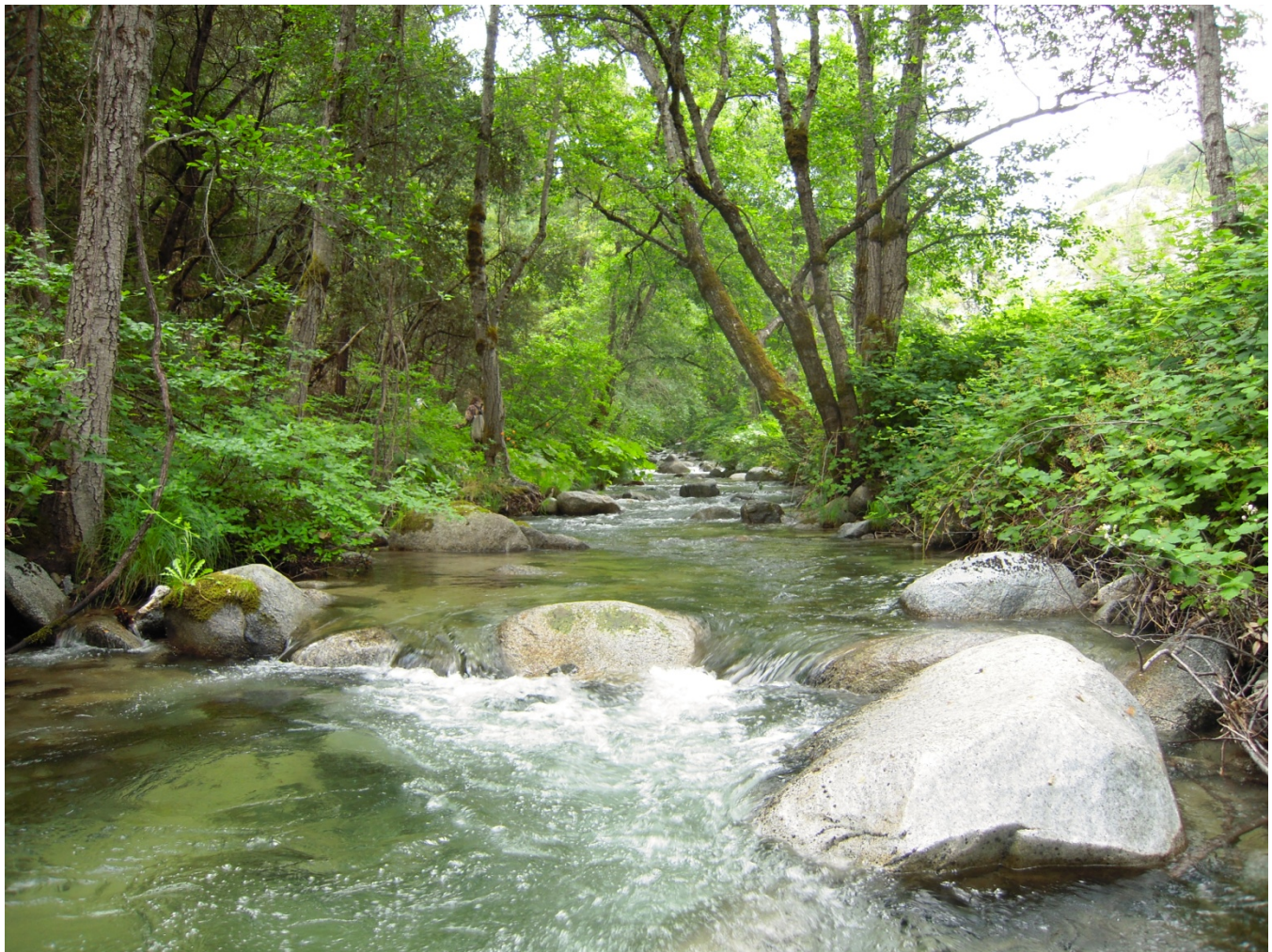




# **Integrated Aquatic Community and Water Quality Monitoring of Wadeable Streams in the Klamath Network – Annual Report**

*2011 results from Whiskeytown National Recreation Area and  
Lassen Volcanic National Park*

Natural Resource Technical Report NPS/KLMN/NRTR—2014/904



**ON THE COVER**

Crystal Creek, Whiskeytown National Recreation Area

Photograph by: Charles Stanley, Field Crew Leader

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## **Executive Summary**

Sampling was undertaken to determine the ecological condition status of streams in two park units: Whiskeytown National Recreation Area, and Lassen Volcanic National Park. Ecological condition, “the state of the physical, chemical and biological characteristics, and the processes and interactions that connect them,” was assessed by measuring an array of stream biota, in-stream characteristics, water quality, and stream bank variables and metrics. These measures were then used, either singularly or integrated, to assign sites to conditions categories of “Least disturbed, Intermediate, and Most disturbed.”

### **Whiskeytown National Recreation Area**

A total of 22 sites were sampled and assessed for ecological condition at Whiskeytown from 21 June to 11 August, 2011.

Based on the four groups of physical measures (In-stream Habitat Cover – a measure of stream habitat complexity; Riparian Cover – a measure of streamside plant communities; Relative Bed Stability – a measure of sediment surplus/deficit; and Riparian Disturbance – a measure of human streamside impact), the majority of streams are in the “Least disturbed” category. Several streams were assigned to the “Intermediate” category and two streams to the “Most disturbed” category for Relative Bed Stability; however these assignments may be due to the natural character of the streams rather than an indication of active impairment.

Based on four water quality parameters (total phosphorus and total nitrogen – measures of nutrient enrichment; salinity – (measured as conductivity) indicative of irrigation or water withdrawal; and acid neutralizing capacity – measure of sensitivity to acid rain), all streams were assigned to the “Least disturbed” category for all parameters except total phosphorus for which 12 sample sites were assigned to the “Intermediate” category – although many of these 12 measurements barely exceeded the upper level for the “Least disturbed” category.

Biota-based conditions revealed mixed results. Using vertebrates (fish and amphibians), 20 sites were categorized as “Least disturbed” and two as “Intermediate”. A total of five amphibian and six fish species (including non-native brook and brown trout) were recorded. These species have all been previously identified on the park’s certified species lists. Using benthic macroinvertebrates, 19 sites were categorized as “Least disturbed”, two as “Intermediate”, and one, Willow Creek (a current Clean Water Act 303(d) water quality impaired site due to acid mine drainage), was rated as “Most disturbed”. A total of 14,708 benthic macroinvertebrates were collected, comprising 256 separate taxa.

### **Lassen Volcanic National Park**

A total of 24 sites were sampled and assessed for ecological condition at Lassen Volcanic from 15 August to 30 September 2011.

Based on the four groups of physical measures (In-stream Habitat Cover – a measure of stream habitat complexity; Riparian Cover – a measure of streamside plant communities; Relative Bed

Stability – a measure of sediment surplus/deficit; and Riparian Disturbance – a measure of human streamside impact) several streams were in the “Intermediate” category. Particularly, the Riparian Cover showed eight sites in the “Intermediate” category, however, this is a character of the montane, sub-alpine meadow streams common in Lassen Volcanic National Park, and not a sign of degradation, because the stream-side riparian zone is dominated by shrubs and grasses with reduced overstory. Riparian Disturbance was elevated to “Intermediate” in two sites, on Manzanita Creek and Kings Creek; both at specific sites close to park visitor attractions (roadside and near a campground). There were also several sites noted as having smaller than expected substrate sizes base on the Relative Bed Stability measure.

Based on four water quality parameters (total phosphorus and total nitrogen – measures of nutrient enrichment; salinity – (measured as conductivity) indicative of irrigation or water withdrawal; and acid neutralizing capacity – measure of sensitivity to acid rain), all stream sites were assigned to “Least disturbed,” except for total phosphorous, which showed 19 measurements in the “Intermediate” category, although many are borderline with “Least disturbed.” This is indicative of the volcanic nature of the local geology, and not a sign of impairment. Three sites were also “Intermediate” for total nitrogen; two of these are on Lost Creek and one on Summit Creek. These values were barely over threshold values for ranking as “Least disturbed,” but their location near park roadways and campgrounds suggest potential anthropogenic influences.

Biota-based conditions estimates showed mixed results. Using vertebrates (fish and amphibians), most sites except three were “Intermediate,” and another four being unrated due to no vertebrates present. The three not “Intermediate” were “Least disturbed.” Only a single amphibian species was found, and three fish species were recorded (native rainbow trout, and the non-native brook and brown trout). All species were already on certified park species lists. Condition using benthic macroinvertebrate metrics showed all sites in “Least disturbed” category, excepting the use of the Eastern Sierra Multi-Metric Index. When applying the Eastern Sierra, 10 sites were “Intermediate” and 1 site was “Most disturbed.” Because the Eastern Sierra MMI conflicts with the other metrics, it may not be regionally relevant as a condition index. A total of 16,261 individual were collected, comprising 165 separate taxa.

## Acknowledgments

This project was supported by many thoughtful discussions with park staff in the development of the streams monitoring protocol, including discussions of reporting strategies. For this field season, we especially acknowledge the diligence of the streams field crew: Charles Stanley, Joshua Jiannino, Ronald Clark, and Theresa Tillson. Park specialists and resource managers were also invaluable in implementing the monitoring. At Whiskeytown National Recreation Area, special thanks go to Sean Denniston, Jennifer Gibson, and Russ Weatherbee; at Lassen Volcanic National Park, special thanks to Michael Magnuson. Finally, we thank David Hering for a critical review of the draft report. Lise Grace of the North Coast Cascades Network and Gordon Dicus of the Upper Columbia Basin Network also worked to improve the report.



## Introduction

The Klamath Network (KLMN) vital signs selection process identified two freshwater aquatic resource 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 disturbance of freshwater habitats and resources.

Initial selection of aquatic communities and water quality did not differentiate between lentic (lake and pond) versus lotic (stream) habitats. Fundamental differences in ecosystem structure and process between streams and lakes dictated a basic division in sampling methodology. Lentic sampling is covered in a separate protocol ([Dinger et al. 2012](#)).

Because streams are integrated ecosystems central to park landscapes, we have chosen to monitor physical, biological, and chemical parameters in concert. These varied parameters allow measurement of change on multiple scales in time and space. For instance, macroinvertebrate assemblages respond rapidly to impacts, while fish and amphibians (with longer life cycles) will demonstrate longer duration, time-integrated responses. Changes in geomorphic and riparian vegetation features will likely manifest at yet longer time scales. The use of multiple indicators for measuring ecosystem change provides an integrated and robust system for interpreting natural dynamics, and for detecting trends in key ecological features and diverse impacts over time.

