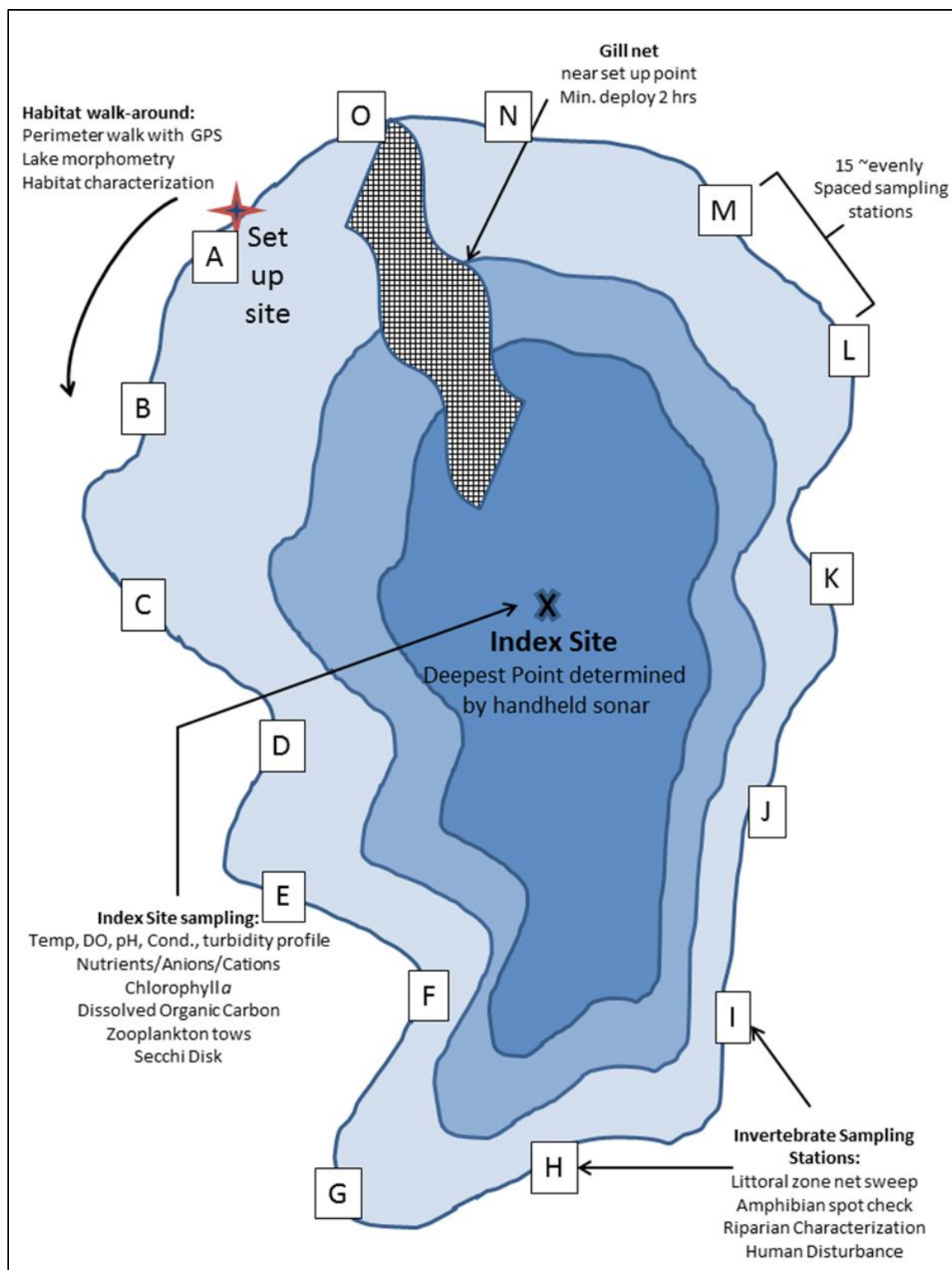


Figure 1. Layout schematic of a pond-lake showing the location and type of sampling completed during each site visit.

In a small inflatable boat, the crew spends approximately 30 minutes determining the deepest measured point of the pond or lake using a hand-held sonar device. This point is the index station and establishes the location for collecting samples for water chemistry, the water quality profile, Secchi Disk depth measurements, and zooplankton sampling.

The crew identifies 15 points estimated to be evenly and systematically spread around the lake perimeter. This is accomplished by estimating a point half-way around the perimeter of the pond or lake and deducing a rough spacing for each sampling location. At each of these locations, the crew collects a macroinvertebrate sample, searches aquatic habitats for amphibians, and characterizes the riparian zone for vegetation and human disturbance.

The crew also searches for a suitable location to stretch out and deploy the gill net for fish sampling near the set-up site so that the gill net can be monitored for fish activity. The site needs to be relatively free of substrate, which can snag and potentially damage the net (e.g., large boulders and submerged tree trunks and branches).

2.4 Water Chemistry and Water Quality Profile

At the deepest part of a pond or lake, one or two water samples are collected using a horizontal Beta Van-Dorn-style water sampler. In deeper ponds and lakes (>2 m deep), a sample is collected at 0.5 m below the surface, and at 0.5 m above the lake bottom. In shallow ponds and lakes (<2 m deep), a single sample is collected at the mid-point depth of the water column. Water collected in the Van-Dorn bottle is stored in a 2-L amber high-density polyethylene (HDPE) sample bottle. On shore, using a 60-mL syringe and filter holder, a 250 mL portion of each water sample is filtered through a 0.45- μ m nylon membrane filter into an amber, acid washed 250-mL HDPE bottle for cation (Ca^{2+} , Na^+ , K^+ , and Mg^{2+}) and anion (SO_4^{2-} and Cl^-) analyses. An additional unfiltered 250 mL of water is decanted into an identical bottle for nutrient analyses (Total Nitrogen, Total Phosphorous). Both bottles are kept cool until they can be frozen (generally <4 hours). Additionally, 120 mL of water is filtered through a precombusted glass-fiber filter into an acid-washed, precombusted glass vial for the quantification of Dissolved Organic Carbon (DOC) sample (also kept cool and later refrigerated). These samples are then shipped to the Cooperative Chemical Analytical Laboratory at Oregon State University, Corvallis. See Dinger et al. (2012) for details on detection limits and analytical techniques for each parameter.

Measurements of temperature ($^{\circ}\text{C}$), pH, specific conductivity ($\mu\text{S cm}^{-1}$), dissolved oxygen (mg L^{-1}), and turbidity (NTU) are completed in a 0.5-m profile at the deepest point of the pond or lake using a Eureka Environmental “Manta” water quality probe. The probe is deployed over the side of the inflatable boat, with an initial measurement at the water surface, and then lowered at 0.5-m increments to obtain measurements until the probe is just above the pond or lake bottom. At each interval the probe is held steady until all parameters being measured have reached equilibrium.

At the deepest point, a 20-cm diameter Secchi Disk is used to measure water clarity.

2.5 Aquatic Communities

Three components (Zooplankton, Littoral Macroinvertebrates-Amphibians, Fish) of the pond or lake aquatic community are sampled at the three location types (Figure 1) around each pond and lake sampled.

2.5.1 Zooplankton

Zooplankton are collected from the deepest measured point of the lake using a 64- μ m mesh Wisconsin-style net with a 12.7 cm diameter opening using five replicate tows (Figure 2). In lakes >5 m deep, the tow is vertical, with the net being lowered 5 m prior to being lifted up through the water column. In lakes <5 m deep, the tow is horizontal, with the net being deployed 5 m away from the inflatable boat by tossing the net attached to a 5 m cord out and away from the boat before being pulled in. All individual tows are composited into a single vial, preserved in 90% ethanol, and sent to a contract taxonomy lab for enumeration and identification. (For this sampling year, the samples were sent to ZPs Taxonomy, LLC.).



Figure 2. 2013 Field Crew Lead Kirsten Underwood finishing horizontal zooplankton tow sampling at Lily Pond, Lake 10430 (from 2013 field season).

2.5.2 Littoral Macroinvertebrates

Macroinvertebrates from the near-shore littoral zone are sampled at the 15 sampling stations using a 1 ft. (0.304 m) wide D-frame 500- μ m mesh net, by sweeping the net along a 1 m path in the dominant substrate at the station (Figure 3). After sweeping 1 m, the net is turned and the 1 m path is re-swept. The samples from all 15 stations are composited into a single sample, subject to field splitting to minimize sample volume. The sample is then preserved in 90% ethanol and sent to a contract taxonomy lab for enumeration and identification. (For this sampling year, the samples were sent to Rhithron Associates, Inc.).



Figure 3. 2013 Crew Leader Kirsten Underwood sampling littoral zone macroinvertebrates in Summit Lake (10793) (left) and Lily Pond (10430) (right) (from 2013 field season).

During collection of the macroinvertebrate samples, and during the lake walk-around, a visual encounter survey and targeted search for amphibians is also conducted, and species and abundances recorded in the GPS unit.

2.5.3 Fish

Fish are sampled with a 42 m long, 1 m deep monofilament gill net with 3 panels: 1) 25-mm mesh X 6 m length; 2) 35 mm X 12 m length; and 3) 50 mm X 24 m length. The net is deployed perpendicular from the shore out toward the deeper part of the pond or lake (Figure 4), with the 25 mm panel being closest to the shore. The net is deployed from a small inflatable boat and kept in the water for a minimum of two hours, but can be left out longer as crew sampling dictates as long as no substantial fish numbers are accumulating in the net.



Figure 4. Deployment of gill net at Lily Pond (10430). Project lead Eric Dinger in boat, 2013 Crew Member Eric Scott feeding out net (photo from 2013 season).

2.5.4 Zooplankton and Macroinvertebrate reporting

For both zooplankton and littoral zone macroinvertebrates, biodiversity is summarized as taxonomic richness for certain taxonomic categories; for example, zooplankton is summarized for richness in Cladoceran and Copepoda, among other categories. In summing the richness, the count is the number of distinct taxa within that category. Due to taxonomic ambiguity, the taxa contributing to the count may be at the species, genus, family, or higher level of taxonomic resolution. This ambiguity is generally due to damaged or immature specimens, or unavailability of adequate taxonomic references.

Two additional metrics are provided: Shannon Diversity and Evenness. In brief, Shannon Diversity (or Shannon-Weaver Index) is a diversity measure based on the sum of the individual proportion of a taxa multiplied by the natural log of the proportion. It incorporates the concept of abundance and the number of species into a fuller measure of biodiversity. Evenness is a ratio of observed Shannon Diversity to a situation where the abundance is spread equally among species (e.g., Evenness of 1.0 indicates no one taxa is more abundant than the other; and the closer the Evenness to 0, the more a single or a few taxa dominate the sample numerically). Full details on these metrics are provided in the full protocol (Dinger et al. 2012).

2.6 Physical Habitat and Lake Morphometrics

The habitat of the lake is measured during a walk-around the lake perimeter, staying as close to the shoreline as possible. During the walk-around, a GPS unit (Trimble XH or similar) is used to record a detailed GIS (Geographic Information System) feature delineating the shoreline. When the crew member performing the walk-around observes a change in substrate at the water-shore interface, the substrate type GIS segment is recorded along with the feature, denoting the various substrate types present (boulders, bedrock, cobble, detritus, emergent macrophytes, submergent macrophytes, gravel, sand, fines, or woody debris). The crew member then estimates the percent occurrence of each substrate category for the segment (e.g., a specific segment might be composed of 80% bedrock, 15% gravel, and 5% woody debris). The segment length and percent of substrate type can then be used in a weighted average of overall lake shoreline substrate.

The recorded lake perimeter segments are combined in ArcGIS 10.2 to calculate an overall perimeter and lake area. These are then used to calculate Shoreline Development, the ratio of the actual shoreline to that of a circumference of a perfect circle of the same surface area. A perfectly round lake will approach 1, whereas a lake with a complex shoreline will have higher numbers of shoreline development. This metric is a reflection of the possibility of increased development of littoral communities, proportional to lake size.

3.0 Results

3.1 Lassen Volcanic National Park

Sampling occurred in Lassen Volcanic National Park from 20 July 2016 to 31 August 2016. A total of 30 probabilistically chosen ponds and lakes, and one judgment lake (Lake Helen) were visited. One of the 30 ponds and lakes were found to be dry (Table 1) resulting in a total of 29 probabilistic ponds and lakes sampled (Figure 5). Time constraints precluded visiting additional sites to make up for the dry lake. In future years (i.e., 2019 onward) this lake will be replaced with an oversample lake from the GRTS draw. Basic parameters for the 29 sampled ponds and lakes and the one judgment lake are presented in Table 2.

Table 1. Location of one dry lake encountered in Lassen Volcanic National Park. It was not sampled. Coordinates are in NAD1983 datum, UTM Zone 10N.

Site Code	Lake Name	X Coord	Y Coord	Date Visited
11037	Unnamed	643737	4481876	20160801

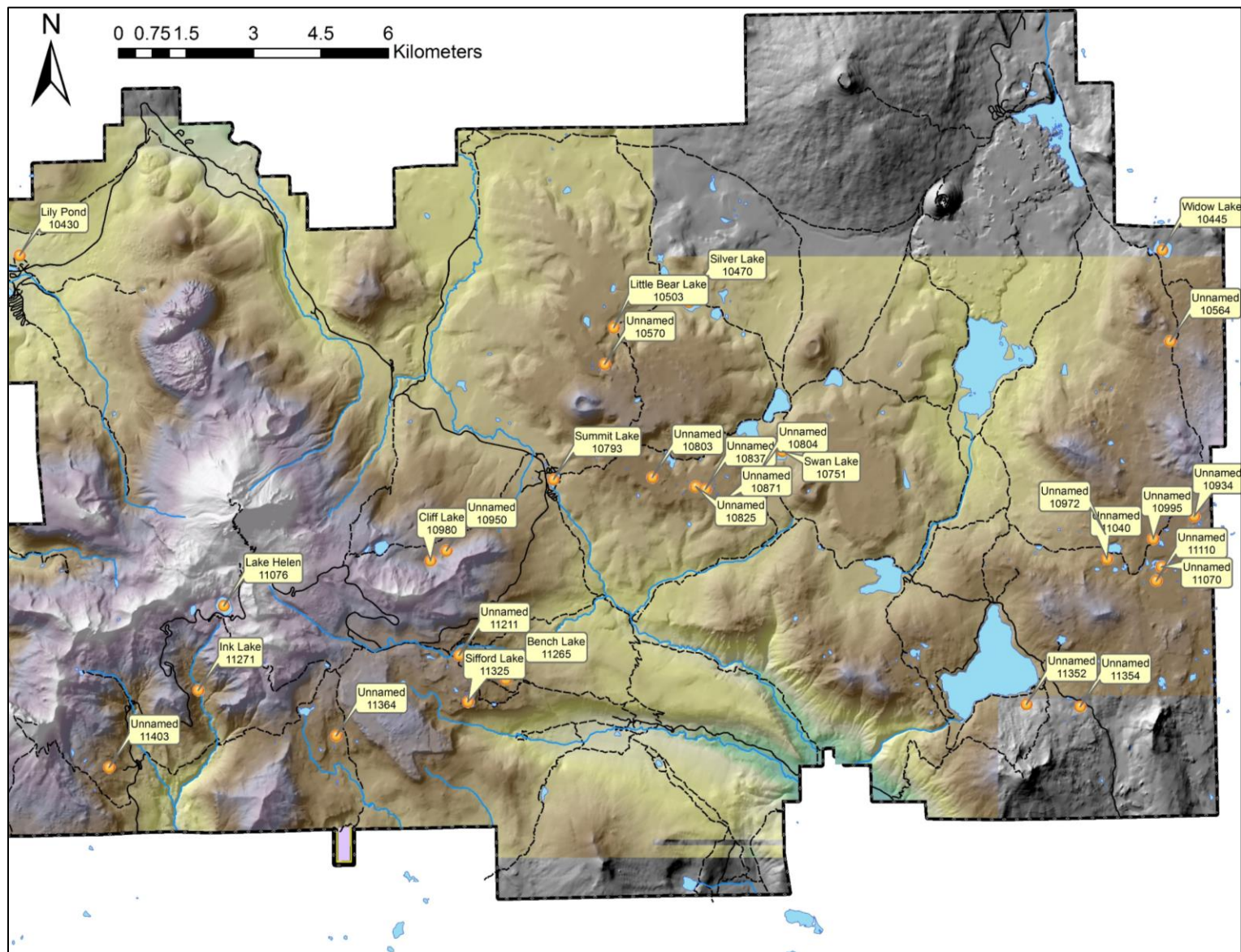


Figure 5. Locations of ponds and lakes sampled in Lassen Volcanic National Park, 2016. Lake Helen (11076) is the judgment site.

Table 2. Morphometric and location data for ponds and lakes sampled at Lassen Volcanic National Park, 2016.

Type	Site Code	Lake Name	UTM X Coord	UTM Y Coord	Date Sampled	Max Depth (m)	Area (m ²)	Area (ha)	Area (ac)	Circumference (m)	Shoreline Development ^E
Judgment ^A	11076	Lake Helen	626236	4480167	8/2/2016	35.7	112111	11.21	27.70	1259	1.06
Probalistic	10430	Lily Pond	621729	4488653	7/20/2016	2.0	1685	0.17	0.42	235	1.62
	10793	Summit Lake	633606	4483666	7/21/2016	2.5	55989	5.6	13.84	1087	1.30
	11211	Unnamed	631504	4479747	7/25/2016	1.7	2428	0.24	0.60	215	1.23
	11403	Unnamed	623716	4477252	7/26/2016	1.5	1169	0.12	0.29	170	1.40
	11271	Ink Lake	625701	4478966	7/27/2016	5.7	1116 ^B	0.11 ^B	0.27 ^B	164 ^B	1.39 ^B
	11364	Unnamed	628770	4477953	7/28/2016	1.4	3612	0.36	0.89	251	1.18
	11354	Unnamed	645319	4478603	8/1/2016	1.6	13667	1.37	3.38	672	1.62
	10980	Cliff Lake	630866	4481851	8/3/2016	3.6	22414	2.24	5.54	734	1.38
	10950 ^C	Unnamed	631219	4482079	8/3/2016	1.0	2725	0.27	0.67	226	1.22
	11352	Unnamed	644122	4478656	8/4/2016	1.3	1665	0.17	0.41	217	1.50
	11325	Sifford Lakes S	631699	4478711	8/9/2016	2.5	568	0.06	0.14	91	1.08
	10837	Unnamed	636982	4483446	8/10/2016	0.7	995	0.1	0.25	142	1.27
	10825	Unnamed	636764	4483507	8/10/2016	0.6	932	0.09	0.23	184	1.70
	10871	Unnamed	637329	4483145	8/11/2016	0.5	518	0.05	0.13	93	1.16
	10803	Unnamed	635802	4483710	8/11/2016	1.1	2503	0.25	0.62	318	1.80
	10804 ^D	Unnamed	638137	4483763	8/12/2016	1.2	2450	0.24	0.61	197	1.12
	10751	Swan Lake	638700	4484295	8/16/2016	6.9	70144	7.01	17.33	1179	1.26
	11265	Bench Lake	632551	4479207	8/17/2016	0.3	1553	0.16	0.38	160	1.15

^A Judgment site, Lake Helen, is not included in summary statistics.

^B Certain lakes were missing habitat lines, so size and shape parameters had to be reported for 2013 as estimates.

^C Lake 10950 was believed to be Lake 10968 by the 2016 crew.

^D Lake 10804 was believed to be Lake 10807 by the 2016 crew.

^E Ratio of the actual shoreline to that of a circumference of a perfect circle of the same surface area. A perfectly round lake will approach 1, whereas a lake with a complex shoreline will have higher numbers of shoreline development.

Table 2 (continued). Morphometric and location data for ponds and lakes sampled at Lassen Volcanic National Park, 2016.

Type	Site Code	Lake Name	UTM X Coord	UTM Y Coord	Date Sampled	Max Depth (m)	Area (m ²)	Area (ha)	Area (ac)	Circumference (m)	Shoreline Development ^E
Probalistic (continued)	10570	Unnamed	634742	4486235	8/18/2016	1.8	2108	0.21	0.52	216	1.33
	10503	Little Bear Lake	634947	4487042	8/18/2016	3.5	18944	1.89	4.68	548	1.12
	10470	Silver Lake	636611	4487609	8/23/2016	14.5	121383	12.14	29.99	1477	1.20
	10564	Unnamed	647319	4486743	8/24/2016	1.2	2378	0.24	0.59	214	1.24
	10445	Widow Lake	647144	4488772	8/25/2016	10.7	115354	11.54	28.5	1860	1.54
	11040	Unnamed	645916	4481889	8/29/2016	2.6	5956	0.6	1.47	327	1.19
	10972	Unnamed	645882	4482443	8/29/2016	1.4	1601	0.16	0.40	235	1.66
	10934	Unnamed	647856	4482841	8/30/2016	0.4	419	0.04	0.10	139	1.91
	10995	Unnamed	646944	4482336	8/30/2016	1.7	1856 ^B	0.19 ^B	0.45 ^B	224 ^B	1.47 ^B
	11110	Unnamed	647012	4481406	8/31/2016	0.9	1435	0.14	0.35	170	1.27
	11070	Unnamed	647126	4481717	8/31/2016	1.8	3264	0.33	0.81	239	1.18
Average	—	—	—	—	—	2.6	15891	1.59	3.93	413	1.36
SD	—	—	—	—	—	3.2	32698	3.27	8.08	444	0.22
Median	—	—	—	—	—	1.6	2378	0.24	0.59	224	1.27
Range	—	—	—	—	—	0.3 - 14.5	419 - 121383	0.04 - 12.14	0.1 - 29.99	91 - 1860	1.08 - 1.91

^A Judgment site, Lake Helen, is not included in summary statistics.

^B Certain lakes were missing habitat lines, so size and shape parameters had to be reported for 2013 as estimates.

^C Lake 10950 was believed to be Lake 10968 by the 2016 crew.

^D Lake 10804 was believed to be Lake 10807 by the 2016 crew.

^E Ratio of the actual shoreline to that of a circumference of a perfect circle of the same surface area. A perfectly round lake will approach 1, whereas a lake with a complex shoreline will have higher numbers of shoreline development.

The close proximity of ponds and lakes to one another caused two sampling errors by the 2016 field crew, when they sampled a neighboring pond instead of the correct pond that was sampled in 2013. The error was not known until GIS data collected was compared to previous years, along with mutual comparison to the master data of water bodies. In future years, sampling will consist of the original ponds. First, the crew sampled lake code 10950 instead of lake code 10968, which were 45 meters apart (Figure 6 and 7). Secondly, the crew sampled 10804 instead of 10807, which were 21 meters apart (Figure 8 and 9). Inclusion of site photo in future years as part of the navigating to sites will reduce or eliminate this error in future years. These two lakes, 10804 and 10950 are included in the park wide estimates of status, but won't be included in trend analyses.

As of this sampling, 26 lakes have been sampled in both 2013 and 2016. Twenty-eight lakes were sampled in 2013, and two of those were not sampled due to the location error (above) resulting in the 26 lakes.



Figure 6. View of Lake 10950 from Lake 10968 from 2013 field crew (looking north).



Figure 7. Looking south from Lake 10950 towards Lake 10968 from 2016 field crew.



Figure 8. Looking north from Lake 10807 towards Lake 10804 from 2013 field crew, field crew leader Kirsten Underwood in foreground.



Figure 9. Looking south from Lake 10804, 21 meters away from the proper Lake 10807 by the 2016 field crew.

The 29 probabilistically chosen ponds and lakes were mostly shallow, with an average depth of 2.6 m and a median depth of 1.6 m. The average surface area was 1.59 hectares, with a range of 0.04 to 12.14 hectares. In general, the common notion of a pond is associated with smaller surface areas, whereas a mountain lake is commonly associated with larger surface areas (Figure 10).

The average Shoreline Development Index for the 29 ponds and lakes sampled was 1.36 (note that the closer the index is to 1 the more the lake outline approaches a perfect circle).



Figure 10. Examples of the variety of Lassen Volcanic National Park ponds and lakes. Widow Lake (10445) – Top, the second largest areal lake sampled; Bottom, Unnamed pond (10564), one of the smaller areal lakes.

3.1.1 Physical substrate

Physical habitat characteristics for the Lassen Volcanic National Park ponds and lakes are presented in Table 3. Secchi Disk clarity is included in this table as a physical measurement, although it is a direct measurement of water clarity. At the majority of sites, the disk was visible through the water column to the bottom, resulting in a reading of NA (Not Applicable). In these cases, direct readings of turbidity are a better measure of water clarity than the Secchi Disk depth (see Water Quality, below).

The dominant substrate type at most ponds and lakes was fine sediment, although emergent vegetation, detritus, and woody debris were also common substrates. Lake Helen (11076), Unnamed (10950), and Little Bear Lake (10503) stand out as having higher prevalence of coarse substrate than other sites (e.g., boulders, cobbles, and gravel).

3.1.2 Water Chemistry

Water chemistry samples, taken either at the mid-point of shallow ponds (<2 m) or at the near surface and near bottom of deeper lakes, are presented in Table 4.

3.1.3 Water Quality

Water quality data, based on *in situ* real-time measurements taken with a probe, are presented in Table 5. The values are the site-specific averages for the depth profile measured, with deeper lakes having more measurements than shallower lakes. Even with this difference in number of measurements, the averages are still the best method for conveying the typical conditions in each lake, representing an integrated depth assessment. During the season, the turbidity probe was non-functional and could not be repaired. Data is reported as NA (Not Available).

Table 3. Physical substrate composition and Secchi Disk depths for ponds and lakes sampled in Lassen Volcanic National Park, 2016.

Type	Site Code	Lake Name	Sample Date	Secchi Disk Depth (m) ^A	Bed-rock	Boulder	Cobble	Gravel	Sand	Fines	Woody Debris	Emergent Vegetation	Sub-mergent Vegetation	Detritus
Judgment ^B	11076	Lake Helen	8/2/2016	16.65	0%	8%	15%	32%	0%	43%	0%	0%	0%	2%
Probablistic	10430	Lily Pond	7/20/2016	1.85	0%	0%	0%	0%	0%	20%	9%	71%	0%	0%
	10793	Summit Lake	7/21/2016	NA	0%	2%	1%	0%	14%	34%	13%	9%	0%	27%
	11211	Unnamed	7/25/2016	NA	0%	0%	17%	0%	0%	43%	7%	14%	0%	20%
	11403	Unnamed	7/26/2016	NA	0%	0%	0%	0%	0%	69%	12%	3%	0%	16%
	11271	Ink Lake	7/27/2016	4.15	0%	0%	0%	0%	0%	85%	5%	0%	0%	10%
	11364	Unnamed	7/28/2016	NA	0%	0%	0%	0%	0%	35%	10%	44%	0%	11%
	11354	Unnamed	8/1/2016	NA	0%	21%	4%	11%	0%	56%	0%	8%	0%	0%
	10950 ^C	Unnamed	8/3/2016	NA	0%	20%	20%	25%	25%	11%	0%	0%	0%	0%
	10980	Cliff Lake	8/3/2016	NA	0%	3%	7%	11%	11%	44%	14%	8%	0%	2%
	11352	Unnamed	8/4/2016	NA	0%	0%	0%	0%	0%	29%	7%	54%	0%	10%
	11325	Sifford Lakes S	8/9/2016	NA	0%	0%	0%	28%	0%	42%	4%	11%	0%	14%
	10825	Unnamed	8/10/2016	NA	0%	0%	0%	0%	0%	60%	15%	15%	0%	10%
	10837	Unnamed	8/10/2016	NA	0%	0%	0%	0%	0%	50%	10%	30%	0%	10%
	10803	Unnamed	8/11/2016	NA	0%	7%	0%	0%	0%	45%	15%	26%	0%	6%

^A At the majority of sites, the disk was visible through the water column to the bottom, resulting in a reading of NA (Not Applicable).

^B Judgment site, Lake Helen, is not included in summary statistics.

^C Lake 10950 was believed to be Lake 10968 by the 2016 crew.

^D Lake 10804 was believed to be Lake 10807 by the 2016 crew.

Table 3 (continued). Physical substrate composition and Secchi Disk depths for ponds and lakes sampled in Lassen Volcanic National Park, 2016.

Type	Site Code	Lake Name	Sample Date	Secchi Disk Depth (m) ^A	Bed-rock	Boulder	Cobble	Gravel	Sand	Fines	Woody Debris	Emergent Vegetation	Sub-mergent Vegetation	Detritus
Probabilistic (continued)	10871	Unnamed	8/11/2016	NA	0%	0%	0%	0%	0%	15%	5%	60%	0%	20%
	10804 ^D	Unnamed	8/12/2016	NA	0%	15%	0%	0%	0%	60%	5%	10%	0%	10%
	10751	Swan Lake	8/16/2016	NA	0%	3%	3%	21%	28%	18%	14%	3%	0%	10%
	11265	Bench Lake	8/17/2016	NA	0%	5%	5%	8%	0%	75%	0%	0%	0%	7%
	10503	Little Bear Lake	8/18/2016	NA	0%	10%	15%	0%	40%	10%	5%	10%	5%	5%
	10570	Unnamed	8/18/2016	NA	0%	0%	0%	0%	0%	60%	10%	15%	0%	15%
	10470	Silver Lake	8/23/2016	11.6	0%	1%	5%	13%	51%	4%	11%	0%	0%	13%
	10564	Unnamed	8/24/2016	NA	0%	5%	0%	0%	0%	40%	5%	40%	0%	10%
	10445	Widow Lake	8/25/2016	7.7	1%	2%	5%	4%	40%	24%	5%	18%	0%	1%
	10972	Unnamed	8/29/2016	NA	0%	4%	7%	0%	0%	70%	4%	0%	0%	15%
	11040	Unnamed	8/29/2016	NA	0%	0%	0%	0%	0%	65%	15%	13%	0%	8%
	10934	Unnamed	8/30/2016	NA	0%	5%	10%	0%	0%	60%	5%	5%	15%	0%
	10995	Unnamed	8/30/2016	NA	0%	5%	0%	0%	0%	45%	25%	5%	0%	20%
	11070	Unnamed	8/31/2016	NA	0%	3%	6%	0%	0%	52%	8%	25%	0%	5%
	11110	Unnamed	8/31/2016	NA	0%	10%	5%	0%	0%	65%	10%	0%	0%	10%

^A At the majority of sites, the disk was visible through the water column to the bottom, resulting in a reading of NA (Not Applicable).

^B Judgment site, Lake Helen, is not included in summary statistics.

^C Lake 10950 was believed to be Lake 10968 by the 2016 crew.

^D Lake 10804 was believed to be Lake 10807 by the 2016 crew.

Table 3 (continued). Physical substrate composition and Secchi Disk depths for ponds and lakes sampled in Lassen Volcanic National Park, 2016.