Sampling was undertaken to determine the ecological condition status of streams in two network parks: Whiskeytown National Recreation Area (hereafter “Whiskeytown”) and Lassen Volcanic National Park (hereafter “Lassen Volcanic”). To meet this goal, two definitions are important:

- “Ecological condition” – From the Environmental Protection Agency (EPA) Report on the Environment, “ecological condition” is defined as “the state of the physical, chemical and biological characteristics of the environment, and the processes and interactions that connect them ([USEPA 2008](#)).”
- “Status” – “defined as some statistic (e.g., a mean/median/proportion) of a parameter over all monitoring sites within a single or well-bounded window of time. Status will always have some measure of statistical precision (e.g., a confidence interval, standard error, variance)... ([Sarr et al. 2007](#)).”

For determining the common conceptual use of “ecological condition” and “status” we use condition thresholds of 11 metrics used by the EPA. These thresholds are used to categorize sites into condition classes: “Least disturbed, Intermediate, and Most disturbed.” Other reports by the EPA use “Good, Fair, and Poor” for the same classes and metrics. These classes, based on west-wide and mountainous reference conditions, are meant to be guides and not absolutes in defining park condition. Final assessment may require follow-up investigations or consultation with park specialists.



## Methods

Full, detailed methods of all aspects of the project are available in [Dinger et al. \(2013\)](#). Methods are taken in large part from the EPA Environmental Monitoring and Assessment Program, now the [National Rivers and Streams Assessment](#) program ([EPA 2009](#)), with modifications to fit KLMN time, logistics, and budgetary constraints. Abbreviated methods are provided here; interested readers are encouraged to peruse the full Dinger et al. (2013) protocol which is available online (<http://science.nature.nps.gov/im/units/klmn/monitor/streams.cfm>). Additionally, methods are provided for some field sampling that is not analyzed or reported herein – it is included here for providing an overview of the portfolio of data that will be available in future Analysis and Synthesis reports (Dinger et al. 2013).

### Site Selection

Sites were selected following SOP #3 of the KLMN Wadeable Streams Protocol (Dinger et al. 2013). In brief, 30 sites (and another 30 “oversample” sites) were probabilistically identified using Generalized Random Tessellation Stratified spatially balanced design ([Stevens and Olson 2004](#)) in the [spsurvey package](#) ([Kincaid 2012](#)) for R statistical software (version 2.11.1; [R Core Development Team](#), Vienna, Austria). The sampling frame was all perennial streams within a park unit that: (1) were < 1000 meters from an established road or trail, and (2) had a streambed gradient less than 15%. Shapefiles of streams were obtained from the USGS [National Hydrography Dataset](#). The oversample sites represent alternate sample sites to maintain the spatially balanced random sample in the event that the initial sites were unsafe, dry, or otherwise unsampleable. The selection or rejection of field sites was determined by the field crew leader on-site.

### Site Layout

At each selected sample site, a sample reach 40 times longer than the typical wetted width of the stream is set up. Eleven equally spaced transects perpendicular to stream flow are marked with temporary flagging. A minimum reach length of 150 meters and a maximum reach length of 500 meters were imposed. A schematic showing some qualities of the sampling reach are shown in Figure 1.

### Water Chemistry and Quality

A [Eureka Environmental](#) “Manta” water quality probe was used to take seven cross-section measurements of temperature (°C), pH, specific conductivity ( $\mu\text{Scm}^{-1}$ ), dissolved oxygen ( $\text{mg L}^{-1}$ ), and turbidity (NTU) in a well-mixed riffle. Specific conductivity was used to ensure that the riffle was well mixed, by scanning the seven cross-section measurements for little or no variability. If the specific conductivity had more than a  $5 \mu\text{Scm}^{-1}$  differential across the stream, the measurement was repeated in an upstream riffle until a well-mixed riffle was confirmed.

When a well-mixed riffle was confirmed, a 2 liter amber high-density poly-ethylene (HDPE) sample bottle was submerged to collect a water sample. On shore, using a 60 ml syringe and filter holder, a portion of each water sample was filtered through a  $0.45 \mu\text{m}$  nylon membrane filter into an amber, acid washed 250 ml HDPE bottle for cation ( $\text{Ca}^{2+}$ ,  $\text{Na}^{+}$ ,  $\text{K}^{+}$ , and  $\text{Mg}^{2+}$ ) and anion ( $\text{SO}_4^{2-}$  and  $\text{Cl}^{-}$ )

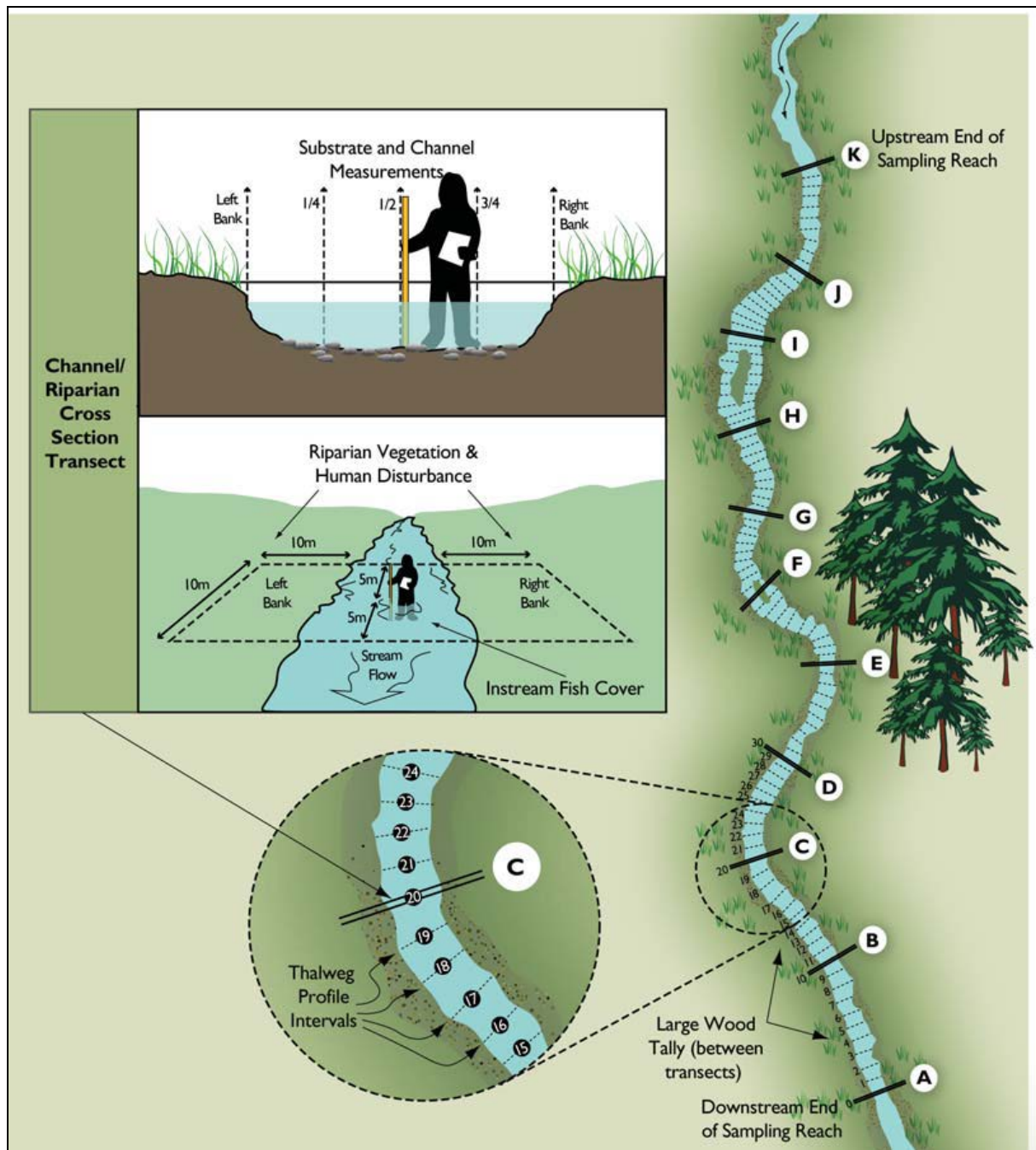


**Figure 1.** Schematic of sampling site reach layout (from EPA Wadeable Streams Assessment, 2006, Figure 11).

analyses. An additional unfiltered 250 ml of water was decanted into an identical bottle for nutrient analyses (total nitrogen, total phosphorous). Both bottles were kept cool until we were able to freeze them (generally <4 hours). Additionally, 120 mL of water were filtered through pre-combusted glass fiber filters into an acid-washed, pre-combusted glass vial for Dissolved Organic Carbon (also kept cool and later refrigerated). These samples were then shipped to the [Cooperative Chemical Analytical Laboratory](#) at Oregon State University, Corvallis.

## **Stream Habitat/Riparian Corridor Characteristics**

For the length of the reach, we assessed the following geomorphic characteristics: channel constraint type and percent constrained, channel pattern (braided, anastomosing, single), and evidence of recent torrents.

At each of the 11 transects, we measured cross-sectional information including wetted width, bank angles, undercut banks, presence and height of incised banks, and bankfull width and height. Across the transect (left bank,  $\frac{1}{4}$ ,  $\frac{1}{2}$ ,  $\frac{3}{4}$ , and right bank) we measured: depth, substrate embeddedness, substrate size, and algal periphyton thickness (as in [Fetscher et al. 2010](#)).

On each bank and in the middle of the stream at each transect, we collected measures of overhead shading with a convex, spherical densiometer. Areal categorization of fish habitat cover 5m above and 5m below the transect in the following classes were estimated: Artificial substrate (e.g. concrete), Boulders, Filamentous Algae, Large wood, Macrophytes, Overhanging banks, Roots, Small wood, and Undercut banks. In a 10m X 10m quadrat next to the transect, we also estimated measures of riparian coverage (dominant vegetation type, cover classes [sparse, moderate, heavy, very heavy] of small trees and large trees, herbs, grasses, etc.) in the ground layer (< 0.5m), understory (0.5m to 5.0m), and overhead canopy (> 5m). In this same quadrat, we quantified the presence of human influences (e.g., walls, dikes, inlet/outlet pipes, camping, etc.).

We also performed thalweg measurements for the entire reach, taking either 100 or 150 equally spaced measurements of max depth, presence of soft or small sediments, and channel form type (pool, glide, riffle, rapid, etc.). At the mid-point between transects, we repeat the cross section measurements (as above) of substrate type and algal thickness.

Inter-transect measures of downed woody debris were also made for the length of the reach. Woody debris was tallied for categories of length and diameter, both within the bankfull stream channel and in adjacent areas above bankfull height.

Stream gradient is measured between transects using a stadia rod and hand-held level. An observer with the hand level stands at the approximate half-way point, and a stadia rod is placed at the transects and the difference between upstream and downstream is recorded for the rise. In this way, the total slope and variation in stream gradient can be measured.

Dominant tree along each transect is also recorded, and a hand-held laser level is used to calculate approximate total height. The broad taxonomic group of the largest tree is also recorded (Alder/Birch, Willow, Maple, Oak, Pine, Spruce, etc.).

## **Aquatic Communities**

Benthic macroinvertebrates were collected using the EPA Reach-wide benthos technique. At each transect, a 1 ft. wide D-frame net (500µm pore size) was used; in fast water habitats, the upstream substrate in a 1 sq. ft. area was disturbed so that organisms flow into the net for collection. In slack water habitats, an active sweep was used in a 1 sq. ft. area to collect the organisms. The 11 collections were composited and elutriated (i.e., the lighter debris/invertebrates are separated from the heavier inorganic substrates). The sample was 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.](#)).

Aquatic vertebrates were sampled with a Smith-Root LR-24 electrofisher, using single pass. The time spent on a particular reach varies, but total targeted shock time was between 900 and 1200 seconds. Fish and amphibians netted were stored in a bucket with a battery powered aerator. Specimen species were recorded to species, enumerated, and the total lengths of the longest and smallest specimen were recorded. For salmonid species, the number of each size class was also recorded (< 60mm, 60 - 90mm, 90 - 120mm, 120 - 150mm, and > 150mm).

Algal biomass was collected by taking a sample from each transect, following the reach-wide benthic technique. Collection technique varied based on dominant substrate at each transect: (1) if cobble, then a 12.6 cm<sup>2</sup> area was scrubbed using a stiff brush and a rubber delimiter to mark the area, (2) if gravel/sand, then a 12.6 cm<sup>2</sup> core was used to collect the substrate, and (3) if bedrock then a 5.3 cm<sup>2</sup> sample was taken with a disposable scrubber *in situ*. Samples from each transect were processed, and composited into a single container. An aliquot was then taken for Ash Free Dry Mass and filtered onto a glass-fiber filter. A second aliquot was filtered on nylon membrane filters for chlorophyll *a* analysis. Filters were then kept on ice and frozen as soon as possible (along with water samples). Chlorophyll processing (extraction and measurement of concentration with fluorometer) was completed at a contract laboratory; in this sample year we worked with Cascade Research ([John Salinas](#) of Grants Pass, Oregon).

### **Condition Assessments**

Following the EPA established “indicators of aquatic stress” used in the EPA Wadeable Streams Assessment (EPA 2006) and the EPA EMAP Ecological Assessment of Western Streams and Rivers (Stoddard et al. 2005a), we use 10 indicators of condition. These indicators cover three broad categories of assessment: 1) Biological, 2) Chemical, and 3) Physical Habitat. For each indicator, the EPA uses thresholds for determining three condition classes: “Least disturbed,” “Intermediate,” and “Most disturbed.” Additionally, a regional macroinvertebrate Multi-Metric Index using state of California thresholds was used in assessing condition. Each indicator and its calculation are described briefly below (text adapted from Stoddard et al. 2005a).

#### ***Total Phosphorous***

Total phosphorous is a nutrient, and is usually considered to be the most likely nutrient limiting algal growth in freshwaters throughout the U.S. It is a common ingredient in fertilizers, and high concentrations may be associated with agricultural and urban land use. In the KLMN, this sample is taken at a single, well-mixed riffle near the midpoint of the stream reach, and an unfiltered portion frozen and sent to an analytical laboratory.

#### ***Total Nitrogen***

Nitrogen is another nutrient, and is particularly important as a contributor to coastal and estuarine algal blooms. Sources include fertilizers, wastewater, animal wastes, and atmospheric deposition. In the KLMN, this sample is taken at a single, well-mixed riffle near the midpoint of the stream reach, and an unfiltered portion frozen and sent to an analytical laboratory.

### **Salinity**

Excessive salinity occurs in areas with high evaporative losses of water, and can be exacerbated by repeated use of water for irrigation, or by water withdrawals (by slowing transit time of flowing waters). Both electrical conductivity and total dissolved solids (TDS) can be used as measures of salinity; for KLMN monitoring we follow NPS Water Resources Division (WRD) guidance and measure specific conductivity.

### **Acid Neutralizing Capacity**

From the Wadeable Streams Assessment (EPA 2006) – Streams and rivers can become acidic through the effect of acid deposition (e.g., acid rain) or acid mine drainage, particularly from coal mining. In assessing acid pollution (either acid rain or mine drainage), the KLMN relies on a measure of water’s ability to buffer inputs of acid (Acid Neutralizing Capacity; ANC). When ANC falls below zero, the water is considered acidic and can be directly or indirectly toxic to biota (i.e., by mobilizing toxic metals, such as aluminum). When ANC is between 0 and 25 µeq/L (0 and 1.25 mg/L CaCO<sub>3</sub>), a stream is considered sensitive to episodic acidification.

### **Streambed Stability (aka Relative Bed Stability)**

Streams and rivers adjust their channel shape and streambed particle size in response to the supply of water and sediments from their drainage areas. One measure of this interplay between sediment supply and transport is relative bed stability (RBS). The measure of RBS used here is a ratio comparing the particle size of observed sediments to the size of sediment each stream can move or scour during its flood stage, based on the size, slope and other physical characteristics of the stream channel. The RBS ratio differs naturally among regions, depending upon landscape characteristics that include geology, topography, hydrology, natural vegetation, and natural disturbance history. Values of the RBS can be either substantially lower (prevalence of fine sediments) or higher (coarser, more stable streambeds) than those expected based on the range of the least disturbed sites – both high (altered flow) and low (increased sedimentation) values are considered to be indicative of impairment (Figure 2). In the KLMN, we utilize an RBS value based purely on stream gradient and average stream depth; the quick estimate of [Kaufmann et al. \(1999\)](#). A more refined RBS, incorporating residual pool depth, woody debris, and bankfull characteristics will be used in later reports when reporting and analysis tools are available from the EPA.



**Figure 2.** Numeric range and thresholds for RBS condition assessment. Red line = “Most disturbed”, Yellow line = “Intermediate”, and Green line = “least disturbed”. Higher values suggest stable streambeds with altered flow regimes (e.g., upstream dams) and lower values suggest increased sediments from human landscape use. See text for more details.

### ***Habitat Complexity (aka Fish Cover or In-stream Habitat Cover)***

This metric is termed “habitat complexity” in Stoddard et al. (2005a), but is synonymous with In-stream Fish Habitat in EPA (2006), and Fish Cover in Kaufmann et al. (1999). We follow the terminology of Stoddard et al (2005a).

The most diverse fish and macroinvertebrate assemblages are found in streams and rivers that have complex forms of habitat: large wood, boulders, undercut banks, tree roots, etc. Human use of streams and riparian areas often result in the simplification of this habitat, with potential effects on biotic integrity. We use a measure that sums the amount of in-stream habitat consisting of undercut banks, boulders, large pieces of wood, and cover from overhanging vegetation within a meter of the water surface. It is a scalar metric for which the highest values represent the highest habitat complexity. Because multiple categories of areal coverage are summed, values can exceed 100% (or 1.0 on a decimal scale).

### ***Riparian Vegetation Complexity***

The presence of a complex, multi-layered vegetation corridor along streams and rivers is an indication of how well the stream network is buffered against sources of stress in the watershed. Intact riparian areas can help reduce nutrient and sediment runoff from the surrounding landscape, prevent bank erosion, provide shade to reduce water temperature, and provide leaf litter and large wood that serve as food and habitat for stream organisms. The presence of canopy trees in the riparian corridor indicates longevity; the presence of smaller woody vegetation typically indicates that riparian vegetation is reproducing, and suggests the potential for future sustainability of the riparian corridor. As in Stoddard et al. (2005a), we use a measure of riparian complexity that sums the amount of woody cover provided by three layers of riparian vegetation: ground layer, woody shrubs (understory layer), and the overhead canopy. Because multiple categories of areal coverage are summed, values can exceed 100% (or 1.0 on a decimal scale).

### ***Riparian Disturbance***

The vulnerability of the stream network to potentially detrimental human activities increases with the proximity of those activities to the streams themselves. For this assessment, we use a direct measure of riparian human disturbance that tallies 11 specific forms of human activities and disturbances (e.g., roads/trails, landfills, piping, building, farming, etc.), and weights them according to how close to the stream channel they are observed. The index generally varies from 0 (no observed disturbance) to 6 (multiple types observed in the stream, throughout the reach).

### ***Multi-Metric Indices (MMIs)***

Ecological condition can be assessed using biological assemblages because of the inherent capacity of organisms to integrate chemical and physical stressors that affect them over varying spatial and temporal time scales ([Rosenberg and Resh 1992](#), [Karr and Chu 1999](#), [Brousseau and Randall 2008](#)). We use three separate MMIs for assessment: 1) Aquatic Vertebrates index; 2) West-Wide Macroinvertebrates index, and 3) a regional state-based Macroinvertebrate index. Multi-Metric Indices use a sum of scores for a variety of individual measures, that make up the key characteristics of biotic integrity (e.g., taxonomic richness, habitat/trophic composition, sensitivity to human disturbance, etc.). Examples of how the metrics were calculated are presented in Appendix A.

### Aquatic Vertebrate MMI

This metric includes measures chosen to represent key characteristics of biological integrity: taxonomic richness, taxonomic composition, habitat use, reproductive strategies, pollution tolerance, feeding groups, and the presence of non-native species. The resulting MMI combines all the measures into an index for which values range from 0 to 100, with 100 denoting the best possible condition. The development process is given in more detail in the EMAP West Statistical Summary ([Stoddard et al. 2005b](#)).

### West-Wide Macroinvertebrate MMI

Characteristics used for the West-Wide Macroinvertebrate MMI were: taxonomic richness, taxonomic compositions, taxonomic diversity, feeding groups, habits, and pollution tolerance. Like the Vertebrate MMI, the scores in each category are summed, and scaled to a 0 to 100 range, with 100 denoting the best possible condition.

### Regional Macroinvertebrate MMIs

We utilized two regionally relevant MMIs developed by state or academic researchers in different part of the Klamath Region: 1) For Whiskeytown National Recreation Area, the California Surface Water Ambient Monitoring Program (SWAMP) developed an MMI for the North Coast Region, including the inland area of Whiskeytown NRA ([Rehn et al. 2005](#)); and 2) a Sierra Nevada MMI developed by water quality researchers for montane streams of the Sierra Nevada – of which Lassen Volcanic National Park may share similar attributes ([Herbst and Silldorff 2009](#)). Both of these are briefly described below.