Type	Site Code	Lake Name	Sample Date	Secchi Disk Depth (m) ^A	Bed-rock	Boulder	Cobble	Gravel	Sand	Fines	Woody Debris	Emergent Vegetation	Sub-mergent Vegetation	Detritus
Average	—	—	—	—	0%	4%	4%	4%	7%	44%	9%	17%	1%	10%
SD	—	—	—	—	0%	6%	6%	8%	15%	21%	6%	19%	3%	7%
Median	—	—	—	—	0%	2%	0%	0%	0%	45%	8%	10%	0%	10%
Range	—	—	—	—	0 - 1%	0 - 21%	0 - 20%	0 - 28%	0 - 51%	4 - 85%	0 - 25%	0 - 71%	0 - 15%	0 - 27%

^A At the majority of sites, the disk was visible through the water column to the bottom, resulting in a reading of NA (Not Applicable).

^B Judgment site, Lake Helen, is not included in summary statistics.

^C Lake 10950 was believed to be Lake 10968 by the 2016 crew.

^D Lake 10804 was believed to be Lake 10807 by the 2016 crew.

Table 4. Water chemistry results for ponds and lakes of Lassen Volcanic National Park, 2016.

Type	Site Code	Lake Name	Date	Depth	Total Nitrogen (mg/L)	Total Phosphorous (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Dissolved Organic Carbon (mg/L)
Judgment ^B	11076	Lake Helen	8/2/2016	Shallow	0.04	0.000 ^A	0.1	0.04	0.16	0.07	0.38	0.05	0.72
	11076	Lake Helen	8/2/2016	Deep	0.05	0.001 ^A	0.14	0.05	0.17	0.07	0.47	0.04	0.46
Probalistic	10430	Lily Pond	7/20/2016	Shallow	0.28	0.068	0.31	0.05	9.14	2.85	6.22	4.47	2.38
	10793	Summit Lake	7/21/2016	Shallow	0.21	0.004	0.26	0.01 ^A	1.59	0.54	2.8	0.66	2.88
	10793	Summit Lake	7/21/2016	Deep	0.88	0.029	0.29	0.01 ^A	1.58	0.52	2.68	0.65	2.35
	11211	Unnamed	7/25/2016	Shallow	0.47	0.039	0.12	0.01 ^A	0.12	0.07	0.26	0.07	3.35
	11403	Unnamed	7/26/2016	Shallow	0.03	0.001 ^A	0.27	38.83	7.34	1.29	29.01	1.7	0.47
	11271	Ink Lake	7/27/2016	Shallow	0.15	0.009	0.17	28.61	3.8	0.22	37.59	3.54	0.93
	11271	Ink Lake	7/27/2016	Deep	0.19	0.015	0.18	27.4	3.66	0.27	36.88	3.47	0.64
	11364	Unnamed	7/28/2016	Shallow	0.34	0.013	0.19	0.05	0.66	0.13	0.78	0.17	4.06
	11354	Unnamed	8/1/2016	Shallow	0.35	0.023	0.17	0.02	0.82	0.3	1.47	0.52	3.37
	10950 ^C	Unnamed	8/3/2016	Shallow	0.26	0.017	0.14	0.08	0.41	0.13	0.83	0.12	1.32
	10980	Cliff Lake	8/3/2016	Shallow	0.08	0.016	0.23	0.21	2.32	0.52	7.51	4.56	0.7
	10980	Cliff Lake	8/3/2016	Deep	0.11	0.02	0.25	0.22	2.38	0.55	8.08	4.79	0.43
	11352	Unnamed	8/4/2016	Shallow	0.67	0.05	0.35	0.01 ^A	0.1	0.38	0.61	0.25	10.07

^A Values are below the quantifiable limit of the analytical technique, but are still included in the park wide averages.

^B Judgment site, Lake Helen, is not included in summary statistics.

^C Lake 10950 was believed to be Lake 10968 by the 2016 crew.

^D Lake 10804 was believed to be Lake 10807 by the 2016 crew.

Table 4 (continued). Water chemistry results for ponds and lakes of Lassen Volcanic National Park, 2016.

Type	Site Code	Lake Name	Date	Depth	Total Nitrogen (mg/L)	Total Phosphorous (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Dissolved Organic Carbon (mg/L)
Probalistic (continued)	11325	Sifford Lakes S	8/9/2016	Shallow	0.34	0.019	0.18	0.01 ^A	0.11	0.12	0.32	0.14	3.63
	11325	Sifford Lakes S	8/9/2016	Deep	0.33	0.018	0.22	0.01 ^A	0.1	0.11	0.28	0.13	3.39
	10825	Unnamed	8/10/2016	Shallow	0.53	0.03	0.14	0.00 ^A	0.11	0.28	0.42	0.47	7.79
	10837	Unnamed	8/10/2016	Shallow	0.62	0.03	0.11	0.00 ^A	0.1	0.17	0.39	0.51	6.86
	10803	Unnamed	8/11/2016	Shallow	0.53	0.034	0.17	0.00 ^A	0.2	0.21	0.53	0.49	7.07
	10871	Unnamed	8/11/2016	Shallow	0.72	0.028	0.24	0.01 ^A	0.21	0.66	0.57	0.71	14.45
	10804 ^D	Unnamed	8/12/2016	Shallow	0.63	0.035	0.23	0.01 ^A	0.18	0.5	0.38	0.64	6.84
	10751	Swan Lake	8/16/2016	Shallow	0.16	0.006	0.18	0.03	0.14	0.14	0.21	0.26	2.12
	10751	Swan Lake	8/16/2016	Deep	0.16	0.006	0.17	0.03	0.15	0.14	0.23	0.25	1.96
	11265	Bench Lake	8/17/2016	Shallow	0.89	0.088	0.36	0.04	0.5	0.28	0.3	0.17	7
	10503	Little Bear Lake	8/18/2016	Shallow	0.24	0.012	0.24	0.02	0.29	0.43	0.46	0.28	2.82
	10503	Little Bear Lake	8/18/2016	Deep	0.23	0.011	0.25	0.02	0.28	0.42	0.43	0.27	2.98
	10570	Unnamed	8/18/2016	Shallow	0.55	0.024	0.36	0.01 ^A	0.25	0.27	0.51	0.3	5.52
	10980	Unnamed	8/22/2016	Shallow	0.09	0.014	0.28	0.24	2.27	0.54	8.69	4.84	0.62
	10980	Unnamed	8/22/2016	Deep	0.15	0.023	0.28	0.26	2.37	0.6	9.17	5.04	0.73

^A Values are below the quantifiable limit of the analytical technique, but are still included in the park wide averages.

^B Judgment site, Lake Helen, is not included in summary statistics.

^C Lake 10950 was believed to be Lake 10968 by the 2016 crew.

^D Lake 10804 was believed to be Lake 10807 by the 2016 crew.

Table 4 (continued). Water chemistry results for ponds and lakes of Lassen Volcanic National Park, 2016.

Type	Site Code	Lake Name	Date	Depth	Total Nitrogen (mg/L)	Total Phosphorous (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Dissolved Organic Carbon (mg/L)
Probalistic (continued)	10470	Silver Lake	8/23/2016	Shallow	0.15	0.003	0.34	0.04	0.42	0.54	0.61	0.43	2.18
	10470	Silver Lake	8/23/2016	Deep	0.68	0.046	0.66	0.04	0.44	0.58	0.7	0.47	2.01
	10564	Unnamed	8/24/2016	Shallow	0.89	0.036	0.29	0.01 ^A	0.26	0.3	0.62	1.06	10.87
	10445	Widow Lake	8/25/2016	Shallow	0.25	0.007	0.25	0.01 ^A	1.07	0.89	2.38	1.15	3.54
	10445	Widow Lake	8/25/2016	Deep	0.28	0.012	0.15	0.01 ^A	1.1	0.86	2.62	1.24	3.07
	10972	Unnamed	8/29/2016	Shallow	0.52	0.029	0.46	0.01 ^A	0.37	0.19	0.67	0.88	3.29
	11040	Unnamed	8/29/2016	Shallow	0.27	0.011	0.32	0.01 ^A	0.51	0.2	0.51	0.74	3.28
	11040	Unnamed	8/29/2016	Deep	0.31	0.011	0.29	0.16	0.5	0.2	0.52	0.75	6.37
	10934	Unnamed	8/30/2016	Shallow	0.81	0.018	0.53	0.01 ^A	0.51	0.4	0.74	1.69	11.06
	10995	Unnamed	8/30/2016	Shallow	0.64	0.043	0.31	0.01 ^A	0.13	0.14	0.53	0.57	5.87
	11070	Unnamed	8/31/2016	Shallow	0.42	0.012	0.33	0.00 ^A	0.21	0.14	0.29	0.46	4.5
	11110	Unnamed	8/31/2016	Shallow	0.56	0.028	0.25	0.00 ^A	0.15	0.11	0.36	0.53	4.82
Average	—	—	—	—	0.4	0.023	0.26	2.44	1.17	0.43	4.2	1.24	4.19
SD	—	—	—	—	0.25	0.018	0.11	8.53	1.91	0.47	9.15	1.54	3.27
Median	—	—	—	—	0.34	0.019	0.25	0.02	0.42	0.29	0.61	0.55	3.32
Range	—	—	—	—	0.03 - 0.89	0 - 0.088	0.11 - 0.66	0.0 - 38.83	0.1 - 9.14	0.07 - 2.85	0.21 - 37.59	0.07 - 5.04	0.43 - 14.45

^A Values are below the quantifiable limit of the analytical technique, but are still included in the park wide averages.

^B Judgment site, Lake Helen, is not included in summary statistics.

^C Lake 10950 was believed to be Lake 10968 by the 2016 crew.

^D Lake 10804 was believed to be Lake 10807 by the 2016 crew.

Table 5. Averaged water quality profiles for ponds and lakes of Lassen Volcanic National Park, 2016.

Type	Site Code	Lake Name	Date Sampled	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	Turbidity (NTUs) ^A	Oxidation-Reduction Potential (mV)	Specific Conductivity (μS/cm)	Temperature (°C)	pH
Judgment ^B	11076	Lake Helen	8/2/2016	115.9	10.3	NA	214.1	3	8	5.59
Probabilistic	10430	Lily Pond	7/20/2016	67.4	5.9	NA	136	109.8	11.8	6.87
	10793	Summit Lake	7/21/2016	102.3	7.4	NA	133	28.3	19.1	7.49
	11211	Unnamed	7/25/2016	85	6	NA	173.2	3	20.8	5.36
	11403	Unnamed	7/26/2016	109.9	10	NA	244	244.3	8.2	5.3
	11271	Ink Lake	7/27/2016	87.8	7.1	NA	129.2	251.8	13.8	7.18
	11364	Unnamed	7/28/2016	93.7	6.7	NA	167.2	7	19.2	5.94
	11354	Unnamed	8/1/2016	97.2	6.6	NA	152.5	15	22.4	6.95
	10950 ^C	Unnamed	8/3/2016	105.6	7.1	NA	171.3	7	21.8	6.71
	10980	Cliff Lake	8/3/2016	123.1	9.8	NA	161.6	89.9	13.6	8.67
	11352	Unnamed	8/4/2016	54.6	4	NA	161.7	6.7	18.4	5.4
	11325	Sifford Lakes S	8/9/2016	82.4	5.9	NA	146.2	3	18.2	5.62
	10825	Unnamed	8/10/2016	63.5	5.1	NA	192.5	7	13.8	5.68
	10837	Unnamed	8/10/2016	76	5.9	NA	174.5	6	15.2	5.88
	10803	Unnamed	8/11/2016	83.8	6.2	NA	193.8	8.5	17.9	5.98
	10871	Unnamed	8/11/2016	74	5.9	NA	198.5	11	14.2	5.67
	10804 ^D	Unnamed	8/12/2016	86.5	6.6	NA	175.7	9	17.1	6.07
	10751	Swan Lake	8/16/2016	91.2	6.4	NA	200.3	4	20.6	6.6
	11265	Bench Lake	8/17/2016	77.2	5.9	NA	183	7	16.3	6.03

^A Turbidity probe was non-functional during sampling, resulting in NA (Not Available).

^B Judgment site, Lake Helen, is not included in summary statistics.

^C Lake 10950 was believed to be Lake 10968 by the 2016 crew.

^D Lake 10804 was believed to be Lake 10807 by the 2016 crew.

Table 5 (continued). Averaged water quality profiles for ponds and lakes of Lassen Volcanic National Park, 2016.

Type	Site Code	Lake Name	Date Sampled	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	Turbidity (NTUs) ^A	Oxidation-Reduction Potential (mV)	Specific Conductivity (µS/cm)	Temperature (°C)	pH
Probabilistic (continued)	10503	Little Bear Lake	8/18/2016	102.4	7.1	NA	187.6	7	20.8	6.79
	10570	Unnamed	8/18/2016	93.8	6.5	NA	179.5	6	20.8	5.86
	10470	Silver Lake	8/23/2016	109.3	7.8	NA	157.8	10.1	20	6.77
	10564	Unnamed	8/24/2016	79.3	5.8	NA	167.7	12	18	6.13
	10445	Widow Lake	8/25/2016	114.5	8.3	NA	156.7	28.4	19.1	7.93
	10972	Unnamed	8/29/2016	83.6	6.5	NA	163.6	10.1	15.5	6.81
	11040	Unnamed	8/29/2016	95.2	7	NA	197.4	11	18.2	6.87
	10934	Unnamed	8/30/2016	94.4	6.8	NA	129.5	19	18	7.03
	10995	Unnamed	8/30/2016	61.8	4.7	NA	188.8	7.8	16.1	5.95
	11070	Unnamed	8/31/2016	89.2	6.8	NA	162.1	5.2	16.1	6.51
	11110	Unnamed	8/31/2016	86.4	6.3	NA	156.7	6	18.2	6.2
Average	—	—	—	88.7	6.6	—	170.4	32.4	17.3	6.42
SD	—	—	—	16.1	1.3	—	25	64.4	3.2	0.79
Median	—	—	—	87.8	6.5	—	167.7	8.5	18	6.2
Range	—	—	—	54.6 - 123.1	4 - 10	—	129.2 - 244	3 - 251.8	8.2 - 22.4	5.3 - 8.67

^A Turbidity probe was non-functional during sampling, resulting in NA (Not Available).

^B Judgment site, Lake Helen, is not included in summary statistics.

^C Lake 10950 was believed to be Lake 10968 by the 2016 crew.

^D Lake 10804 was believed to be Lake 10807 by the 2016 crew.

Two ponds and lakes stand out as being different from other ponds and lakes at Lassen Volcanic National Park – Ink Lake (11271) and Unnamed 11403 – when examining water chemistry and water quality. Both are high in anions and cations, especially SO_4^{2-} (Sulfate, Table 3), and are high in specific conductivity. Both of these lakes occur in the southwest part of the park, in the area of Little Hot Springs Valley, Bumpass Hell, and Sulphur Works areas.

3.1.4 Zooplankton

Zooplankton summary metrics are provided in Table 6. A full listing of zooplankton taxa is presented in Appendix A. The average number of taxa at the probabilistically chosen sites was 12.9, with a minimum of 3 (at Unnamed site 10968) and a maximum of 23 (Unnamed site, 10934). The judgment site, Lake Helen, had one collected taxa. Most of the average taxonomic richness was in Cladoceran diversity.

3.1.5 Littoral Zone Macroinvertebrates

Macroinvertebrate metrics are presented in Table 7, with a complete list of taxa collected available in Appendix B. The highest taxonomic richness was at an unnamed site (11364), a site with large amounts of submergent and emergent vegetation. The lowest taxonomic richness was at Unnamed pond 10968. Chironomidae (common name: midges) made up most of the diversity with an average taxonomic richness of 12.1 across the probabilistic choose sites, with a maximum richness of 18 at Unnamed site (10803).