#### *California Northern Coastal Region MMI*

This MMI was developed for three northern California Omernik Level III ecoregions ([Omernik 1987](#)): coast range, Klamath mountains, and the southern and central California chaparral and oak woodlands. The components used were: total richness of mayflies, stoneflies, and caddis flies; beetle richness; true fly richness, tolerant individuals, non-snail scraping individuals, predatory individuals, and shredding functional feeding groups taxa; and the number of non-insect taxa. It is scored from 0 to 100 (100 denoting the best possible condition), and condition assessed on categories of Very Poor, Poor, Fair, Good, and Very Good.

#### *Sierra Nevada MMI for Lassen Volcanic National Park*

The application of this condition metric should be conservative since the development and calibration of this metric is based on streams that may be geomorphically similar, but the organisms may differ in their biogeography (e.g., Lassen Volcanic NP stream fauna may have more similarity to the Cascades than the Sierra Nevadas). Unfortunately, no other regional metric exists as of this report. The value of this metric may be in establishing a separate, integrative condition that can be assessed for change over time, but may not pertain to exact conditions. The Sierra Nevada MMI uses multiple measures of taxa richness, the amount of tolerant taxa, Shredder functional feeding groups abundance, dominance of taxa, and community tolerance. All the metrics are summed for a score of 0 to 100 (100 denoting the best possible condition).

## Condition Thresholds

The above condition metrics all use an assessment of sites based on thresholds; if a score is higher than the threshold criterion, it is rated “least disturbed”, or if it is lower than a certain threshold, it is rated “Most disturbed.” Values that lie in between these thresholds are termed “Intermediate.” Here, we maintain this scheme for denoting condition (some EPA reports convert these categories to “good, fair, or poor.” Values used for condition assessment are presented in Table 1.

The EPA derived these thresholds by comparing physical and chemical data from sites collected across the west to determine reference condition. These criteria vary from region to region, and developed iteratively, irrespective of land use, to identify the areas with the least amount of ambient human disturbance. Sites that meet these criteria are the “best of what’s left” in the West (from EPA 2005).

**Table 1.** Threshold for condition rating used in the Klamath Network. See text for further description and source of threshold values.

| Category                                 | Most disturbed        | Least disturbed            |
|------------------------------------------|-----------------------|----------------------------|
| Biological                               |                       |                            |
| EPA Invertebrate MMI                     | < 57                  | ≥ 71                       |
| EPA Vertebrate MMI                       | < 37                  | ≥ 62                       |
| Chemical                                 |                       |                            |
| Acid neutralizing capacity (µeq/L)       | < 0                   | > 0                        |
| Specific conductance (µS/cm)             | >1000                 | ≤500                       |
| Total nitrogen (mg/L)                    | > 0.2                 | ≤0.125                     |
| Total phosphorous (mg/L)                 | >0.04                 | ≤0.01                      |
| Physical                                 |                       |                            |
| In-stream habitat cover                  | <0.14                 | ≥0.33                      |
| Relative Bed Stability (log transformed) | <-1.3 or >0.6         | ≥-0.7 and ≤0.1             |
| Riparian Cover                           | <0.23                 | ≥0.67                      |
| Riparian disturbance                     | >0.95                 | ≤0.35                      |
| State Regional Invertebrate Metrics      |                       |                            |
| Eastern Sierra MMI                       | < 63.2                | > 80.4                     |
|                                          | <u>"fair to poor"</u> | <u>"good to very good"</u> |
| CA North Coast MMI                       | < 60                  | >60                        |

## Additional Reporting

In addition to the metrics used for condition assessment, we report on two commonly used macroinvertebrate metrics (Shannon Index and Hilsenhoff Biotic Index). The Shannon Index ( $H'$ ) is measure of community structure defined by the relationship between the number of distinct taxa and their relative abundance, incorporating both into a single number. It is calculated as:  $H' = -\sum p_i \ln p_i$  where  $p_i$  is the proportion of the  $i$ th species. Values generally range from 0 to 3. Higher values generally suggest a more balanced, diverse, and cosmopolitan assemblage. The Hilsenhoff Biotic Index (HBI) is a weighted average of tolerance values derived from empirical observations of

macroinvertebrate responses to pollution (Hilsenhoff 1987, 1988). It is calculated as  $HBI = \frac{\sum n_i a_i}{N}$  where  $n_i$  = the number of individuals for taxa  $i$ ,  $a_i$  = the assigned tolerance value of taxa  $i$ , and  $N$  = the total number of individuals for a sample. The HBI sums the overall tolerances of the taxa collected. This index is used to detect nutrient enrichment, high sediment loads, low dissolved oxygen, and thermal impacts. Shifts in HBI from low values to high values suggest a community change towards a more pollutant tolerant community. The source of tolerance values used is a regionally developed list by the [Southwest Association of Freshwater Invertebrate Taxonomists \(SAFIT\)](#). Despite the name, the taxa lists are broadly applicable to the entire western US.

### Water Quality Exceedances

States implement water quality criteria with strict methodologies (for example, a 4 or 5 day average water temperature). This protocol, focused on ecological and environmental status and trends, is not a perfect fit for many of these parameters because it only collects single measurements triennially. However, when there is some indication of an exceedance, it should be reported with the suggestion that the park follow-up with site-specific measurements, if warranted. The thresholds used are based on NPS criteria embedded within NPSTORET, State of California drinking water criteria, and EPA criteria for drinking water, health advisory, and National Ambient Water Quality Criteria (Table 2). However, note that although these are promulgated thresholds, their applicability is not strict; we provide the drinking water criteria and health advisory criteria only for comparative purposes, because natural stream systems are not drinking water sources for the population.

**Table 2.** Available water quality criteria used for possible exceedances, including drinking water (not applicable for natural waters, but provided for comparative reasons). See Dinger et al. 2013 for sources.

| Parameter                                                     | NPS Criteria | California     | EPA Criteria   |                 |                                                                          |
|---------------------------------------------------------------|--------------|----------------|----------------|-----------------|--------------------------------------------------------------------------|
|                                                               |              | Drinking Water | Drinking Water | Health Advisory | National Ambient Water Quality Criteria                                  |
| Alkalinity (mg/l)                                             | > 10         |                |                |                 | > 20                                                                     |
| Chloride (mg/l)                                               |              | < 250          |                |                 | <230 <sup>3</sup> ; <860 <sup>1</sup> - when associated only with Sodium |
| Dissolved Oxygen (mg/l)                                       | > 4          |                |                |                 | > 8.0 1 day minimum (water column)                                       |
| Total Nitrogen (as NO <sub>2</sub> + NO <sub>3</sub> ) (mg/l) |              | < 10           | < 10           |                 |                                                                          |
| pH                                                            | > 6.5        |                | 6.5 to 8.5     |                 | 5 to 9 <sup>2</sup> , 6.5 to 9 <sup>3</sup> (max)                        |
| Sodium (mg/l)                                                 |              |                |                | 20              |                                                                          |
| Sulfate (mg/l)                                                |              |                | 500            |                 | 250*                                                                     |
| Turbidity (NTU)                                               | < 50         | < 1            | < 1            |                 |                                                                          |

<sup>1</sup>Max concentration (1 hour average)<sup>2</sup>Taste & Odor <sup>3</sup>Freshwater Aquatic life protection (4 day average)



# Results

## Whiskeytown National Recreation Area

Twenty-two sites were sampled at Whiskeytown between June 21 and August 11, 2011 (Figure 3). The original target number of sites was 25 to 30; however, several sites were unable to be sampled due to safety or logistical concerns (Table 3). Several sites were planned to be sampled later (WHISWQ29, 31, and 32), but the mid-season change over to Lassen Volcanic National

**Table 3.** Original site list for streams to be sampled in Whiskeytown. Sites marked with an \* were not sampled due to a variety of reasons. Sites requiring more than 1.5 hours to access were deemed too far to safely sample in a single day.

| Stream Name         | Site Code | Date Sampled | Reason for not sampling                |
|---------------------|-----------|--------------|----------------------------------------|
| Willow Creek        | WHISWQ01  | 6/27/2011    |                                        |
| Boulder Creek       | WHISWQ02  | 6/21/2011    |                                        |
| Unnamed             | WHISWQ03  | 7/20/2011    |                                        |
| Clear Creek (SE)    | WHISWQ04  | *            | Too deep to sample safely              |
| Boulder Creek       | WHISWQ05  | *            | Too steep and distant from vehicle     |
| Grizzly Gulch       | WHISWQ06  | 7/7/2011     |                                        |
| Unnamed             | WHISWQ07  | *            | Too distant from vehicle               |
| Paige Boulder Creek | WHISWQ08  | 6/29/2011    |                                        |
| Mill Creek          | WHISWQ09  | 8/9/2011     |                                        |
| Papoose Creek       | WHISWQ10  | *            | Too steep                              |
| Crystal Creek       | WHISWQ11  | *            | Too steep and distant from vehicle     |
| Brandy Creek        | WHISWQ12  | 7/13/2011    |                                        |
| Clear Creek         | WHISWQ13  | *            | Too deep                               |
| Unnamed             | WHISWQ14  | 7/5/2011     |                                        |
| Crystal Creek       | WHISWQ15  | 7/18/2011    |                                        |
| Unnamed             | WHISWQ16  | *            | Too distant from vehicle               |
| Boulder Creek       | WHISWQ17  | 6/30/2011    |                                        |
| Brandy Creek        | WHISWQ18  | 7/11/2011    |                                        |
| Unnamed             | WHISWQ19  | *            | Potentially dry; not evaluated further |
| Clear Creek (SE)    | WHISWQ20  | *            | Too deep to sample safely              |
| Willow Creek        | WHISWQ21  | 8/4/2011     |                                        |
| Unnamed             | WHISWQ22  | 7/26/2011    |                                        |
| Crystal Creek       | WHISWQ23  | 7/19/2011    |                                        |
| Unnamed             | WHISWQ24  | 8/8/2011     |                                        |
| Clear Creek         | WHISWQ25  | 7/25/2011    |                                        |
| Whiskey Creek       | WHISWQ26  | 7/1/2011     |                                        |
| Unnamed             | WHISWQ27  | *            | Potentially dry; not evaluated further |
| Paige Boulder Creek | WHISWQ28  | 7/6/2011     |                                        |
| Clear Creek         | WHISWQ29  | *            | Was planned to be sampled later        |
| Boulder Creek       | WHISWQ30  | 6/22/2011    |                                        |
| Unnamed             | WHISWQ31  | *            | Was planned to be sampled later        |
| Paige Boulder Creek | WHISWQ32  | *            | Was planned to be sampled later        |
| Boulder Creek       | WHISWQ33  | 8/1/2011     |                                        |
| Brandy Creek        | WHISWQ34  | 8/11/2011    |                                        |
| Unnamed             | WHISWQ35  | 7/26/2011    |                                        |

**Figure 3.** Sites sampled in Whiskeytown National Recreation Area, 2011.

Park in early August prevented final inclusion of these sites. Difficulties finding a fourth crew member also limited the crew to sites with shorter access times so that a three person field crew could finish all tasks.

The streams of Whiskeytown are characterized by mostly high gradient streambeds (6.1% average gradient of sampled streams [despite a sampling frame limiting higher gradient streams]), boulder and other large substrate (average of stream median substrate size just under 1 meter in diameter), high amounts of riparian cover (average cover of 110%), and lingering evidence of legacy land use (e.g., pipes or other riparian disturbance). Examples of these are shown in Figure 4.

#### ***Physical characteristics of Whiskeytown streams***

Summary statistics for the monitoring streams are presented in Table 4. These are general geomorphological summaries of the streams (e.g., location, elevation, slope, discharge) and do not impart any conditional information. Clear Creek was the largest stream sampled, with the widest width, greatest average depth, and highest instantaneous discharge. Deeper, faster streams are generally more hazardous to sample. The smallest stream, with the lowest average depth and discharge, was an unnamed tributary to Brandy Creek (WHISWQ14).

#### ***Physical condition metrics of Whiskeytown streams***

The four EPA physical condition metrics along with substrate size and average embeddedness for Whiskeytown are presented in Table 5. A stream's median substrate size is a more useful descriptor because the average substrate size can be significantly influenced by a few, very large pieces of substrate. Overall, as indicated above, Whiskeytown streams are typified by large boulder substrates. Although perhaps not intuitive, we also provide the park-wide median and average median for the surveyed streams. The higher prevalence of large substrates, and relative lack of smaller substrates (e.g., sand, silt, etc.), resulted in a relatively low embeddedness (compared to Lassen Volcanic, for example).

Riparian cover was uniformly high in all Whiskeytown streams, and were all rated as "Least disturbed" based on EPA threshold criteria. In-stream habitat cover was also high in most streams, with the exception of Whiskey Creek, Clear Creek, and one site on Willow Creek (WHISWQ21), which were all rated as "Intermediate." Riparian disturbance was also rated as "Intermediate" in three sites (Boulder Creek, Clear Creek, and Crystal Creek), generally based on roads/trails and pipes, and, to a lesser degree pavement, a building, and other minor influences.

The preliminary examination of Relative Bed Stability (RBS) in Whiskeytown indicates 10 "Intermediate" sites and 2 "Most disturbed" sites. These are preliminary values based on the rapid calculation of RBS, and do not incorporate the effects of woody debris, bankfull characteristics, or residual pool depth on the expected median particle size – these are more complex equations not available yet. Although preliminary, there was a prevalence of positive values in a majority of the sites. Likewise the average and median park-wide RBS value were also elevated into the "Intermediate" category.



**Figure 4.** Examples of typical stream characteristics in Whiskeytown National Recreation Area. A, B = Unnamed tributary to Boulder Creek (WHISWQ22), C = Mill Creek (WHISWQ09), D = Brandy Creek (WHISWQ18), E = Willow Creek (WHISWQ21), F = Riparian zone of Boulder Creek (WHISWQ33). Note prevalence of large amounts of riparian cover and large substrates (e.g., boulders).

**Table 4.** Physical characteristics and location of streams sampled in Whiskeytown, 2011. UTM = Universal Transverse Mercator, Zone 10N.

| Stream Name            | Site Code | Date Sampled | UTM Coordinates |         | Elevation (m) | Reach Length (m) | Average Width (m) | Average Depth (cm) | Slope        | Instantaneous Discharge        |                                 |
|------------------------|-----------|--------------|-----------------|---------|---------------|------------------|-------------------|--------------------|--------------|--------------------------------|---------------------------------|
|                        |           |              | X               | Y       |               |                  |                   |                    |              | m <sup>3</sup> s <sup>-1</sup> | ft <sup>3</sup> s <sup>-1</sup> |
| Boulder Creek          | WHISWQ02  | 6/21/2011    | 533723          | 4494841 | 437           | 200              | 5.4               | 48.7               | 5.9%         | 0.40                           | 14.19                           |
| Boulder Creek          | WHISWQ17  | 6/30/2011    | 531478          | 4497477 | 679           | 160              | 5.6               | 35.0               | 11.5%        | 0.19                           | 6.80                            |
| Boulder Creek          | WHISWQ30  | 6/22/2011    | 533055          | 4497896 | 779           | 160              | 5.8               | 40.2               | 7.4%         | 0.36                           | 12.77                           |
| Boulder Creek          | WHISWQ33  | 8/1/2011     | 532031          | 4497974 | 579           | 200              | 3.4               | 29.3               | 9.3%         | 0.06                           | 1.99                            |
| Brandy Creek           | WHISWQ12  | 7/13/2011    | 533565          | 4494015 | 618           | 360              | 8.0               | 41.2               | 7.0%         | 0.42                           | 14.94                           |
| Brandy Creek           | WHISWQ18  | 7/11/2011    | 535797          | 4495485 | 412           | 400              | 7.9               | 41.1               | 4.5%         | 0.48                           | 16.80                           |
| Brandy Creek           | WHISWQ34  | 8/11/2011    | 535906          | 4495842 | 389           | 280              | 7.6               | 31.1               | 4.2%         | 0.26                           | 9.11                            |
| Clear Creek            | WHISWQ25  | 7/25/2011    | 530951          | 4501643 | 389           | 400              | 11.4              | 54.5               | 0.3%         | 1.46                           | 51.51                           |
| Crystal Creek          | WHISWQ15  | 7/18/2011    | 528099          | 4500183 | 485           | 240              | 7.4               | 44.3               | 2.7%         | 0.50                           | 17.67                           |
| Crystal Creek          | WHISWQ23  | 7/19/2011    | 527325          | 4498185 | 701           | 240              | 7.1               | 34.2               | 4.7%         | 0.29                           | 10.08                           |
| Grizzly Gulch          | WHISWQ06  | 7/7/2011     | 533862          | 4501055 | 391           | 150              | 2.9               | 14.5               | 4.4%         | 0.04                           | 1.57                            |
| Mill Creek             | WHISWQ09  | 8/9/2011     | 533690          | 4493369 | 506           | 160              | 5.3               | 16.6               | 7.1%         | 0.06                           | 2.18                            |
| Paige Boulder Creek    | WHISWQ08  | 6/29/2011    | 536843          | 4492334 | 463           | 200              | 6.1               | 26.5               | 5.5%         | 0.17                           | 5.93                            |
| Paige Boulder Creek    | WHISWQ28  | 7/6/2011     | 535411          | 4491948 | 714           | 160              | 3.9               | 25.8               | 13.9%        | 0.06                           | 2.01                            |
| Unnamed (Crystal Trib) | WHISWQ03  | 7/20/2011    | 526873          | 4497896 | 766           | 150              | 2.7               | 14.2               | 6.6%         | 0.03                           | 0.97                            |
| Unnamed (Brandy Trib)  | WHISWQ14  | 7/5/2011     | 534005          | 4493859 | 582           | 150              | 2.5               | 7.7                | 6.1%         | 0.004                          | 0.15                            |
| Unnamed (Boulder Trib) | WHISWQ22  | 7/26/2011    | 532531          | 4497474 | 576           | 240              | 3.1               | 18.6               | 8.7%         | 0.03                           | 1.20                            |
| Unnamed (Brandy Trib)  | WHISWQ24  | 8/8/2011     | 533725          | 4493372 | 705           | 150              | 1.7               | 16.7               | 12.3%        | 0.02                           | 0.74                            |
| Unnamed (Crystal Trib) | WHISWQ35  | 7/26/2011    | 526331          | 4497739 | 820           | 150              | 1.6               | 10.9               | 7.8%         | 0.01                           | 0.45                            |
| Whiskey Creek          | WHISWQ26  | 7/1/2011     | 537219          | 4500746 | 371           | 200              | 6.6               | 23.0               | 0.8%         | 0.23                           | 8.29                            |
| Willow Creek           | WHISWQ01  | 6/27/2011    | 529525          | 4502317 | 421           | 160              | 4.7               | 28.9               | 2.4%         | 0.15                           | 5.27                            |
| Willow Creek           | WHISWQ21  | 8/4/2011     | 530433          | 4501776 | 384           | 320              | 6.3               | 31.6               | 0.8%         | 0.46                           | 16.38                           |
| <b>Average</b>         |           |              |                 |         | 553           | 220              | 5.3               | 28.8               | 6.1%         | 0.26                           | 9.14                            |
| <b>SD</b>              |           |              |                 |         | 149           | 83               | 2.4               | 12.8               | 3.6%         | 0.32                           | 11.23                           |
| <b>Median</b>          |           |              |                 |         | 541           | 200              | 5.5               | 29.1               | 6.0%         | 0.18                           | 6.37                            |
| <b>Range</b>           |           |              |                 |         | 371 – 820     | 150 - 400        | 1.6 - 11.4        | 7.7 - 54.5         | 0.3% - 13.9% | 0.004 - 1.46                   | 0.15 - 51.51                    |

**Table 5.** Physical condition metrics for Whiskeytown streams sampled in 2011. Cells marked in amber are sites meeting EPA threshold criteria for “Intermediate,” whereas cells marked in red are sites meeting EPA criteria for “Most Disturbed.” For cells not colored under Physical Habitat Condition Metrics, the condition is “Least Disturbed.”