3.1.6 Vertebrates

Only four vertebrate species were collected or observed using gill nets and visual encounter surveys (Table 8). For highly abundant observations, numbers were often estimated. Long-toed Salamanders (*Ambystoma macrodactylum*) were seen at 10 sites, and most abundant at Cliff Lake, 10980. Western Toads (*Anaxyrus boreas*) were observed at three lakes. Pacific Tree Frogs (*Pseudacris regilla*) were the most common and widespread at 18 of the 29 probabilistic sites. Gill netting only captured one fish species, Lahontan Redside (*Richardsonius egregius*) (Figure 11), at Widow Lake (10445). In 2013, these were mistaken identified and reported as Golden Shiners (*Notemigonus crysoleucas*).

Table 6. Zooplankton metrics for ponds and lakes sampled at Lassen Volcanic National Park, 2016.

Type	Site Code	Lake Name	Date Sampled	Taxa Richness	Cladoceran Richness	Calanoida Richness	Rotifer Richness	Cyclopoida Richness	Other Richness ^A	Shannon Diversity	Evenness
Judgement ^B	11076	Lake Helen	8/2/2016	1	1	0	0	0	0	0	–
Probabilistic	10430	Lily Pond	7/20/2016	18	7	0	2	2	4	1.84	0.64
	10445	Widow Lake	8/25/2016	5	3	0	1	1	0	0.1	0.06
	10470	Silver Lake	8/23/2016	11	2	6	3	0	0	1.28	0.53
	10503	Little Bear Lake	8/18/2016	12	5	4	1	0	0	0.6	0.24
	10564	Unnamed	8/24/2016	16	7	2	2	2	1	1.54	0.56
	10570	Unnamed	8/18/2016	15	6	2	2	1	1	0.31	0.12
	10751	Swan Lake	8/16/2016	9	4	3	1	1	0	1.54	0.7
	10793	Summit Lake	7/21/2016	18	7	4	1	2	2	1.09	0.38
	10803	Unnamed	8/11/2016	13	5	2	2	1	1	1.29	0.5
	10804 ^D	Unnamed	8/12/2016	14	6	3	2	1	1	1.28	0.48
	10825	Unnamed	8/10/2016	16	7	2	1	1	3	0.77	0.28
	10837	Unnamed	8/10/2016	16	7	2	3	1	1	1.25	0.45
	10871	Unnamed	8/11/2016	13	4	2	2	2	2	1.63	0.63
	10934	Unnamed	8/30/2016	27	9	1	1	3	6	2.19	0.66
	10950 ^C	Unnamed	8/3/2016	3	0	3	0	0	0	0.08	0.07
	10972	Unnamed	8/29/2016	16	9	3	1	1	2	0.04	0.01
	10980	Cliff Lake	8/3/2016	6	2	4	0	0	0	0.51	0.28
	10995	Unnamed	8/30/2016	17	6	1	3	2	3	1.05	0.37

^A Other richness includes aquatic mites and insect larvae.

^B Judgment site, Lake Helen, is not included in summary statistics.

^C Lake 10950 was believed to be Lake 10968 by the 2016 crew.

^D Lake 10804 was believed to be Lake 10807 by the 2016 crew.

Table 6 (continued). Zooplankton metrics for ponds and lakes sampled at Lassen Volcanic National Park, 2016.

Type	Site Code	Lake Name	Date Sampled	Taxa Richness	Cladoceran Richness	Calanoida Richness	Rotifer Richness	Cyclopoida Richness	Other Richness ^A	Shannon Diversity	Evenness
Probabilistic (continued)	11040	Unnamed	8/29/2016	13	4	4	1	1	1	1.48	0.58
	11070	Unnamed	8/31/2016	11	5	4	1	1	0	0.4	0.17
	11110	Unnamed	8/31/2016	20	8	2	2	4	4	1.75	0.59
	11211	Unnamed	7/25/2016	10	5	2	2	0	0	0.97	0.42
	11265	Bench Lake	8/17/2016	6	2	2	0	0	2	0.42	0.23
	11271	Ink Lake	7/27/2016	11	3	1	1	2	3	0.66	0.27
	11325	Sifford Lakes S	8/9/2016	13	6	3	1	1	0	1.28	0.5
	11352	Unnamed	8/4/2016	17	7	2	3	1	3	0.93	0.33
	11354	Unnamed	8/1/2016	6	2	2	1	1	0	1.12	0.63
	11364	Unnamed	7/28/2016	14	6	4	1	1	1	0.62	0.24
	11403	Unnamed	7/26/2016	7	3	1	0	1	1	1.84	0.95
Average	—	—	—	12.9	5.1	2.4	1.4	1.2	1.4	1.03	0.41
SD	—	—	—	5.2	2.3	1.4	0.9	0.9	1.5	0.58	0.22
Median	—	—	—	13	5	2	1	1	1	1.09	0.42
Range	—	—	—	3 - 27	0 - 9	0 - 6	0 - 3	0 - 4	0 - 6	0.04 - 2.19	0.01 - 0.95

^A Other richness includes aquatic mites and insect larvae.

^B Judgment site, Lake Helen, is not included in summary statistics.

^C Lake 10950 was believed to be Lake 10968 by the 2016 crew.

^D Lake 10804 was believed to be Lake 10807 by the 2016 crew.

Table 7. Macroinvertebrate metrics collected in pond and lake littoral zones in Lassen Volcanic National Park, 2016.

Type	Site Code	Lake Name	Date Sampled	Total Taxa Richness	Ephemeroptera Richness	Trichoptera Richness	Odonata Taxa Richness	Coleoptera Richness	Diptera Richness (non-Chironomidae)	Chironomidae Richness	Shannon Diversity	Evenness
Judgment ^A	11076	Lake Helen	8/2/2016	4	0	1	0	2	0	1	1.02	0.73
Probabilistic	10430	Lily Pond	7/20/2016	37	0	1	2	4	4	14	2.43	0.67
	10793	Summit Lake	7/21/2016	35	2	4	3	1	1	13	2.95	0.83
	11211	Unnamed	7/25/2016	29	1	1	4	1	0	14	2.24	0.67
	11403	Unnamed	7/26/2016	28	0	1	0	2	2	14	2.57	0.77
	11271	Ink Lake	7/27/2016	25	1	1	2	1	1	10	2.46	0.76
	11364	Unnamed	7/28/2016	44	1	2	5	2	3	15	2.74	0.72
	11354	Unnamed	8/1/2016	27	1	0	1	4	1	11	2.64	0.8
	10950 ^B	Unnamed	8/3/2016	11	1	0	0	0	1	5	0.9	0.38
	10980	Cliff Lake	8/3/2016	36	1	2	1	2	3	15	2.39	0.67
	11352	Unnamed	8/4/2016	24	0	2	4	1	1	7	2.04	0.64
	11325	Sifford Lakes S	8/9/2016	32	1	3	4	0	1	13	2.33	0.67
	10825	Unnamed	8/10/2016	35	0	1	1	5	0	15	2.59	0.73
	10837	Unnamed	8/10/2016	30	0	1	3	4	2	15	2.27	0.67

^A Judgment site, Lake Helen, is not included in summary statistics.

^B Lake 10950 was believed to be Lake 10968 by the 2016 crew.

^C Lake 10804 was believed to be Lake 10807 by the 2016 crew.

Table 7 (continued). Macroinvertebrate metrics collected in pond and lake littoral zones in Lassen Volcanic National Park, 2016.

Type	Site Code	Lake Name	Date Sampled	Total Taxa Richness	Ephemeroptera Richness	Trichoptera Richness	Odonata Taxa Richness	Coleoptera Richness	Diptera Richness (non-Chironomidae)	Chironomidae Richness	Shannon Diversity	Evenness
Probabilistic (continued)	10803	Unnamed	8/11/2016	41	0	2	2	2	1	17	2.95	0.8
	10871	Unnamed	8/11/2016	37	1	2	3	2	2	14	2.88	0.8
	10804 ^C	Unnamed	8/12/2016	35	1	2	2	1	2	14	2.77	0.78
	10751	Swan Lake	8/16/2016	40	2	5	3	2	1	12	2.85	0.77
	11265	Bench Lake	8/17/2016	19	1	2	1	3	0	5	1.91	0.65
	10503	Little Bear Lake	8/18/2016	28	1	3	4	1	0	12	2.25	0.67
	10570	Unnamed	8/18/2016	35	0	2	3	1	2	14	1.87	0.53
	10470	Silver Lake	8/23/2016	37	2	5	2	0	2	15	3.06	0.85
	10564	Unnamed	8/24/2016	29	0	0	1	2	1	11	2.52	0.75
	10445	Widow Lake	8/25/2016	31	1	3	3	0	1	12	2.89	0.84
	10972	Unnamed	8/29/2016	32	1	2	2	1	1	13	2.1	0.61
	11040	Unnamed	8/29/2016	19	1	4	1	0	2	7	2.45	0.83
	10934	Unnamed	8/30/2016	39	1	2	3	3	2	14	3.01	0.82
	10995	Unnamed	8/30/2016	27	1	1	2	1	1	11	1.93	0.58
	11070	Unnamed	8/31/2016	21	1	2	3	0	2	8	2.06	0.68
	11110	Unnamed	8/31/2016	34	1	2	3	1	1	11	2.25	0.64

^A Judgment site, Lake Helen, is not included in summary statistics.

^B Lake 10950 was believed to be Lake 10968 by the 2016 crew.

^C Lake 10804 was believed to be Lake 10807 by the 2016 crew.

Table 7 (continued). Macroinvertebrate metrics collected in pond and lake littoral zones in Lassen Volcanic National Park, 2016.

Type	Site Code	Lake Name	Date Sampled	Total Taxa Richness	Ephemeroptera Richness	Trichoptera Richness	Odonata Taxa Richness	Coleoptera Richness	Diptera Richness (non-Chironomidae)	Chironomidae Richness	Shannon Diversity	Evenness
Average	—	—	—	30.9	0.8	2	2.3	1.6	1.4	12.1	2.42	0.71
SD	—	—	—	7.4	0.6	1.3	1.3	1.4	0.9	3.1	0.46	0.11
Median	—	—	—	32	1	2	2	2	1	13	2.45	0.72
Range	—	—	—	11 - 44	0 - 2	0 - 5	0 - 5	0 - 5	0 - 4	5 -17	0.9 - 3.06	0.38 - 0.85

^A Judgment site, Lake Helen, is not included in summary statistics.

^B Lake 10950 was believed to be Lake 10968 by the 2016 crew.

^C Lake 10804 was believed to be Lake 10807 by the 2016 crew.

Table 8. Number of vertebrates encountered at Lassen Volcanic National Park sampling sites during gill netting and visual encounter surveys, 2016.

Type	Site Code	Lake Name	Date Sampled	Long-Toed Salamander (<i>Ambystoma macrodactylum</i>)	Western Toad (<i>Anaxyrus boreas</i>)	Pacific Tree Frog (<i>Pseudacris regilla</i>)	Unknown Tadpole	Lahontan Redside (<i>Richardsonius egregius</i>)
Judgment	11076	Lake Helen	8/2/2016	0	0	0	0	0
Probabilistic	10430	Lily Pond	7/20/2016	0	0	2	0	0
	10793	Summit Lake	7/21/2016	0	1	0	0	0
	11211	Unnamed	7/25/2016	0	0	0	1	0
	11403	Unnamed	7/26/2016	0	0	0	0	0
	11271	Ink Lake	7/27/2016	0	0	0	10	0
	11364	Unnamed	7/28/2016	0	0	0	5	0
	11354	Unnamed	8/1/2016	1	0	2	30	0
	10980	Cliff Lake	8/3/2016	400	5	10	5000	0
	10950 ^A	Unnamed	8/3/2016	1	0	0	25	0
	11352	Unnamed	8/4/2016	3	0	0	5	0
	11325	Sifford Lakes S	8/9/2016	0	0	0	1	0
	10837	Unnamed	8/10/2016	1	0	15	10	0
	10825	Unnamed	8/10/2016	1	0	0	5	0
	10803	Unnamed	8/11/2016	0	0	0	10	0
	10871	Unnamed	8/11/2016	0	0	10	20	0
	10804 ^B	Unnamed	8/12/2016	0	0	25	5	0
	10751	Swan Lake	8/16/2016	0	0	2	20	0
	11265	Bench Lake	8/17/2016	1	0	100	100	0
	10570	Unnamed	8/18/2016	0	0	3	0	0

^A Lake 10950 was believed to be Lake 10968 by the 2016 crew.

^B Lake 10804 was believed to be Lake 10807 by the 2016 crew.

Table 8 (continued). Number of vertebrates encountered at Lassen Volcanic National Park sampling sites during gill netting and visual encounter surveys, 2016.

Type	Site Code	Lake Name	Date Sampled	Long-Toed Salamander (<i>Ambystoma macrodactylum</i>)	Western Toad (<i>Anaxyrus boreas</i>)	Pacific Tree Frog (<i>Pseudacris regilla</i>)	Unknown Tadpole	Lahontan Redside (<i>Richardsonius egregius</i>)
Probabilistic (continued)	10503	Little Bear Lake	8/18/2016	0	0	30	100	0
	10470	Silver Lake	8/23/2016	1	1	1	10	0
	10564	Unnamed	8/24/2016	2	0	10	0	0
	10445	Widow Lake	8/25/2016	0	0	40	0	12
	11040	Unnamed	8/29/2016	0	0	4	5	0
	10972	Unnamed	8/29/2016	1	0	1	0	0
	10934	Unnamed	8/30/2016	0	0	2	1	0
	10995	Unnamed	8/30/2016	0	0	0	0	0
	11110	Unnamed	8/31/2016	0	0	8	0	0
	11070	Unnamed	8/31/2016	0	0	5	0	0

^A Lake 10950 was believed to be Lake 10968 by the 2016 crew.

^B Lake 10804 was believed to be Lake 10807 by the 2016 crew.



Figure 11. Lahontan Redside (*Richardsonius egregius*) from Widow Lake, 10455.

3.2 Crater Lake National Park

Sampling occurred in Crater Lake National Park from 13 September 2013 to 16 September 2013. A total of six mountain ponds and lakes were found to be potentially perennial from site visits in 2008 (25 visited) and 2013 (16 visited) (see Dinger 2016 for details). All of the six sites sampled comprise the known population of perennial lentic habitats in Crater Lake National Park outside of the caldera sampleable under this protocol.

The six ponds sampled were mostly shallow (maximum depth was 1.6 m at CRLAWQL04, Spruce Lake) and located in the southwest portion of the park (except for Spruce Lake; Figure 12). Table 9 presents basic morphometric and location data for the six ponds sampled. The average surface area was 0.17 hectares, with the largest being Spruce Lake at 0.39 hectares. Spruce Lake, despite the name, is more representative of a pond than a lake (see Figure 13 for examples of sampled Crater Lake National Park lentic habitats).