| Stream Name            | Site Code | Date Sampled | Stream Substrate diameter (mm) |               | Average Embeddedness (%) | Pool (%) | Riffle (%) | Physical Habitat Condition Metrics |                |                        |                      |
|------------------------|-----------|--------------|--------------------------------|---------------|--------------------------|----------|------------|------------------------------------|----------------|------------------------|----------------------|
|                        |           |              | Average                        | Median        |                          |          |            | In-Stream habitat cover            | Riparian Cover | Relative Bed Stability | Riparian Disturbance |
| Boulder Creek          | WHISWQ02  | 6/21/2011    | 423.5                          | 1047.1        | 20.2                     | 41%      | 17%        | 0.50                               | 0.97           | 0.17                   | 0                    |
| Boulder Creek          | WHISWQ17  | 6/30/2011    | 179.4                          | 1047.1        | 59.1                     | 21%      | 16%        | 0.89                               | 0.55           | -0.30                  | 0.59                 |
| Boulder Creek          | WHISWQ30  | 6/22/2011    | 350.6                          | 1047.1        | 28.0                     | 11%      | 24%        | 1.01                               | 1.49           | 0.07                   | 0                    |
| Boulder Creek          | WHISWQ33  | 8/1/2011     | 169.0                          | 114.8         | 42.5                     | 29%      | 48%        | 0.42                               | 0.77           | -0.13                  | 0.07                 |
| Brandy Creek           | WHISWQ12  | 7/13/2011    | 286.4                          | 1047.1        | 47.8                     | 24%      | 19%        | 0.85                               | 1.17           | -0.02                  | 0.14                 |
| Brandy Creek           | WHISWQ18  | 7/11/2011    | 147.8                          | 1047.1        | 48.5                     | 22%      | 38%        | 0.90                               | 1.57           | -0.12                  | 0.18                 |
| Brandy Creek           | WHISWQ34  | 8/11/2011    | 448.7                          | 1047.1        | 37.0                     | 13%      | 20%        | 0.71                               | 1.32           | 0.50                   | 0.29                 |
| Clear Creek            | WHISWQ25  | 7/25/2011    | 135.5                          | 114.8         | 28.3                     | 0%       | 35%        | 0.16                               | 0.85           | 0.97                   | 0.60                 |
| Crystal Creek          | WHISWQ15  | 7/18/2011    | 122.2                          | 346.7         | 45.6                     | 21%      | 22%        | 0.80                               | 1.01           | 0.06                   | 0                    |
| Crystal Creek          | WHISWQ23  | 7/19/2011    | 224.3                          | 1047.1        | 43.5                     | 33%      | 24%        | 0.67                               | 0.97           | 0.14                   | 0.86                 |
| Grizzly Gulch          | WHISWQ06  | 7/7/2011     | 279.8                          | 114.8         | 27.8                     | 19%      | 57%        | 0.51                               | 1.03           | 0.55                   | 0.06                 |
| Mill Creek             | WHISWQ09  | 8/9/2011     | 116.1                          | 114.8         | 54.9                     | 10%      | 53%        | 0.61                               | 1.21           | -0.02                  | 0                    |
| Paige Boulder Creek    | WHISWQ08  | 6/29/2011    | 222.8                          | 1047.1        | 30.3                     | 15%      | 29%        | 0.96                               | 1.05           | 0.11                   | 0                    |
| Paige Boulder Creek    | WHISWQ28  | 7/6/2011     | 1047.1                         | 9549.9        | 19.1                     | 26%      | 21%        | 0.69                               | 0.98           | 0.51                   | 0                    |
| Unnamed (Crystal Trib) | WHISWQ03  | 7/20/2011    | 31.8                           | 38.0          | 64.4                     | 24%      | 43%        | 0.95                               | 1.54           | -0.50                  | 0                    |
| Unnamed (Brandy Trib)  | WHISWQ14  | 7/5/2011     | 127.6                          | 114.8         | 37.1                     | 11%      | 64%        | 1.03                               | 0.74           | 0.33                   | 0.14                 |
| Unnamed (Boulder Trib) | WHISWQ22  | 7/26/2011    | 243.3                          | 1047.1        | 44.9                     | 25%      | 32%        | 0.93                               | 1.46           | 0.13                   | 0                    |
| Unnamed (Brandy Trib)  | WHISWQ24  | 8/8/2011     | 1103.7                         | 1047.1        | 20.7                     | 9%       | 64%        | 0.54                               | 0.84           | 0.60                   | 0                    |
| Unnamed (Crystal Trib) | WHISWQ35  | 7/26/2011    | 35.2                           | 38.0          | 55.5                     | 13%      | 60%        | 0.73                               | 1.32           | -0.40                  | 0.15                 |
| Whiskey Creek          | WHISWQ26  | 7/1/2011     | 37.2                           | 38.0          | 30.9                     | 11%      | 40%        | 0.22                               | 0.93           | 0.33                   | 0                    |
| Willow Creek           | WHISWQ01  | 6/27/2011    | 79.7                           | 114.8         | 51.0                     | 20%      | 37%        | 0.35                               | 0.95           | 0.04                   | 0                    |
| Willow Creek           | WHISWQ21  | 8/4/2011     | 263.0                          | 114.8         | 35.5                     | 1%       | 62%        | 0.16                               | 0.74           | 1.00                   | 0.04                 |
| Average                |           |              | 276.1                          | 967.5         | 39.7                     | 18%      | 37%        | 0.66                               | 1.07           | 0.18                   | 0.14                 |
| SD                     |           |              | 283.3                          | 1973.5        | 13.1                     | 10%      | 17%        | 0.27                               | 0.29           | 0.39                   | 0.24                 |
| Median                 |           |              | 201.1                          | 696.9         | 39.8                     | 20%      | 36%        | 0.70                               | 0.99           | 0.12                   | 0.02                 |
| Range                  |           |              | 31.8 - 1103.7                  | 38.0 - 9549.9 | 19.1 – 64.4              | 0 - 41%  | 16 – 64%   | 0.16 - 1.03                        | 0.55 - 1.57    | -0.50 - 1.00           | 0.00 – 0.86          |

### ***Chemical characteristics and condition estimates of Whiskeytown streams***

Selected water chemistry results are presented in Table 6. Parameters measured in-situ with a water probe (see methods) are listed under “water quality” and parameters measured in an analytical laboratory or with a stream-side assay (Acid Neutralizing Capacity) are presented as “water chemistry.”

At two sites, malfunctions in the water probe prevented the collection of water quality data (Brandy Creek [WHISWQ18] and Unnamed tributary of Crystal Creek [WHISWQ35]). A mid-season field audit of crew technique showed that the procedure being used to calibrate the dissolved oxygen meter prior to the audit was flawed, and hence the quality of the data produced is unknown. Accordingly, these dissolved oxygen values should be considered only as estimates and used with caution.

**pH** was found to be circum-neutral (pH of 7 = neutral), to slightly alkaline with an average of 7.73. Values did not exceed any water quality criteria (Table 2), and the average pH was solidly within the acceptable range. **Acid Neutralizing Capacities** were all positive, indicating “Least disturbed.”

**Temperature** is presented as a descriptor of conditions during sampling, but varies on a daily, monthly, and seasonal basis. As such, no status or condition should be inferred from temperature readings. However, several of the streams harboring Tailed Frogs (*Ascaphus truei*) had temperatures above their average optimum of 11 °C (de Vlaming and Bury 1970, Bury 2009); but our measurements were generally at mid-day in the middle of the summer and presumably represent nearly maximal annual temperatures. **Specific conductivity** was uniformly low, and well under the EPA threshold criteria for “least disturbed” at all sites (used as a surrogate for salinity by the EPA). Although the **dissolved oxygen** values should be used only as approximate values, owing to flawed calibration procedures, all values appear well within regulatory criteria for available water quality criteria (Table 2).

**Turbidity** readings were generally low, with an average of 39.9 NTU (being driven by two relatively large readings in Boulder Creek (high in the watershed). The median of 1.3 NTU is a more appropriate statistic in this case. Based on available water quality criteria, many values are elevated with respect to *drinking water* criteria; but four sites are also above NPS criterion (Boulder Creek [2 sites; WHISWQ17, 30], Brandy Creek [WHISWQ12], and Willow Creek [WHISWQ21]). At Willow Creek, the crew surmised that the high turbidity reading was a result of a steep cascade upstream of the sampling point that churned the substrate. Qualitatively, the stream clarity appeared similar to the other stretches of Willow Creek (WHISWQ01). Although not tracked, there were no known periods of precipitation during the summer field season, which might temporarily increase the turbidity with run-off events.

**Table 6.** Water chemistry parameters for streams sampled in Whiskeytown, 2011. \* Dissolved oxygen data is unverified due to faulty calibrations, and should be seen only as estimates. NA indicates Not Available; probe was malfunctioning during the site visit. Data collected with water probe are under “Water Quality,” whereas data from laboratory analyses are under “Water Chemistry.” Cells colored amber indicate EPA condition estimate of “Intermediate.” All other cells not colored indicate “least disturbed” where EPA thresholds exist.