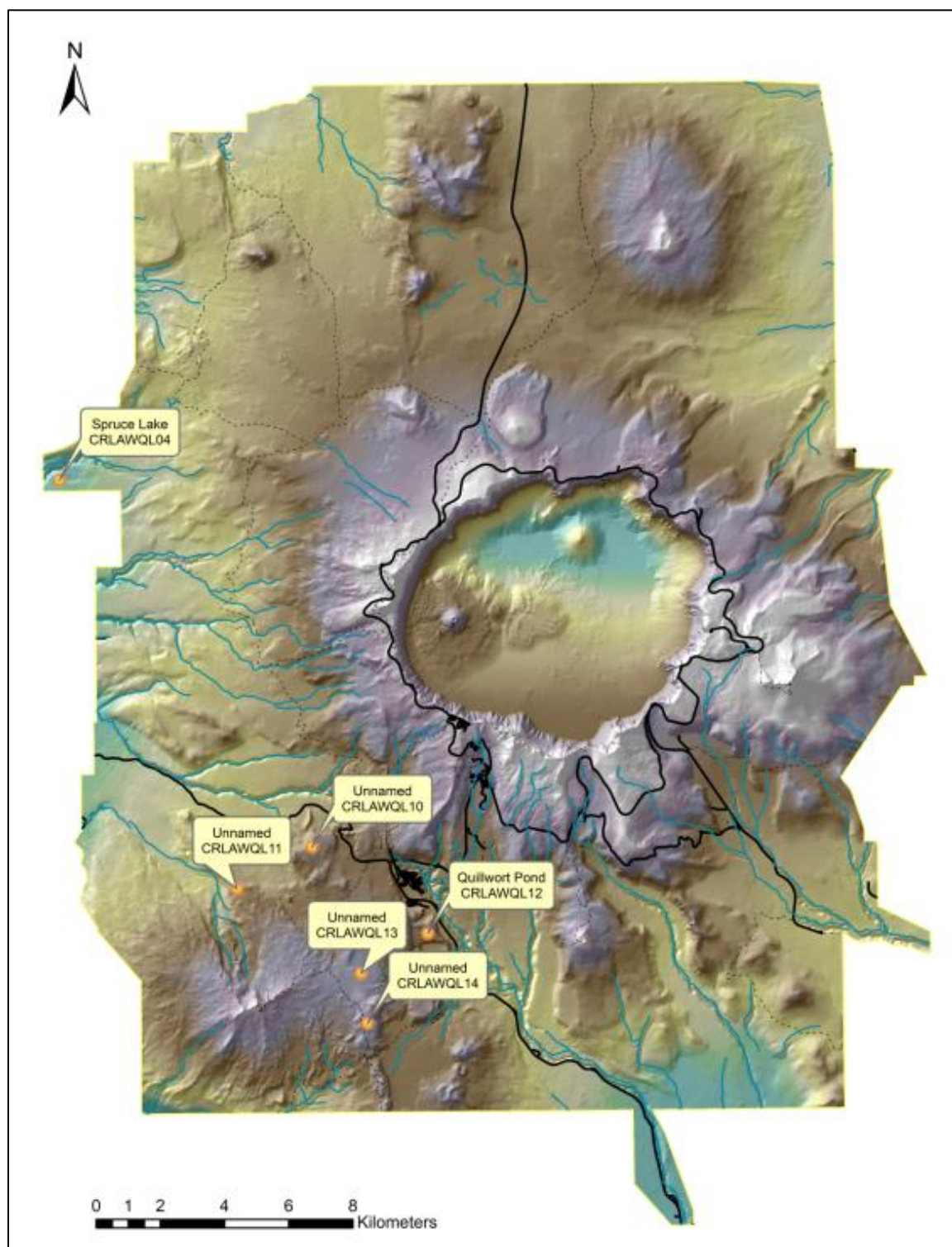


Figure 12. Locations of ponds sampled in Crater Lake National Park, 2016.

Table 9. Morphometric and location data for ponds sampled in Crater Lake National Park, 2016.

Site Code	Lake Name	UTM X Coord	UTM Y Coord	Date Sampled	Max Depth (m)	Area (M2)	Area (ha)	Area (ac)	Circumference (m)	Shoreline Development
CRLAWQL04	Spruce Lake	557363	4758725	9/13/2016	1.6	3869	0.39	0.96	369	1.67
CRLAWQL11	Unnamed	562893	4746002	9/14/2016	0.4	125	0.01	0.03	59	1.48
CRLAWQL10	Unnamed	565231	4747306	9/14/2016	0.5	595	0.06	0.15	127	1.47
CRLAWQL13	Unnamed	566758	4743368	9/15/2016	0.4	825	0.08	0.2	141	1.39
CRLAWQL14	Unnamed	566953	4741818	9/15/2016	0.6	2133 ^A	0.21 ^A	0.52 ^A	289 ^A	1.77 ^A
CRLAWQL12	Quillwort Pond	568835	4744609	9/16/2016	0.9	2930	0.29	0.72	256	1.33
Average	—	—	—	—	0.73	1746	0.17	0.43	207	1.52
SD	—	—	—	—	0.46	1473	0.15	0.36	116	0.17
Median	—	—	—	—	0.55	1479	0.145	0.36	198.5	1.48
Range	—	—	—	—	0.4 - 1.6	125 - 3869	0.01 - 0.39	0.03 - 0.96	59 - 369	1.33 - 1.77

^A One lake was missing habitat lines, so size and shape parameters had to be reported for 2013 as estimates.



Figure 13. Three characteristic ponds sampled in Crater Lake National Park, 2016. Left: CRLAWQL11; Center: CRLAWQL10, Right: CRLAWQL13.

3.2.1 Physical Substrate

Physical habitat characteristics for the Crater Lake National Park ponds are presented in Table 10. Secchi Disk depth is included in this table as a physical measurement, although it is a direct measurement of water clarity which is affected by sediments and algal growth. In four of the six sites, the disk was visible through the water column to the bottom of the pond, resulting in a reading of NA (not applicable). In these cases, direct readings of turbidity are a better measure of water clarity (see Water Quality, below).

The physical substrate of the sites was characteristic of late successional ponds, with fine sediments the most dominant substrate type (e.g., an average of 78% and as high as 95% in CRLAWQL13). There were no coarse substrates observed (gravel or larger) at the six sites.

3.2.2 Water Chemistry

The six sampled sites in Crater Lake National Park were shallow (<2 m), so only a single sample was collected for each site at the midpoint of the water column (Table 11). At two sites, CRLAWQL11 and CRLAWQL13, the water was so turbid that filtering the samples for anions and cations was not possible. Both of these sites were characterized by high Total Nitrogen and Total Phosphorous concentrations; for example, the Total Nitrogen concentration at CRLAWQL11 was almost 10 times higher than at Spruce Lake.

3.2.3 Water Quality

Water quality data, based on *in situ* real-time measurements taken with a probe, are presented in Table 12. The values are the site-specific averages for the depth profile measured, with deeper lakes having more measurements than shallower lakes. Even with this difference in number of measurements, the averages are still the best method for conveying the typical conditions in each site, representing an integrated depth assessment. These ponds are also so shallow that many of them have depth profiles of only three readings; one at the surface, one at the 0.5 m depth, and one reading just above the pond bottom.

3.3.4 Zooplankton

Zooplankton summary metrics are provided in Table 13. A full listing of zooplankton taxa collected is presented in Appendix C. The average number of taxa at each site was 14.2, with the highest number of taxa ($n = 16$) at CRLAWQL10, and the least ($n = 12$) at CRLAWQL12, Quillwort Pond. Cladocerans made up most of the taxonomic richness, with an average of 4.6 taxa per site. The sample from one site, CRLAWQL11, desiccated prior to being analyzed – no data is available.

Table 10. Physical substrate composition and Secchi Disk depths for ponds sampled in Crater Lake National Park, 2016.

Site Code	Lake Name	Date Sampled	Secchi Disk Depth (m)	Bedrock	Boulder	Cobble	Gravel	Sand	Fines	Woody Debris	Emergent Vegetation	Submergent Vegetation	Detritus
CRLAWQL04	Spruce Lake	9/13/2016	NA ^A	0%	0%	0%	0%	0%	51%	10%	23%	8%	8%
CRLAWQL11	Unnamed	9/14/2016	0.02	0%	0%	0%	0%	0%	90%	5%	0%	0%	5%
CRLAWQL10	Unnamed	9/14/2016	NA ^A	0%	0%	0%	0%	0%	80%	5%	15%	0%	0%
CRLAWQL14	Unnamed	9/15/2016	0.02	0%	0%	0%	0%	0%	85%	10%	5%	0%	0%
CRLAWQL13	Unnamed	9/15/2016	0.03	0%	0%	0%	0%	0%	95%	5%	0%	0%	0%
CRLAWQL12	Quillwort Pond	9/16/2016	NA ^A	0%	0%	0%	0%	0%	65%	15%	15%	5%	0%
Average	—	—	—	0%	0%	0%	0%	0%	78%	8%	10%	2%	2%
SD	—	—	—	0%	0%	0%	0%	0%	15%	4%	9%	3%	3%
Median	—	—	—	0%	0%	0%	0%	0%	82%	8%	10%	0%	0%
Range	—	—	—	0 - 0%	0 - 0%	0 - 0%	0 - 0%	0 - 0%	51 - 95%	5 - 15%	0 - 23%	0 - 8%	0 - 8%

^A At some of the sites, the disk was visible through the water column to the bottom, resulting in a reading of NA (Not Applicable).

Table 11. Water chemistry results for the ponds of Crater Lake National Park, 2016.

Site Code	Lake Name	Date	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Dissolved Organic Carbon (mg/L)
CRLAWQL04	Spruce Lake	9/13/2016	0.6	0.026	0.14	0.01b	2.97	1.64	2.48	0.79	6.3
CRLAWQL10	Unnamed	9/14/2016	2.28	0.295	0.91	0.01b	0.17	0.35	0.63	0.14	8.93
CRLAWQL11	Unnamed	9/14/2016	6.28	1.073	NA ^A	NA ^A	NA ^A	NA ^A	NA ^A	NA ^A	27.58
CRLAWQL13	Unnamed	9/15/2016	3.2	0.731	NA ^A	NA ^A	NA ^A	NA ^A	NA ^A	NA ^A	12.49
CRLAWQL14	Unnamed	9/15/2016	1.54	0.343	0.99	0.01 ^B	0.25	0.48	0.68	0.1	9.86
CRLAWQL12	Quillwort Pond	9/16/2016	0.46	0.031	0.36	0.01 ^B	0.07	0.04	0.42	0.09	4.74
Average	—	—	2.39	0.417	0.6	0.01	0.87	0.63	1.05	0.28	11.65
SD	—	—	2.17	0.413	0.42	0.01	1.41	0.7	0.96	0.34	8.26
Median	—	—	1.91	0.319	0.64	0.01	0.21	0.42	0.66	0.12	9.4
Range	—	—	0.46 - 6.28	0.026 - 1.073	0.14 - 0.99	0.01 - 0.01	0.07 - 2.97	0.04 - 1.64	0.42 - 2.48	0.09 - 0.79	4.74 - 27.58

^A Filtered samples were not collected because the water was too turbid to filter.

^B Values are below the quantifiable limit of the analytical technique, but are still included in the park wide averages.

Table 12. Averaged water quality probe profiles for ponds of Crater Lake National Park, 2016.

Site Code	Lake Name	Date Sampled	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	Turbidity (NTUs)	Oxidation-Reduction Potential (mV)	Specific Conductivity (µS/cm)	Temperature (°C)	pH
CRLAWQL04	Spruce Lake	9/13/2016	77.2	7.4	NA ^A	156.5	34	9.3	6.93
CRLAWQL10	Unnamed	9/14/2016	97.9	7.4	NA ^A	178	5	17.3	5.52
CRLAWQL11	Unnamed	9/14/2016	91.4	8.7	NA ^A	145.5	17.5	8.1	5.95
CRLAWQL13	Unnamed	9/15/2016	91.3	8.2	NA ^A	220.5	8	9.3	5.99
CRLAWQL14	Unnamed	9/15/2016	84.3	7.9	NA ^A	188.5	6	8	5.88
CRLAWQL12	Quillwort Pond	9/16/2016	84.5	7.3	NA ^A	194.3	3	11.9	5.71
Average	—	—	87.8	7.8	—	180.1	12.3	10.7	6
SD	—	—	7.2	0.6	—	27.1	11.8	3.5	0.48
Median	—	—	87.9	7.7	—	183.3	7	9.3	5.92
Range	—	—	77.2 - 97.9%	7.3 - 8.7	—	145.5 - 220.5	3 - 34	8 - 17.3	5.52 - 6.93

^A Turbidity probe was non-functional during sampling, resulting in NA (Not Available).

Table 13. Zooplankton metrics for ponds sampled in Crater Lake National Park, 2016.

Site Code	Lake Name	Date Sampled	Taxa Richness	Cladoceran Richness	Calanoida Richness	Rotifer Richness	Cyclopoida Richness	Other Richness ^B	Shannon Diversity	Evenness
CRLAWQL04	Spruce Lake	9/13/2016	15	3	2	2	3	3	1.36	0.5
CRLAWQL10	Unnamed	9/14/2016	16	6	3	1	2	2	0.62	0.22
CRLAWQL12	Quillwort Pond	9/16/2016	12	6	2	1	1	2	0.23	0.09
CRLAWQL13	Unnamed	9/15/2016	15	4	2	1	2	2	1.43	0.53
CRLAWQL14	Unnamed	9/15/2016	13	4	2	1	2	2	1.77	0.69
CRLAWQL11 ^A	Unnamed	9/14/2016	—	—	—	—	—	—	—	—
Average	—	—	14.2	4.6	2.2	1.2	2	2.2	1.08	0.41
SD	—	—	1.6	1.3	0.4	0.4	0.7	0.4	0.63	0.24
Median	—	—	15	4	2	1	2	2	1.36	0.5
Range	—	—	12 - 16	3 - 6	2 - 3	1 - 2	1 - 3	2 - 3	0.23 - 1.77	0.09 - 0.69

^A The sample for CRLAWQL11 desiccated prior to analysis.

^B Other richness includes aquatic mites and insect larvae.

3.3.5 Littoral Zone Macroinvertebrates

Macroinvertebrate metrics are presented in Table 14, with a full list of taxa collected presented in Appendix D. The highest taxonomic richness (n = 36 taxa) was at Spruce Lake (CRLAWQL04), whereas the lowest richness was at CRLAWQL13 and CRLAWQL14 (n = 10 taxa). At Spruce Lake, Chironomidae (n = 11 taxa) accounted for most of the macroinvertebrate diversity. Spruce Lake was also the only site where mayflies of the genus *Callibaetis* (Ephemeroptera,) were collected.

3.3.6 Vertebrates

Four amphibian species (plus unknown tadpoles) were recorded during visual encounter surveys (Table 15). Most ponds were too shallow for the deployment of gill nets, and no visible signs of fish were observed at any of the ponds. Individuals of the salamander genus *Ambystoma* spp. were the most numerous and widespread of the amphibians observed; two species are believed to occur in the park, *A. macrodactylum* and *A. gracile*, but distinguishing larval forms of these species is difficult. Observation of the Cascades Frog (*Rana cascadae*) during visual encounter surveys is notable because this species has been extirpated from Lassen Volcanic National Park but is still present in Crater Lake National Park (Figure 14).

The finding of Tailed Frogs (*Ascaphus truei*) is notable since adults are predominantly associated with stream habitats, and these were likely individuals from a nearby stream.

Table 14. Macroinvertebrate metrics collected from ponds in Crater Lake National Park, 2016.

Site Code	Lake Name	Date Sampled	Total Taxa Richness	Ephemeroptera Richness	Trichoptera Richness	Odonata Taxa Richness	Coleoptera Richness	Diptera Richness (non-Chironomidae)	Chironomidae Richness	Shannon Diversity	Evenness
CRLAWQL04	Spruce Lake	9/13/2016	36	1	1	2	1	4	11	2.88	0.8
CRLAWQL10	Unnamed	9/14/2016	17	0	0	1	2	0	5	1.5	0.53
CRLAWQL11	Unnamed	9/14/2016	11	0	0	1	2	0	4	1.17	0.49
CRLAWQL12	Quillwort Pond	9/16/2016	16	0	0	3	0	2	7	1.6	0.58
CRLAWQL13	Unnamed	9/15/2016	10	0	1	0	0	1	5	1.36	0.59
CRLAWQL14	Unnamed	9/15/2016	10	0	0	1	0	0	6	1.13	0.49
Average	—	—	16.7	0.2	0.3	1.3	0.8	1.2	6.3	1.61	0.58
SD	—	—	10	0.4	0.5	1	1	1.6	2.5	0.65	0.11
Median	—	—	13.5	0	0	1	0.5	0.5	5.5	1.43	0.56
Range	—	—	10 - 36	0 - 1	0 - 1	0 - 3	0 - 2	0 - 4	4 - 11	1.13 - 2.88	0.49 - 0.8

Table 15. Number of vertebrates encountered at Crater Lake National Park sampling sites during visual encounter surveys, 2016.

Site Code	Lake Name	Date Sampled	Unknown Salamander (<i>Ambystoma</i> sp.)	Tailed Frog (<i>Ascaphus truei</i>)	Pacific Tree Frog (<i>Pseudacris regilla</i>)	Cascades Frog (<i>Rana cascadae</i>)	Unknown Tadpole
CRLAWQL04	Spruce Lake	9/13/2016	50	0	1	1	0
CRLAWQL11	Unnamed	9/14/2016	10	5	0	30	0
CRLAWQL10	Unnamed	9/14/2016	20	0	2	0	0
CRLAWQL14	Unnamed	9/15/2016	100	0	0	0	10
CRLAWQL13	Unnamed	9/15/2016	5	0	0	0	0
CRLAWQL12	Quillwort Pond	9/16/2016	2	0	4	0	0



Figure 14. Cascades Frog, *Rana cascadae*, at Spruce Lake (CRLAWQL04).

3.3 Redwood National Park

Sampling in Redwood National Park occurred on 20-21 September 2016, at the single judgment site, Freshwater Lagoon (Table 16, Figure 15). The size of the lagoon (approximately 7 times as big as the largest lake in Lassen Volcanic National Park), in addition to the copious amounts of vegetation, necessitated that the sampling occur over two days.

3.3.1 Physical Substrate

The physical habitat comprising Freshwater Lagoon was largely emergent vegetation (38%), fine sediment (26%), and sand (24%) (Table 17). The dominance of emergent vegetation is clear in Figure 16. Secchi Disk clarity was included in this table as a physical measurement, although it is a direct measurement of water clarity.

3.3.2 Water Chemistry

Water chemistry samples, taken at both 0.5 m below the water surface and at 0.5 m above the lagoon bottom, are presented in Table 18.

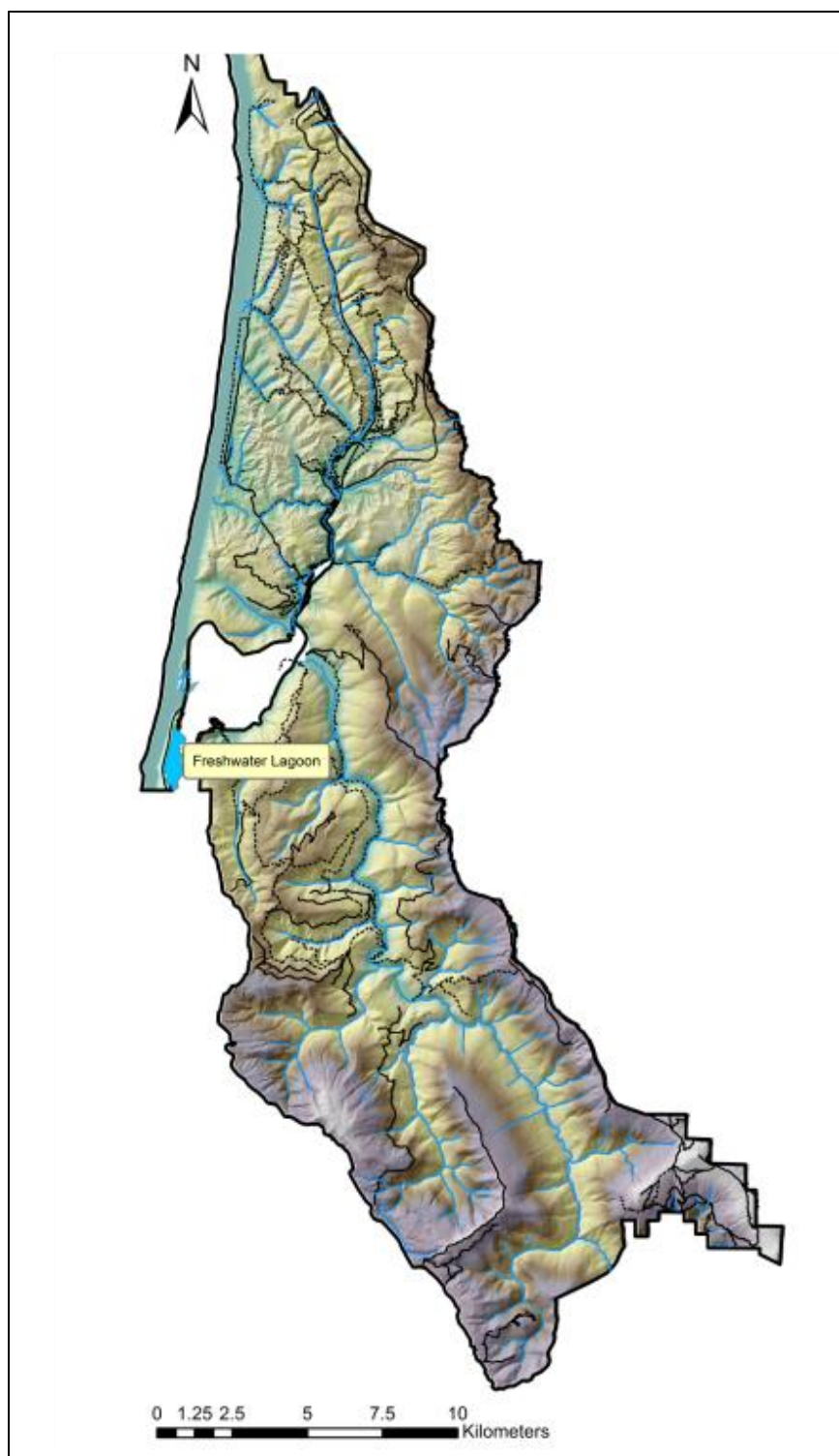


Figure 15. Location of Freshwater Lagoon in the southern portion of Redwood National Park, sampled in 2016.



Figure 16. Freshwater Lagoon at Redwood National Park, showing abundance of inundated grasses along the shoreline.

Table 16. Morphometric and location data for Freshwater Lagoon sampled in Redwood National Park, 2016.

Site Code	Lake Name	UTM X Coord	UTM Y Coord	Date Sampled	Max Depth (m)	Area (m ²)	Area (ha)	Area (ac)	Circum- ference (m)	Shoreline Development
REDW Lagoon	Freshwater Lagoon	408468	4569094	9/20/2016	3.1	877116	87.71	216.74	5302	1.6

Table 17. Physical substrate composition and Secchi Disk depth of Freshwater Lagoon sampled in Redwood National Park, 2016.

Lake Name	Date Sampled	Secchi Disk Depth (m)	Bedrock	Boulder	Cobble	Gravel	Sand	Fines	Woody Debris	Emer- gent Vege- tation	Submer- gent Vege- tation	Detritus
Freshwater Lagoon	9/20/2016	1.75	0%	0%	3%	10%	0%	41%	0%	37%	7%	2%

Table 18. Water chemistry results for Freshwater Lagoon sampled in Redwood National Park, 2016.

Lake Name	Date Sampled	Depth	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Dissolved Organic Carbon (mg/L)
Freshwater Lagoon	9/20/2016	Shallow	0.33	0.023	35.64	1.61	15.9	1.24	3.75	3.77	3.32
Freshwater Lagoon	9/20/2016	Deep	0.33	0.023	35.75	1.60	15.64	1.25	3.76	3.76	4.08

3.3.3 Water Quality

Water quality data, based on *in situ* real-time measurements taken with a probe, are presented in Table 19. The values represent a single average for each parameter and are the averages for the depth profile of Freshwater Lagoon.

3.3.4 Zooplankton and Littoral Zone Macroinvertebrates

Zooplankton summary metrics are provided in Table 20, and littoral zone macroinvertebrate metrics in Table 21. Littoral zone macroinvertebrates included three introduced exotic species, the Chinese mystery snail (*Bellamya chinensis*; synonym *Cipangopaludina chinensis*; Figure 17) and the New Zealand Mud Snail (*Potamopyrgus antipodarum*). The third, the Asian clam (*Corbicula fluminea*) was found during the collection process but not recorded in the sample (Figure 17). Both the Asian clam and the Chinese mystery snail have been introduced from Asia as a culinary food source in the late 1800s and early 1900s. All zooplankton and macroinvertebrate taxa collected are listed in Appendixes E and F.

Table 19. Averaged water quality profile for Freshwater Lagoon, Redwood National Park, 2016.

Lake Name	Date Sampled	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	Turbidity (NTUs)	Oxidation-Reduction Potential (mV)	Specific Conductivity (μS/cm)	Temperature (°C)	pH
Freshwater Lagoon	9/20/2016	107.6	10	NA ^A	149.6	167	19.2	7.43

^A Turbidity probe was non-functional during sampling, resulting in NA (Not Available).

Table 20. Zooplankton metrics for Freshwater Lagoon, Redwood National Park, 2016.

Lake Name	Date Sampled	Taxa Richness	Cladoceran Richness	Calanoida Richness	Rotifer Richness	Cyclopoida Richness	Other Richness ^A	Shannon Diversity	Evenness
Freshwater Lagoon	9/20/2016	2	2	0	0	0	0	0.69	1

^A Other richness includes aquatic mites and insect larvae.

Table 21. Littoral zone macroinvertebrate metrics for Freshwater Lagoon, Redwood National Park, 2016.

Lake Name	Date Sampled	Total Taxa Richness	Ephemeroptera Richness	Trichoptera Richness	Odonata Taxa Richness	Coleoptera Richness	Diptera Richness (non-Chironomidae)	Chironomidae Richness	Shannon Diversity	Evenness
Freshwater Lagoon	9/20/2016	26	0	0	2	3	1	5	1.51	0.46



Figure 17. Asian clam (*Corbicula*), left, and Chinese Mystery Snail (*Cipangopaludina chinensis*), right, from Freshwater Lagoon, 2016.

3.3.5 Vertebrates

Five species of vertebrates were encountered in Freshwater Lagoon (Table 22): *Oncorhynchus mykiss* (Rainbow Trout) and *Micropterus salmoides* (Largemouth Bass) were captured in gill nets, and one of the Rainbow Trout had a *Hypomesus olidus* (Japanese Pond Smelt) (Figure 18). Additionally, the crew encountered two additional species of fish in their invertebrate sweep net collections:

Gasterosteus aculeatus (Three Spine Stickleback) and *Cottus asper* (Prickly Sculpin) (Figure 18).

The identifications of the Japanese Pond Smelt, Prickly Sculpin, and Three Spine Stickleback were made via consultation with David Anderson, Redwood National Park fisheries biologist and photo vouchers. Many more fish species are known to be present in Freshwater Lagoon, which illustrates the need for more comprehensive sampling and the use of additional techniques (e.g., boat electrofishing and minnow traps) for sampling larger sites (which are not included in the Klamath Network mountain and ponds and lake sampling protocol). California Department of Game and Fish may inventory the fish populations on a regular basis.

Table 22. Number of vertebrates observed and collected at Freshwater Lagoon, Redwood National Park, 2016.

Lake Name	Date Sampled	Largemouth Bass (<i>Micropterus salmoides</i>)	Japanese Pond Smelt (<i>Hypomesus olidus</i>)	Rainbow Trout (<i>Oncorhynchus mykiss</i>)	3 Spine Stickleback (<i>Gasterosteus aculeatus</i>)	Prickly Sculpin (<i>Cottus asper</i>)
Freshwater Lagoon	9/20/2016	1	1	3	Present	Present



Figure 18. Japanese Pond Smelt (*Hypomesus olidus*) (top), Three Spine Stickleback (*Gasterosteus aculeatus*) (middle), and Prickly Sculpin (*Cottus asper*) (bottom) from Freshwater Lagoon, Redwood National Park, 2016.

4.0 Conclusion

In 2016, 29 probabilistically chosen lakes and one judgment lake (Lake Helen) were sampled in Lassen Volcanic National Park. However, the crew mistakenly sampled Lake 10950 instead of 10968. In Crater Lake National Park, we sampled six ponds-lakes that comprise the known population of perennial lentic habitats outside of the Crater Lake caldera. In Redwood National Park, Freshwater Lagoon was sampled as a judgment site. Most of these sites were first sampled in 2013 (Dinger 2016) will be resampled in 2019. The data collected in 2013 and 2016 represent initial baseline measurements of the physical habitat, water chemistry and quality, and aquatic communities of the sites sampled, and lays the groundwork for future Analysis and Synthesis Reports that will eventually include the analysis of trends of the measured lentic attributes.

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Appendix A. Zooplankton Taxa of Lassen Volcanic National Park

Table A1. List of taxa collected at Lassen Volcanic National Park, 2016. The Category and Taxon are the values reported by the taxonomic contractor – CLA = Cladoceran, OLI = Oligochaete, INS = Insect, ROT = Rotifer, CYC = Cyclopoida, CAL = Calanoida, PRT = Protista, CNI = Cnidarian, NEM = Nemata, OST = Ostracod, ARC = Arachnid. ITIS.gov Taxon is the current taxa name using the Integrated Taxonomic Information System, and may vary from the contractor reported value. TSN = Taxonomic Serial Number. Total Accumulated Density is across all samples (including QA/QC samples) and is presented as a measure of relative abundance across taxa. Note that Sites (for No. of Sites and % of Sites) includes QA/QC repeat sites.

Category	Taxon	ITIS.gov Taxon	TSN	Total Accumulated Density (per m ³)	No. of Sites	Percent of Sites
COP	Acanthocyclops vernalis	Acanthocyclops vernalis	88770	20209	1	3.30%
CLA	Alona costata	Alona costata	83983	78349	7	23.30%
CLA	Alona guttata	Alona guttata	83975	295976	2	6.70%
OLI	aquatic oligochaete	Oligochaeta	68422	632	1	3.30%
ROT	Asplanchna brightwelli	Asplanchna brightwelli	59236	632	1	3.30%
ROT	Asplanchna priodonta	Asplanchna priodonta	59240	10104	1	3.30%
CLA	Bosmina longirostris	Bosmina longirostris	83938	2631568	17	56.70%
CLA	Ceriodaphnia dubia	Ceriodaphnia dubia	83912	5960362	7	23.30%
CLA	Ceriodaphnia pulchella	Ceriodaphnia pulchella	83908	2402964	7	23.30%
CLA	Ceriodaphnia sp.	Ceriodaphnia sp.	83905	1579	1	3.30%
INS	Chaoborus larvae	Chaoborus sp.	125904	311659	9	30.00%
INS	chironomid larvae	Chironomidae	127917	210930	11	36.70%
CLA	Chydorus sphaericus	Chydorus sphaericus	83993	1862573	23	76.70%
ROT	Collotheca mutabilis	Collotheca mutabilis	59435	15157	1	3.30%
ROT	Conochilus unicornis	Conochilus unicornis	59419	311044695	18	60.00%
CYC&CAL	copepod nauplii	Copepoda	85257	510064	16	53.30%
CAL	copepodid, Calanoida	Calanoida	85258	16489269	24	80.00%
CYC	copepodid, Cyclopoida	Cyclopoida	88530	896420	18	60.00%
CLA	Daphnia ambigua	Daphnia ambigua	83888	116833	4	13.30%
CLA	Daphnia mendotae	Daphnia galeata mendotae	83877	186932	1	3.30%
CLA	Daphnia pulex	Daphnia pulex	83874	1432620	15	50.00%
CLA	Daphnia rosea	Daphnia rosea	83891	1396794	3	10.00%
COP	Diacyclops navus	Diacyclops navus	88786	1895	1	3.30%
CLA	Diaphanosoma brachyurum	Diaphanosoma brachyurum	83838	21143333	21	70.00%
CAL	Diaptomus (L.) siciloides	Diaptomus siciloides	85793	2303183	6	20.00%
CAL	Diaptomus (L.) signicauda	Diaptomus signicauda	85824	4838768	9	30.00%
CAL	Diaptomus (L.) tyrrelli	Diaptomus tyrrelli	85802	4555211	9	30.00%