| Stream Name            | Site Code | Water Quality |              |                               |                          |                 | Water Chemistry |                |                 |                       |                          |                            |         |
|------------------------|-----------|---------------|--------------|-------------------------------|--------------------------|-----------------|-----------------|----------------|-----------------|-----------------------|--------------------------|----------------------------|---------|
|                        |           | pH            | Temp. (°C)   | Specific Conductivity (µS/cm) | Dissolved Oxygen (mg/L)* | Turbidity (NTU) | Sodium (mg/L)   | Sulfate (mg/L) | Chloride (mg/L) | Total Nitrogen (mg/L) | Total Phosphorous (mg/L) | Acid Neutralizing Capacity |         |
|                        |           |               |              |                               |                          |                 |                 |                |                 |                       |                          | (µeq/L)                    | (mg/L)  |
| Boulder Creek          | WHISWQ02  | 7.69          | 11.9         | 39                            | 10.0                     | 0.0             | 2.72            | 0.21           | 0.49            | 0.05                  | 0.009                    | 340                        | 17      |
| Boulder Creek          | WHISWQ30  | 7.52          | 12.2         | 38                            | 10.2                     | 263.5           | 2.72            | 0.21           | 0.40            | 0.10                  | 0.009                    | 380                        | 19      |
| Boulder Creek          | WHISWQ17  | 7.57          | 9.4          | 32                            | 10.2                     | 297.4           | 2.01            | 0.10           | 0.29            | 0.03                  | 0.009                    | 400                        | 20      |
| Boulder Creek          | WHISWQ33  | 7.53          | 14.4         | 49                            | 9.1                      | 0.0             | 3.15            | 0.16           | 0.41            | 0.09                  | 0.012                    | 780                        | 39      |
| Brandy Creek           | WHISWQ18  | NA            | NA           | NA                            | NA                       | NA              | 3.30            | 0.19           | 1.67            | 0.08                  | 0.01                     | 640                        | 32      |
| Brandy Creek           | WHISWQ12  | 7.81          | 13.0         | 43                            | 9.9                      | 97.8            | 3.04            | 0.12           | 0.52            | 0.09                  | 0.011                    | 600                        | 30      |
| Brandy Creek           | WHISWQ34  | 7.79          | 15.5         | 53                            | 9.6                      | 0.0             | 3.93            | 0.16           | 1.47            | 0.07                  | 0.011                    | 520                        | 26      |
| Clear Creek            | WHISWQ25  | 7.71          | 17.5         | 88                            | 8.6                      | 0.4             | 2.58            | 1.75           | 0.45            | 0.10                  | 0.032                    | 920                        | 46      |
| Crystal Creek          | WHISWQ15  | 7.73          | 12.0         | 54                            | 10.3                     | 13.7            | 3.22            | 0.16           | 0.48            | 0.09                  | 0.011                    | 600                        | 30      |
| Crystal Creek          | WHISWQ23  | 7.72          | 10.6         | 62                            | 10.3                     | 0.0             | 3.66            | 0.18           | 0.54            | 0.07                  | 0.01                     | 660                        | 33      |
| Grizzly Gulch          | WHISWQ06  | 8.05          | 16.9         | 162                           | 9.1                      | 8.7             | 5.38            | 4.23           | 0.84            | 0.07                  | 0.01                     | 1320                       | 66      |
| Mill Creek             | WHISWQ09  | 7.74          | 15.0         | 102                           | 8.8                      | 26.7            | 5.12            | 0.51           | 0.68            | 0.06                  | 0.016                    | 1060                       | 53      |
| Paige Boulder Creek    | WHISWQ08  | 7.61          | 12.9         | 51                            | 9.7                      | 0.3             | 3.33            | 0.40           | 0.68            | 0.09                  | 0.011                    | 580                        | 29      |
| Paige Boulder Creek    | WHISWQ28  | 7.63          | 13.5         | 40                            | 9.3                      | 0.0             | 2.54            | 0.12           | 0.35            | 0.06                  | 0.01                     | 460                        | 23      |
| Unnamed (Crystal Trib) | WHISWQ14  | 7.52          | 14.7         | 86                            | 9.2                      | 0.0             | 5.00            | 1.27           | 0.73            | 0.06                  | 0.005                    | 800                        | 40      |
| Unnamed (Brandy Trib)  | WHISWQ03  | 7.99          | 12.3         | 130                           | 9.6                      | 0.6             | 5.95            | 0.35           | 0.70            | 0.06                  | 0.015                    | 1260                       | 63      |
| Unnamed (Boulder Trib) | WHISWQ22  | 7.94          | 12.3         | 118                           | 9.2                      | 3.7             | 3.30            | 0.41           | 0.45            | 0.08                  | 0.008                    | 600                        | 30      |
| Unnamed (Brandy Trib)  | WHISWQ35  | NA            | NA           | NA                            | NA                       | NA              | 5.95            | 0.26           | 0.63            | 0.11                  | 0.021                    | 1360                       | 68      |
| Unnamed (Crystal Trib) | WHISWQ24  | 7.43          | 13.4         | 38                            | 9.2                      | 1.9             | 2.27            | 0.08           | 0.24            | 0.11                  | 0.007                    | 400                        | 20      |
| Whiskey Creek          | WHISWQ26  | 7.73          | 14.0         | 108                           | 9.8                      | 0.8             | 3.64            | 4.25           | 0.67            | 0.11                  | 0.03                     | 740                        | 37      |
| Willow Creek           | WHISWQ01  | 8.03          | 13.6         | 202                           | 9.8                      | 4.8             | 7.76            | 5.95           | 8.26            | 0.06                  | 0.025                    | 1220                       | 61      |
| Willow Creek           | WHISWQ21  | 7.83          | 14.6         | 176                           | 9.1                      | 78.3            | 8.70            | 1.41           | 14.25           | 0.10                  | 0.013                    | 700                        | 35      |
| <b>Average</b>         |           | 7.73          | 13.5         | 84                            | 9.5                      | 39.9            | 4.06            | 1.02           | 1.60            | 0.08                  | 0.013                    | 743                        | 37      |
| <b>SD</b>              |           | 0.18          | 2.0          | 51                            | 0.5                      | 86.7            | 1.78            | 1.63           | 3.28            | 0.02                  | 0.007                    | 317                        | 16      |
| <b>Median</b>          |           | 7.72          | 13.4         | 58                            | 9.6                      | 1.3             | 3.32            | 0.24           | 0.59            | 0.08                  | 0.011                    | 650                        | 33      |
| <b>Range</b>           |           | 7.43 -        | 9.42 - 17.51 | 32 – 202                      | 8.6 – 10.3               | 0 – 297.4       | 2.01 - 8.70     | 0.08 - 5.95    | 0.24 - 14.25    | 0.03 - 0.11           | 0.005 – 0.032            | 340 - 1360                 | 17 – 68 |

The **anions and cations** with available thresholds for water quality were all far below promulgated values, although the highest values of these salts were uniformly in Willow Creek, a stream listed as state of California Clean Water Act 303(d) listed site for 1) Acid Mine Drainage, 2) Zinc, and 3) Copper ([California Environmental Protection Agency State Water Resources Control Board 2010](#)). **Total nitrogen** values were all well below EPA thresholds for “least disturbed.” **Total phosphorous** values, however, had 12 of the 22 sites falling within the classification for “Intermediate.” Some of these however, were only 0.001 mg/L above the “Least disturbed” threshold. The median and average park values for the Total phosphorous were elevated into the “Intermediate” category.

### ***Riparian characteristics of Whiskeytown streams***

The riparian zones of Whiskeytown are characterized by deciduous trees and a diverse community providing high overall shading (88% average, 92% median; Table 7). The site with the least shading was Clear Creek (WHISWQ25), which was the widest stream sampled, which will naturally have less shading than narrow streams. The canopy cover was often mixed community (10% or more of multiple groups; Deciduous, Coniferous, Broadleaf Evergreen), but many sites were also dominated by strictly deciduous trees.

### ***Vertebrate assemblage and condition of Whiskeytown streams***

Results of electrofishing and visual encounters of vertebrate species, along with summaries of abundance, richness, and the EPA Vertebrate MMI are presented in Table 8. A total of five amphibian species and six fish species were encountered, with at least one species found at each site. The most widespread amphibian was the California giant salamander (*Dicamptodon ensatus*), occurring at 16 of the 22 sites. The most widespread fish was rainbow trout (*Oncorhynchus mykiss*), occurring at 13 of the 22 sites. All species had been previously recorded in the park ([KLMN certified species lists](#)).

Condition assessments using the EPA Vertebrate MMI ranked most sites in the “least disturbed” category, with two sites classified as “Intermediate.” One site (Brandy Creek; WHISWQ18) meeting this criteria was driven by the prevalence of non-native brook trout (*Salvelinus fontinalis*) comprising the assemblage, and the other site (Clear Creek; WHISWQ25) due to an absence of species indicative of fast-water habitat. Non-native brook trout were encountered at five sites, in four separate streams (Brandy Creek, Mill Creek, an unnamed tributary to Boulder Creek, and Whiskey Creek).

### ***Invertebrate assemblage and condition of Whiskeytown streams***

A total of 14,708 individual macroinvertebrates were collected, sorted, and identified from Whiskeytown streams (a complete taxa list for the Whiskeytown samples is given in Appendix B). A conservative estimate of the total species richness is 256 separate species (many taxa are only identified to family or genus level, hence the true species richness is likely higher; likewise there are instances where a specific individual was only able to be identified to family, but a separate individual was identified to genus or species, duplicating the “taxonomic units.” See the full protocol [Dinger et al. 2013] or [Cuffney et al. 2007](#) for more detail on ambiguous taxa). Summary statistics (Taxa Richness and measures of biological integrity) for each site are provided in Table 9. The most diverse site was the Unnamed tributary to Crystal Creek (WHISWQ35) with 84 total taxa, while the most depauperate site was Willow Creek (WHISWQ21) with 48 taxa.

For calculating Hilsenhoff Biotic Index (HBI), tolerance values were available for 267 of the total 292 taxonomic units (which include individuals only identified to higher taxonomic units due to poor keys, damaged specimens, or immature life stages). Taxa with no tolerance value were excluded from HBI calculations. The lowest HBI (indicating a preponderance of intolerant, clean-water indicating organisms) was Willow Creek (WHISWQ01), while the highest HBI (indicating more organisms tolerant of poor water quality) was Whiskey Creek (WHISWQ26).

Only two sites (Clear Creek [WHISWQ25] and Grizzly Gulch [WHISWQ06]) were rated as “Intermediate” using the EPA West-wide Invertebrate MMI. A single site, Willow Creek (WHISWQ01) was rated as “Most disturbed” using the same MMI, and is currently a state of California Clean Water Act 303(d)-listed water quality impaired site. The apparent paradox of the WHISWQ01 site having both the lowest HBI and a “Most disturbed” category comes from low overall diversity and an assemblage dominated by a single caddisfly with a low tolerance value (but tolerant to metals). The remainder of sites (19 out of 22) were rated in the “Least disturbed” condition.

The California Regional Water Quality Control Board North Coast MMI rates stream condition as either good (12 sites) or very good (10 sites) for the streams of Whiskeytown. Additionally, the index can be used for designation of “impaired” or “unimpaired” status; all sampled streams were rated “unimpaired.”

**Table 7.** Riparian characteristics of Whiskeytown streams sampled in 2011. For compositions: D = Deciduous, C = Coniferous, E = Broadleaf Evergreen, N = None, and M = Mixed (10% or more of multiple types).