Category	Taxon	ITIS.gov Taxon	TSN	Total Accumulated Density (per m ³)	No. of Sites	Percent of Sites
COP	Dicyclops thomasi	Dacyclops thomasi	88789	2526	1	3.30%
PRT	Diffugia sp.	Diffugia sp.	43948	44102	7	23.30%
INS	Elimidae Larvae	Elmidae	114093	8210	2	6.70%
CAL	Epischura nevadensis	Epischura nevadensis	85857	413789	11	36.70%
CAL	epischurid copepodites	Epischura spp.	85856	387768	7	23.30%
ROT	Euchlanis dilatata	Euchlanis dilatata	58582	15157	2	6.70%
HAR	harpacticoid copepod	Harpacticoida	86110	5684	2	6.70%
CAL	Hesperodiaptomus eiseni occidentalis (a.k.a. H. arcticus)	Hesperodiaptomus arcticus	666938	130275	3	10.00%
CLA	Holopedium gibberum	Holopedium gibberum	83957	4910903	9	30.00%
CLA	immature Daphnia	Daphnia sp.	83873	1579	2	6.70%
ROT	Kellicottia bostonensis	Kellicottia bostoniensis	58487	3181638	3	10.00%
ROT	Kellicottia longispina	Kellicottia longispina	58486	80836	1	3.30%
ROT	Keratella cochlearis var. cochlearis	Keratella cochlearis cochlearis	58362	1864271	2	6.70%
ROT	Keratella serrulata	Keratella serrulata	58384	1263	1	3.30%
ROT	Keratella taurocephala	Keratella taurocephala	58381	25893	4	13.30%
CAL	Leptodiaptomus sp.	Leptodiaptomus sp.	85838	2526	2	6.70%
CYC	Macrocyclus albidus	Macrocyclus albidus	88738	15788	4	13.30%
CLA	Macrothrix (Echinisco) rosea	Macrothrix rosea	84119	65679	2	6.70%
CLA	Macrothrix laticornis	Macrothrix laticornis	84121	223877	6	20.00%
INS	mayfly larvae	Ephemeroptera	100502	23901	3	10.00%
CYC	Microcyclus varicans	Microcyclus varicans	88758	132634	11	36.70%
INS	Misc. Insect Larvae	Insecta	99208	14574	1	3.30%
ROT	Monostyla lunaris	Monostyla lunaris	58753	1263	1	3.30%
INS	Mosquito Pupae	Culicidae	125930	14525	4	13.30%
NEM	nematode	Nematoda	59490	3158	2	6.70%
OST	Ostracoda (seed shrimp)	Ostracoda	84195	10323	5	16.70%
ROT	Ploesoma hudsoni	Ploesoma hudsoni	59291	2526	1	3.30%
ROT	Ploesoma truncatum	Ploesoma truncatum	59283	5052	1	3.30%
ROT	Polyarthra major	Polyarthra major	59275	10104	1	3.30%
ROT	Polyarthra vulgaris	Polyarthra vulgaris	59277	30313	3	10.00%
CLA	Polyphemus pedicures	Polyphemus pediculus	83969	1263	1	3.30%
CLA	Scapholeberis armata	Scapholeberis armata	83928	750116	19	63.30%
CLA	Simocephalus serrulatus	Simocephalus serrulatus	83901	15157	3	10.00%
ROT	Synchaeta sp.	Synchaeta sp.	59255	570416	4	13.30%
INS	water boatman	Corixidae	103364	16735	3	10.00%
ARC	water mite	Trombidiformes	82769	71363	10	33.30%

Appendix B. Littoral Zone Macroinvertebrates of Lassen Volcanic National Park

Table B-1. Taxonomic units of littoral zone benthic macroinvertebrates encountered in Lassen Volcanic National Park, 2016. TSN = Taxonomic Serial Number; see www.itis.gov for full taxonomy. NA indicates cases where no TSN exists, either due to it being a “species group,” or a recently redescribed taxon with no number yet designated.

Order (or higher)	Family	Taxon	TSN	Total No.	No. of Sites	Percent of Sites
Diptera	Chironomidae	Ablabesmyia	128079	628	21	63.60%
Diptera	Chironomidae	Acamptocladius dentolatens	128461	3	2	6.10%
Acari	—	Acari	733321	11	4	12.10%
Coleoptera	Dytiscidae	Acilius abbreviatus	112080	4	3	9.10%
Odonata	Aeshnidae	Aeshna	101603	5	2	6.10%
Odonata	Aeshnidae	Aeshna umbrosa	101605	4	2	6.10%
Odonata	Aeshnidae	Aeshnidae	101596	124	21	63.60%
Coleoptera	Dytiscidae	Agabinae	728212	11	3	9.10%
Coleoptera	Dytiscidae	Agabus	111966	6	2	6.10%
Coleoptera	Dytiscidae	Agabus lutosus	112056	2	2	6.10%
Diptera	Chironomidae	Allocladius	NA	5	1	3.00%
Odonata	—	Anisoptera	101594	245	15	45.50%
Diptera	Chironomidae	Apedilum	206655	162	5	15.20%
Trombidiformes	Arrenuridae	Arrenurus	82864	49	12	36.40%
Trichoptera	Phryganeidae	Banksiola crotchi	115912	549	11	33.30%
Coleoptera	Hydrophilidae	Berosus	112812	8	1	3.00%
Diptera	Chironomidae	Boreochlus	127954	1	1	3.00%
Coleoptera	Dytiscidae	Boreonectes striatellus	NA	49	9	27.30%
Ephemeroptera	Caenidae	Caenis	101478	1	1	3.00%
Ephemeroptera	Caenidae	Caenis youngi	568627	33	2	6.10%
Ephemeroptera	Baetidae	Callibaetis	100903	180	21	63.60%
Hemiptera	Corixidae	Cenocorixa	103501	18	7	21.20%
Hemiptera	Corixidae	Cenocorixa kuiterti	103513	8	4	12.10%
Hemiptera	Corixidae	Cenocorixa wileyae	103509	12	5	15.20%
Diptera	Ceratopogonidae	Ceratopogonidae	127076	7	3	9.10%
Diptera	Ceratopogonidae	Ceratopogoninae	127338	71	16	48.50%
Enchytraeida	Enchytraeidae	Cernovitoviella	68534	17	5	15.20%
Diptera	Chironomidae	Chaetocladius	128520	158	3	9.10%
Diptera	Chaoboridae	Chaoborus	125904	235	8	24.20%
Diptera	Chironomidae	Chironomini	129229	33	14	42.40%

Order (or higher)	Family	Taxon	TSN	Total No.	No. of Sites	Percent of Sites
Diptera	Chironomidae	Chironomus	129254	895	22	66.70%
Diplostraca	—	Cladocera	83832	610	22	66.70%
Diptera	Chironomidae	Cladopelma	129350	290	10	30.30%
Diptera	Chironomidae	Clinotanytus	127996	2	1	3.00%
Odonata	Coenagrionidae	Coenagrionidae	102077	109	15	45.50%
Copepoda	—	Copepoda	85257	388	18	54.50%
Coleoptera	Dytiscidae	Coptotomus	112371	5	3	9.10%
Coleoptera	Dytiscidae	Coptotomus longulus	112373	12	4	12.10%
Odonata	Corduliidae	Cordulia shurtleffii	102015	3	2	6.10%
Odonata	Corduliidae	Corduliidae	102020	66	13	39.40%
Hemiptera	Corixidae	Corisella decolor	103487	1	1	3.00%
Hemiptera	Corixidae	Corixidae	103364	278	23	69.70%
Diptera	Chironomidae	Corynoneura	128563	198	19	57.60%
Diptera	Chironomidae	Cricotopus	128575	26	6	18.20%
Diptera	Chironomidae	Cryptochironomus	129368	16	3	9.10%
Diptera	Ceratopogonidae	Dasyhelea	127278	79	5	15.20%
Trichoptera	Limnephilidae	Desmona	116023	49	4	12.10%
Diptera	Chironomidae	Dicrotendipes	129428	416	13	39.40%
Diptera	Chironomidae	Diplocadius	128670	1	1	3.00%
Diptera	Dixidae	Dixella	125854	2	2	6.10%
Diptera	Dolichopodidae	Dolichopodidae	136824	1	1	3.00%
Coleoptera	Dytiscidae	Dytiscidae	111963	21	5	15.20%
Enchytraeida	Enchytraeidae	Enchytraeus	68531	132	19	57.60%
Diptera	Chironomidae	Endochironomus	129470	42	6	18.20%
Arhynchobdellida	Erpobdellidae	Erpobdella	69444	10	4	12.10%
Enchytraeida	Enchytraeidae	Fridericia	204785	1	1	3.00%
Trombidiformes	Oxidae	Frontipoda	83240	86	12	36.40%
Hemiptera	Gerridae	Gerridae	103801	35	7	21.20%
Hemiptera	Gerridae	Gerris	103829	1	1	3.00%
Hemiptera	Gerridae	Gerris incognitus	103843	24	3	9.10%
Rhynchobdellida	Glossiphoniidae	Glossiphonia	69380	3	1	3.00%
Trichoptera	Sericostomatidae	Gumaga	117003	19	6	18.20%
Diptera	Chironomidae	Guttipeloplia	128161	2	2	6.10%
Basommatophora	Planorbidae	Gyraulus	76592	26	1	3.00%
Basommatophora	Planorbidae	Gyraulus parvus	76595	4	1	3.00%
Coleoptera	Gyrinidae	Gyrinus	112654	4	3	9.10%

Order (or higher)	Family	Taxon	TSN	Total No.	No. of Sites	Percent of Sites
Arhynchobdellida	Haemopidae	Haemopsis	69408	1	1	3.00%
Rhynchobdellida	Glossiphoniidae	Helobdella	69396	135	12	36.40%
Rhynchobdellida	Glossiphoniidae	Helobdella stagnalis	69398	53	3	9.10%
Hemiptera	Corixidae	Hesperocorixa	103444	3	1	3.00%
Hemiptera	Corixidae	Hesperocorixa vulgaris	103450	1	1	3.00%
Trichoptera	Calamoceratidae	Heteroplectron californicum	116538	39	2	6.10%
Diptera	Chironomidae	Heterotrissocladius Marcidus Gr.	NA	109	2	6.10%
Amphipoda	Hyaellidae	Hyaella	94025	21	1	3.00%
Trombidiformes	Hydrachnidae	Hydrachna	83123	6	3	9.10%
Diptera	Chironomidae	Hydrobaenus	128750	1	1	3.00%
Coleoptera	Hydrochidae	Hydrochus	113166	2	2	6.10%
Trombidiformes	Hydrodromidae	Hydrodroma	83225	15	8	24.20%
Coleoptera	Hydrophilidae	Hydrophilidae	112811	2	1	3.00%
Coleoptera	Dytiscidae	Hydroporinae	678402	18	7	21.20%
Coleoptera	Dytiscidae	Hydroporus	112390	8	3	9.10%
Coleoptera	Dytiscidae	Laccophilus maculosus	112279	1	1	3.00%
Trichoptera	Leptoceridae	Leptoceridae	116547	1	1	3.00%
Ephemeroptera	Leptophlebiidae	Leptophlebiidae	101095	10	3	9.10%
Odonata	Lestidae	Lestes	102061	218	10	30.30%
Odonata	Libellulidae	Leucorrhinia glacialis	101886	2	2	6.10%
Odonata	Libellulidae	Libellulidae	101797	37	5	15.20%
Trichoptera	Limnephilidae	Limnephilidae	115933	6	5	15.20%
Trichoptera	Limnephilidae	Limnephilus	116069	48	13	39.40%
Trombidiformes	Limnesiidae	Limnesia	83051	58	9	27.30%
Diptera	Chironomidae	Limnophyes	128776	59	10	30.30%
Coleoptera	Dytiscidae	Liodessus	112580	2	2	6.10%
Coleoptera	Dytiscidae	Liodessus affinis complex	NA	14	3	9.10%
Lumbriculida	Lumbriculidae	Lumbriculidae	68440	110	18	54.50%
Diptera	Chironomidae	Macropelopia	128034	9	1	3.00%
Hemiptera	Mesoveliidae	Mesovelia mulsanti	103956	1	1	3.00%
Diptera	Chironomidae	Micropsectra	129890	88	5	15.20%
Diptera	Chironomidae	Microtendipes	129535	2	1	3.00%
Diptera	Chironomidae	Microtendipes Pedellus Gr.	NA	1077	24	72.70%
Plecoptera	Leuctridae	Moselia infuscata	102910	1	1	3.00%
Diptera	Muscidae	Muscidae	150025	2	2	6.10%
Diptera	—	Muscomorpha	131750	1	1	3.00%
Trichoptera	Leptoceridae	Mystacides	116598	80	7	21.20%

Order (or higher)	Family	Taxon	TSN	Total No.	No. of Sites	Percent of Sites
Tubificida	Naididae	Naididae	68854	11	7	21.20%
Tubificida	Naididae	Nais	68946	39	8	24.20%
Nemata	—	Nemata	563956	213	21	63.60%
Plecoptera	Nemouridae	Nemouridae	102517	2	1	3.00%
Trombidiformes	Unionicolidae	Neumania	83103	2	1	3.00%
Diptera	Chironomidae	Nilothauma	129548	49	9	27.30%
Hemiptera	Notonectidae	Notonecta	103558	390	25	75.80%
Hemiptera	Notonectidae	Notonecta kirbyi	103563	154	24	72.70%
Hemiptera	Notonectidae	Notonecta undulata	103568	19	5	15.20%
Diptera	Chironomidae	Odontomesa	128446	1	1	3.00%
Trichoptera	Leptoceridae	Oecetis	116607	95	11	33.30%
Sarcoptiformes	—	Oribatida	733326	1	1	3.00%
Diptera	Chironomidae	Orthocladinae	128457	9	6	18.20%
Diptera	Chironomidae	Orthocladus	128874	8	3	9.10%
Ostracoda	—	Ostracoda	84195	40	3	9.10%
Trombidiformes	Oxidae	Oxus	83244	1	1	3.00%
Diptera	Chironomidae	Parachironomus	129564	3	3	9.10%
Diptera	Chironomidae	Paracladopelma	129597	4	4	12.10%
Diptera	Chironomidae	Parakiefferiella	128968	8	1	3.00%
Diptera	Chironomidae	Paralimnophyes	128976	2	2	6.10%
Diptera	Chironomidae	Paratanytarsus	129935	168	18	54.50%
Diptera	Chironomidae	Parochlus kiefferi	127989	1	1	3.00%
Diptera	Psychodidae	Pericoma / Telmatoscopus	NA	1	1	3.00%
Diptera	Chironomidae	Phaenopsectra	129637	45	9	27.30%
Trichoptera	Phryganeidae	Phryganeidae	115867	38	5	15.20%
Basommatophora	Physidae	Physella	76698	71	1	3.00%
Trombidiformes	Pionidae	Piona	83350	203	16	48.50%
Trombidiformes	Pionidae	Pionacercus	83400	14	3	9.10%
Veneroida	Sphaeriidae	Pisidium	81400	120	14	42.40%
Diptera	Chironomidae	Polypedilum	129657	286	26	78.80%
Diptera	Chironomidae	Procladius	128277	1858	29	87.90%
Diptera	Chironomidae	Psectrocladius	129018	766	30	90.90%
Diptera	Chironomidae	Psectrotanytus	128048	111	3	9.10%
Diptera	Chironomidae	Pseudochironomus	129851	60	2	6.10%
Diptera	Chironomidae	Pseudodiamesa	128416	2	1	3.00%
Diptera	Chironomidae	Pseudosmittia	129071	39	5	15.20%

Order (or higher)	Family	Taxon	TSN	Total No.	No. of Sites	Percent of Sites
Basommatophora	Lymnaeidae	Radix auricularia	76526	1	1	3.00%
Diptera	Chironomidae	Radotanypus	NA	1	1	3.00%
Coleoptera	Dytiscidae	Rhantus wallisi	112092	1	1	3.00%
Hemiptera	Saldidae	Saldula	104140	1	1	3.00%
Coleoptera	Dytiscidae	Sanfilippodytes	728253	1	1	3.00%
Coleoptera	Scirtidae	Scirtidae	113924	1	1	3.00%
Megaloptera	Sialidae	Sialis	115002	205	19	57.60%
Hemiptera	Corixidae	Sigara omani	103419	30	8	24.20%
Hemiptera	Corixidae	Sigara washingtonensis	103398	1	1	3.00%
Odonata	Corduliidae	Somatochlora albicincta	101952	5	4	12.10%
Veneroida	Sphaeriidae	Sphaeriidae	81389	116	9	27.30%
Diptera	Stratiomyidae	Stratiomys	130627	1	1	3.00%
Anostraca	Streptocephalidae	Streptocephalus sealii	624038	36	3	9.10%
Diptera	Tabanidae	Tabanidae	130934	5	4	12.10%
Diptera	Chironomidae	Tanypodinae	127994	64	16	48.50%
Diptera	Chironomidae	Tanytarsini	129872	10	8	24.20%
Diptera	Chironomidae	Tanytarsus	129978	1081	25	75.80%
Diptera	Chironomidae	Thienemannimyia Gr.	NA	60	8	24.20%
Trombidiformes	Hydryphantidae	Thyopsella	83202	5	1	3.00%
Diptera	Tipulidae	Tipula	119037	2	1	3.00%
Diptera	Tipulidae	Tipulidae	118840	4	1	3.00%
Trepaxonemata	—	Trepaxonemata	914204	2	2	6.10%
Diptera	Chironomidae	Tribelos	129820	157	14	42.40%
Coleoptera	Hydrophilidae	Tropisternus	112938	4	3	9.10%
Coleoptera	Hydrophilidae	Tropisternus lateralis	112944	2	2	6.10%
Tubificida	Naididae	Tubificinae	974289	4	2	6.10%
Diptera	Chironomidae	Tvetenia Bavarica Gr.	NA	2	1	3.00%
Diptera	Chironomidae	Zavrelimyia	128259	750	28	84.80%

Appendix C. Zooplankton Taxa of Crater Lake National Park

Table C-1. List of taxa collected at Crater Lake National Park, 2016. The Category and Taxon are the values reported by the taxonomic contractor – CLA = Cladoceran, OLI = Oligochaete, INS = Insect, ROT = Rotifer, CYC = Cyclopoida, CAL = Calanoida, PRT = Protista, CNI = Cnidarian, NEM = Nemata, OST = Ostracod, ARC = Arachnid. ITIS.gov Taxon is the current taxa name using the Integrated Taxonomic Information System, and may vary from the contractor reported value. TSN = Taxonomic Serial Number. Total Accumulated Density is across all samples (including QA/QC samples) and is presented as a measure of relative abundance across taxa. Note that Sites (for No. of Sites and % of Sites) includes QA/QC repeat sites.

Category	Taxon	ITISgov Taxon	TSN	Total Accumulated Density (per m ³)	No. of Sites	Percent of Sites
PRT	Diffugia sp.	Diffugia sp.	43948	41681	3	60%
ROT	unspecified bdelloid rotifer	Bdelloidea	58246	632	1	20%
ROT	Brachionus calyciflorus	Brachionus calyciflorus	58438	47996	1	20%
ROT	Polyarthra vulgaris	Polyarthra vulgaris	59277	7578	2	40%
ROT	Conochilus unicornis	Conochilus unicornis	59419	30584905	4	80%
OLI	aquatic oligochaete	Oligochaeta	68422	316	1	20%
ARC	water mite	Trombidiformes	82769	2210	3	60%
CLA	Diaphanosoma brachyurum	Diaphanosoma brachyurum	83838	317659	3	60%
CLA	Daphnia pulex	Daphnia pulex	83874	291134	2	40%
CLA	Daphnia rosea	Daphnia rosea	83891	327763	2	40%
CLA	Simocephalus serrulatus	Simocephalus serrulatus	83901	3789	2	40%
CLA	Ceriodaphnia pulchella	Ceriodaphnia pulchella	83908	2526	1	20%
CLA	Ceriodaphnia dubia	Ceriodaphnia dubia	83912	1895	1	20%
CLA	Scapholeberis armata	Scapholeberis armata	83928	73573	3	60%
CLA	Alona costata	Alona costata	83983	23998	3	60%
CLA	Chydorus sphaericus	Chydorus sphaericus	83993	12631	1	20%
CLA	Eurycercus lamellatus	Eurycercus lamellatus	84017	1263	1	20%
CLA	Camptocercus rectirostris	Camptocercus rectirostris	84057	55574	1	20%
CLA	Macrothrix laticornis	Macrothrix laticornis	84121	3158	2	40%
CLA	Ilyocryptus acutifrons	Ilyocryptus acutifrons	84137	2526	1	20%
OST	Ostracoda (seed shrimp)	Ostracoda	84195	16420	1	20%
CYC&CAL	copepod nauplii	Copepoda	85257	53680	4	80%

Category	Taxon	ITISgov Taxon	TSN	Total Accumulated Density (per m ³)	No. of Sites	Percent of Sites
CAL	copepodid, Calanoida	Calanoida	85258	412704	5	100%
CAL	Diaptomus (H.) franciscanus	Diaptomus franciscanus	85786	175565	1	20%
CAL	Diaptomus (A.) leptopus	Diaptomus leptopus	85789	1312947	4	80%
CAL	Diaptomus (L.) siciloides	Diaptomus siciloides	85793	17683	1	20%
CYC	copepodid, Cyclopoida	Cyclopoida	88530	134200	5	100%
CYC	Halicyclops sp.	Halicyclops sp.	88635	1263	1	20%
CYC	Macrocyclus albidus	Macrocyclus albidus	88738	1263	1	20%
CYC	Microcyclus varicans	Microcyclus varicans	88758	33787	4	80%
INS	mayfly larvae	Ephemeroptera	100502	1263	1	20%
INS	Chaoborus larvae	Chaoborus sp.	125904	35997	4	80%
INS	chironomid larvae	Chironomidae	127917	30945	4	80%
ANO	Streptocephalus seali	Streptocephalus sealii	624038	316	1	20%

Appendix D. Littoral Zone Macroinvertebrates of Crater Lake National Park

Table D-1. Taxonomic units of littoral zone benthic macroinvertebrates encountered in Lassen Volcanic National Park, 2016. TSN = Taxonomic Serial Number; see www.itis.gov for full taxonomy. NA indicates cases where no TSN exists, either due to it being a “species group,” or a recently redescribed taxon with no number yet designated.

Order (or higher)	Family	Taxon	TSN	Total No.	No. of Sites	Percent of Sites
Diptera	Chironomidae	Ablabesmyia	128079	44	3	42.90%
Acari	—	Acari	733321	2	1	14.30%
Coleoptera	Dytiscidae	Acilius abbreviatus	112080	1	1	14.30%
Odonata	Aeshnidae	Aeshnidae	101596	8	2	28.60%
Coleoptera	Dytiscidae	Agabus lutosus	112056	4	3	42.90%
Odonata	—	Anisoptera	101594	174	2	28.60%
Trombidiformes	Arrenuridae	Arrenurus	82864	75	2	28.60%
Trichoptera	Phryganeidae	Banksiola crotchii	115912	22	2	28.60%
Tubificida	Naididae	Bratislavia	69021	1	1	14.30%
Ephemeroptera	Baetidae	Callibaetis	100903	36	1	14.30%
Hemiptera	Corixidae	Cenocorixa	103501	1	1	14.30%
Diptera	Ceratopogonidae	Ceratopogoninae	127338	56	2	28.60%
Diptera	Chaoboridae	Chaoborus	125904	33	2	28.60%
Diptera	Chironomidae	Chironomus	129254	186	4	57.10%
Diplostraca	—	Cladocera	83832	29	3	42.90%
Odonata	Coenagrionidae	Coenagrionidae	102077	10	2	28.60%
Copepoda	—	Copepoda	85257	856	5	71.40%
Odonata	Corduliidae	Cordulia shurtleffii	102015	6	2	28.60%
Odonata	Corduliidae	Corduliidae	102020	23	4	57.10%
Hemiptera	Corixidae	Corixidae	103364	6	2	28.60%
Diptera	Chironomidae	Corynoneura	128563	8	3	42.90%
Diptera	Chironomidae	Cricotopus	128575	3	1	14.30%
Diptera	Chironomidae	Cryptochironomus	129368	3	1	14.30%
Diptera	Culicidae	Culicidae	125930	4	1	14.30%
Diptera	Ceratopogonidae	Dasyhelea	127278	17	1	14.30%
Diptera	Chironomidae	Dicrotendipes	129428	2	1	14.30%
Coleoptera	Dytiscidae	Dytiscidae	111963	4	2	28.60%
Enchytraeida	Enchytraeidae	Enchytraeus	68531	1	1	14.30%
Diptera	Chironomidae	Endochironomus	129470	5	1	14.30%

Order (or higher)	Family	Taxon	TSN	Total No.	No. of Sites	Percent of Sites
Trombidiformes	Oxidae	Frontipoda	83240	27	4	57.10%
Hemiptera	Gerridae	Gerridae	103801	4	1	14.30%
Diptera	Chironomidae	Glyptotendipes	129483	3	1	14.30%
Coleoptera	Dytiscidae	Graphoderus occidentalis	112166	1	1	14.30%
Hemiptera	Corixidae	Hesperocorixa laevigata	103452	2	1	14.30%
Trombidiformes	Hydrodromidae	Hydrodroma	83225	21	2	28.60%
Trichoptera	Hydroptilidae	Hydroptilidae	115629	1	1	14.30%
Odonata	Libellulidae	Libellulidae	101797	2	1	14.30%
Trichoptera	Limnephilidae	Limnephilidae	115933	1	1	14.30%
Coleoptera	Dytiscidae	Liodessus abjectus	728507	1	1	14.30%
Lumbriculida	Lumbriculidae	Lumbriculidae	68440	1	1	14.30%
Diptera	Chironomidae	Microtendipes Pedellus Gr.	NA	333	3	42.90%
Tubificida	Naididae	Naididae	68854	3	2	28.60%
Tubificida	Naididae	Nais	68946	3	1	14.30%
Nemata	—	Nemata	563956	56	1	14.30%
Diptera	Chironomidae	Nilothauma	129548	9	2	28.60%
Hemiptera	Notonectidae	Notonecta	103558	3	2	28.60%
Hemiptera	Notonectidae	Notonecta kirbyi	103563	25	4	57.10%
Hemiptera	Notonectidae	Notonecta undulata	103568	11	4	57.10%
Ostracoda	—	Ostracoda	84195	90	1	14.30%
Diptera	Chironomidae	Paratanytarsus	129935	5	1	14.30%
Trombidiformes	Pionidae	Piona	83350	16	3	42.90%
Trombidiformes	Pionidae	Pionacercus	83400	8	2	28.60%
Diptera	Chironomidae	Polypedilum	129657	2	1	14.30%
Diptera	Chironomidae	Procladius	128277	1183	7	100.00%
Diptera	Chironomidae	Psectrocladius	129018	142	4	57.10%
Diptera	Chironomidae	Psectrotanypus	128048	1	1	14.30%
Veneroida	Sphaeriidae	Sphaeriidae	81389	1	1	14.30%
Diptera	Tabanidae	Tabanidae	130934	1	1	14.30%
Diptera	Chironomidae	Tanypodinae	127994	5	2	28.60%
Diptera	Chironomidae	Tanytarsus	129978	827	7	100.00%
Diptera	Chironomidae	Tribelos	129820	4	1	14.30%
Trichoptera	—	Trichoptera	115095	3	1	14.30%
Diptera	Chironomidae	Zavrelimyia	128259	47	1	14.30%

Appendix E. Zooplankton Taxa of Redwood National Park

Table E-1. List of taxa collected at Redwood National Park, 2016. The Category and Taxon are the values reported by the taxonomic contractor – CLA = Cladoceran. ITIS.gov Taxon is the current taxa name using the Integrated Taxonomic Information System, and may vary from the contractor reported value. TSN = Taxonomic Serial Number. Total Accumulated Density is the density at the single site, Freshwater Lagoon.

Category	Taxon	ITIS.gov Taxon	TSN	Total Accumulated Density (per m ³)	No. of Sites	Percent of Sites
CLA	Diaphanosoma brachyurum	Diaphanosoma brachyurum	83838	316	1	100%
CLA	Bosmina longirostris	Bosmina longirostris	83938	316	1	100%

Appendix F. Littoral Zone Macroinvertebrates of Redwood National Park

Table F-1. Taxonomic units of littoral zone benthic macroinvertebrates encountered Redwood National Park, 2016. TSN = Taxonomic Serial Number; see www.itis.gov for full taxonomy. NA indicates cases where no TSN exists, either due to it being a “species group,” or a recently redescribed taxon with no number yet designated.

Order (or higher)	Family	Taxon	TSN	Total No.	No. of Sites	Percent of Sites
Diptera	Chironomidae	Ablabesmyia	128079	3	1	100%
Odonata	Aeshnidae	Aeshnidae	101596	1	1	100%
Diptera	Ceratopogonidae	Ceratopogoninae	127338	2	1	100%
Architaenioglossa	Viviparidae	Cipangopaludina	70328	5	1	100%
Odonata	Coenagrionidae	Coenagrionidae	102077	48	1	100%
Copepoda	—	Copepoda	85257	2	1	100%
Diptera	Chironomidae	Dicrotendipes	129428	2	1	100%
Basommatophora	Ancylidae	Ferrissia	76569	1	1	100%
Diptera	Chironomidae	Glyptotendipes	129483	9	1	100%
Basommatophora	Planorbidae	Gyraulus	76592	2	1	100%
Coleoptera	Halplidae	Halplidae	111857	1	1	100%
Coleoptera	Halplidae	Halplus	111858	1	1	100%
Coleoptera	Halplidae	Halplus leechi	111863	3	1	100%
Coleoptera	Halplidae	Halplus robertsi	111865	4	1	100%
Rhynchobdellida	Glossiphoniidae	Helobdella	69396	3	1	100%
Amphipoda	Hyaellidae	Hyaella	94025	15	1	100%
Trombidiformes	Mideopsidae	Mideopsis	83479	6	1	100%
Ostracoda	—	Ostracoda	84195	71	1	100%
Coleoptera	Halplidae	Peltodytes callosus	111935	3	1	100%
Basommatophora	Physidae	Physella	76698	5	1	100%
Veneroida	Sphaeriidae	Pisidium	81400	7	1	100%
Basommatophora	Planorbidae	Planorbella	76654	1	1	100%
Neotaenioglossa	Hydrobiidae	Potamopyrgus antipodarum	205006	342	1	100%
Diptera	Chironomidae	Procladius	128277	4	1	100%
Diptera	Chironomidae	Psectrotanypus	128048	3	1	100%
Megaloptera	Sialidae	Sialis	115002	1	1	100%
Veneroida	Sphaeriidae	Sphaeriidae	81389	89	1	100%
Trepaxonemata	—	Trepaxonemata	914204	2	1	100%
Tubificida	Naididae	Tubificinae	974289	2	1	100%

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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