| Stream Name            | Site Code | Shading   | Legacy Tree Height (m) | Canopy   |            |                          | Understory |           |                          |
|------------------------|-----------|-----------|------------------------|----------|------------|--------------------------|------------|-----------|--------------------------|
|                        |           |           |                        | Big Tree | Small Tree | Composition              | Woody      | Non-woody | Composition              |
| Boulder Creek          | WHISWQ02  | 65%       | 15.3                   | 21%      | 7%         | 41% D, 27% N, 23% M      | 47%        | 0%        | 86% D, 5% E, 5% M, 5% C  |
| Boulder Creek          | WHISWQ17  | 98%       | 17.3                   | 16%      | 18%        | 64% D, 32% M             | 9%         | 0%        | 95% M, 5% C              |
| Boulder Creek          | WHISWQ30  | 94%       | 43.3                   | 39%      | 29%        | 50% M, 32% D, 18% C      | 46%        | 0%        | 91% D, 9% M              |
| Boulder Creek          | WHISWQ33  | 98%       | 11.2                   | 24%      | 17%        | 64% D, 32% M, 5% C       | 26%        | 5%        | 91% D, 5% M, 5% N        |
| Brandy Creek           | WHISWQ12  | 81%       | 29.3                   | 11%      | 36%        | 45% M, 41% D, 14% E      | 39%        | 2%        | 82% D, 18% M             |
| Brandy Creek           | WHISWQ18  | 85%       | 31.0                   | 27%      | 34%        | 82% M, 9% D, 9% E        | 47%        | 2%        | 68% D, 32% M             |
| Brandy Creek           | WHISWQ34  | 89%       | 25.6                   | 23%      | 28%        | 57% M, 25% D, 1% E       | 43%        | 3%        | 75% D, 25% M             |
| Clear Creek            | WHISWQ25  | 31%       | 29.0                   | 3%       | 14%        | 43% D, 30% M, 20% N      | 39%        | 9%        | 95% D, 5% M              |
| Crystal Creek          | WHISWQ15  | 91%       | 27.1                   | 19%      | 27%        | 55% D, 45% M             | 32%        | 34%       | 84% D, 16% M             |
| Crystal Creek          | WHISWQ23  | 90%       | 28.0                   | 22%      | 22%        | 77% M, 14% D, 5% C, 5% E | 33%        | 3%        | 59% D, 32% M, 5% E, 5% N |
| Grizzly Gulch          | WHISWQ06  | 93%       | 25.5                   | 12%      | 24%        | 68% D, 18% N, 9% E       | 38%        | 9%        | 64% D, 27% M, 9% E       |
| Mill Creek             | WHISWQ09  | 97%       | 26.6                   | 14%      | 20%        | 45% M, 41% D, 14% C      | 49%        | 11%       | 82% D, 18% M             |
| Paige Boulder Creek    | WHISWQ08  | 92%       | 38.6                   | 9%       | 33%        | 77% D, 18% M             | 37%        | 6%        | 86% D, 14% M             |
| Paige Boulder Creek    | WHISWQ28  | 87%       | 37.7                   | 4%       | 39%        | 59% D, 32% M             | 36%        | 1%        | 55% M, 45% D             |
| Unnamed (Boulder Trib) | WHISWQ22  | 97%       | 30.2                   | 31%      | 17%        | 73% M, 23% D             | 53%        | 4%        | 82% D, 18% M             |
| Unnamed (Brandy Trib)  | WHISWQ14  | 95%       | 18.6                   | 19%      | 24%        | 68% M, 18% C, 14% D      | 16%        | 0%        | 45% D, 41% M, 14% C      |
| Unnamed (Brandy Trib)  | WHISWQ24  | 89%       | 13.8                   | 8%       | 24%        | 82% D, 9 %M, 9% N        | 26%        | 2%        | 77% D, 18% M, 5% C       |
| Unnamed (Crystal Trib) | WHISWQ03  | 92%       | 23.4                   | 8%       | 31%        | 45% D, 45% M             | 64%        | 2%        | 86% D, 14% M             |
| Unnamed (Crystal Trib) | WHISWQ35  | 98%       | 24.1                   | 16%      | 35%        | 64% D, 32% M, 5% C       | 43%        | 0%        | 68% D, 32% M             |
| Whiskey Creek          | WHISWQ26  | 85%       | 35.4                   | 7%       | 28%        | 77% D, 23% M             | 29%        | 22%       | 91% D, 9% M              |
| Willow Creek           | WHISWQ01  | 92%       | 24.9                   | 4%       | 34%        | 86% D, 9% M              | 34%        | 0%        | 100% D                   |
| Willow Creek           | WHISWQ21  | 91%       | 34.4                   | 20%      | 18%        | 68% D, 18% M, 14% N      | 27%        | 8%        | 91% D, 9% M              |
| <b>Average</b>         |           | 88%       | 26.8                   | 16%      | 25%        |                          | 37%        | 6%        |                          |
| <b>SD</b>              |           | 15%       | 8.3                    | 9%       | 8%         |                          | 12%        | 8%        |                          |
| <b>Median</b>          |           | 92%       | 26.8                   | 16%      | 25%        |                          | 37%        | 2%        |                          |
| <b>Range</b>           |           | 31% - 98% | 11.2 – 43.3            | 3% - 39% | 7% - 39%   |                          | 9% - 64%   | 0% - 34%  |                          |

**Table 8.** Vertebrate species and metrics for Whiskeytown streams sampled in 2011. Cells colored amber indicate EPA condition estimate of “Intermediate.” All other cells not colored indicate “Least disturbed” where EPA thresholds exist.

| Stream Name            | Site Code | Metrics         |                |                    | Amphibians                                        |                                                      |                                                |                                      |                                          |                                            | Fish                                   |                                      |                                     |                                |                                             |  |
|------------------------|-----------|-----------------|----------------|--------------------|---------------------------------------------------|------------------------------------------------------|------------------------------------------------|--------------------------------------|------------------------------------------|--------------------------------------------|----------------------------------------|--------------------------------------|-------------------------------------|--------------------------------|---------------------------------------------|--|
|                        |           | Total Abundance | Total Richness | EPA Vertebrate MMI | California giant salamander (Dicamptodon ensatus) | Pacific tree frog (Pseudacris regilla) tadpole/adult | Tailed frog (Ascaphus truei) tadpole/metamorph | Western Toad (Bufo boreas) (tadpole) | Yellow-legged frog (Rana boylei) (adult) | Brook trout (Salvelinus fontinalis) EXOTIC | California roach (Lavinia symmetricus) | Hardhead (Mylopharodon conocephalus) | Rainbow trout (Oncorhynchus mykiss) | Rifle sculpin (Cottus gulosus) | Sacramento sucker (Catostomus occidentalis) |  |
| Boulder Creek          | WHISWQ02  | 2               | 2              | 100                | 1                                                 |                                                      |                                                |                                      |                                          |                                            |                                        |                                      | 1                                   |                                |                                             |  |
| Boulder Creek          | WHISWQ17  | 5               | 3              | 87                 | 1                                                 |                                                      |                                                | 1                                    |                                          |                                            |                                        |                                      | 3                                   |                                |                                             |  |
| Boulder Creek          | WHISWQ30  | 4               | 2              | 100                | 1                                                 |                                                      |                                                |                                      |                                          |                                            |                                        |                                      | 3                                   |                                |                                             |  |
| Boulder Creek          | WHISWQ33  | 7               | 3              | 68                 | 1                                                 |                                                      | 1/1                                            |                                      |                                          |                                            |                                        |                                      | 4                                   |                                |                                             |  |
| Brandy Creek           | WHISWQ12  | 3               | 2              | 75                 | 1                                                 |                                                      |                                                |                                      |                                          |                                            |                                        |                                      | 2                                   |                                |                                             |  |
| Brandy Creek           | WHISWQ18  | 4               | 2              | 58                 |                                                   |                                                      |                                                |                                      |                                          | 3                                          |                                        |                                      |                                     | 1                              |                                             |  |
| Brandy Creek           | WHISWQ34  | 5               | 3              | 71                 |                                                   |                                                      |                                                |                                      |                                          | 1                                          |                                        |                                      | 3                                   | 1                              |                                             |  |
| Clear Creek            | WHISWQ25  | 4               | 3              | 59                 |                                                   | 1/1                                                  |                                                |                                      |                                          |                                            | 1                                      |                                      |                                     | 1                              |                                             |  |
| Crystal Creek          | WHISWQ15  | 4               | 3              | 79                 | 1                                                 |                                                      |                                                |                                      |                                          |                                            |                                        |                                      | 2                                   | 1                              |                                             |  |
| Crystal Creek          | WHISWQ23  | 7               | 2              | 68                 |                                                   |                                                      | 2/0                                            |                                      |                                          |                                            |                                        |                                      | 5                                   |                                |                                             |  |
| Grizzly Gulch          | WHISWQ06  | 4               | 4              | 72                 | 1                                                 |                                                      |                                                | 1                                    |                                          |                                            | 1                                      |                                      |                                     | 1                              |                                             |  |
| Mill Creek             | WHISWQ09  | 9               | 5              | 63                 | 1                                                 |                                                      | 1/0                                            |                                      | 1                                        | 1                                          |                                        |                                      | 5                                   |                                |                                             |  |
| Paige Boulder Creek    | WHISWQ08  | 7               | 3              | 87                 | 1                                                 |                                                      |                                                |                                      |                                          |                                            | 1                                      |                                      | 5                                   |                                |                                             |  |
| Paige Boulder Creek    | WHISWQ28  | 2               | 2              | 79                 | 1                                                 |                                                      |                                                | 1                                    |                                          |                                            |                                        |                                      |                                     |                                |                                             |  |
| Unnamed (Crystal Trib) | WHISWQ03  | 4               | 3              | 67                 | 1                                                 |                                                      | 1/1                                            |                                      | 1                                        |                                            |                                        |                                      |                                     |                                |                                             |  |
| Unnamed (Brandy Trib)  | WHISWQ14  | 1               | 1              | 100                | 1                                                 |                                                      |                                                |                                      |                                          |                                            |                                        |                                      |                                     |                                |                                             |  |
| Unnamed (Boulder Trib) | WHISWQ22  | 7               | 4              | 68                 | 1                                                 |                                                      | 1/0                                            |                                      |                                          | 1                                          |                                        |                                      | 4                                   |                                |                                             |  |
| Unnamed (Brandy Trib)  | WHISWQ24  | 2               | 2              | 66                 | 1                                                 | 1/0                                                  |                                                |                                      |                                          |                                            |                                        |                                      |                                     |                                |                                             |  |
| Unnamed (Crystal Trib) | WHISWQ35  | 1               | 1              | 85                 | 1                                                 |                                                      |                                                |                                      |                                          |                                            |                                        |                                      |                                     |                                |                                             |  |
| Whiskey Creek          | WHISWQ26  | 3               | 3              | 75                 |                                                   |                                                      |                                                |                                      |                                          | 1                                          |                                        |                                      |                                     | 1                              | 1                                           |  |
| Willow Creek           | WHISWQ01  | 4               | 4              | 89                 | 1                                                 |                                                      |                                                |                                      |                                          |                                            |                                        |                                      | 1                                   | 1                              | 1                                           |  |
| Willow Creek           | WHISWQ21  | 5               | 3              | 72                 |                                                   | 0/1                                                  |                                                |                                      |                                          |                                            |                                        |                                      | 3                                   | 1                              |                                             |  |
|                        |           | Average         | 2.7            | 76.8               |                                                   |                                                      |                                                |                                      |                                          |                                            |                                        |                                      |                                     |                                |                                             |  |
|                        |           | SD              | 1.0            | 12.8               |                                                   |                                                      |                                                |                                      |                                          |                                            |                                        |                                      |                                     |                                |                                             |  |
|                        |           | Median          | 3              | 73.6               |                                                   |                                                      |                                                |                                      |                                          |                                            |                                        |                                      |                                     |                                |                                             |  |
|                        |           | Range           | 1 - 5          | 58 - 100           |                                                   |                                                      |                                                |                                      |                                          |                                            |                                        |                                      |                                     |                                |                                             |  |

**Table 9.** Invertebrate results and metrics for Whiskeytown streams, 2011. Cells colored amber indicate EPA condition estimate of “Intermediate,” and red cells indicate “Most disturbed.” All other cells not colored indicate “Least disturbed” where EPA thresholds exist.

| Stream Name            | Site Code | Total<br>Taxa<br>Richness | Hilsenhoff<br>Biotic<br>Index | EPA West-<br>Wide<br>Invertebrate<br>MMI | CA<br>North<br>Coast<br>MMI |
|------------------------|-----------|---------------------------|-------------------------------|------------------------------------------|-----------------------------|
| Boulder Creek          | WHISWQ02  | 67                        | 3.24                          | 90                                       | 84                          |
| Boulder Creek          | WHISWQ17  | 77                        | 3.30                          | 92                                       | 80                          |
| Boulder Creek          | WHISWQ30  | 72                        | 4.05                          | 75                                       | 79                          |
| Boulder Creek          | WHISWQ33  | 65                        | 3.63                          | 82                                       | 70                          |
| Brandy Creek           | WHISWQ12  | 76                        | 3.74                          | 85                                       | 85                          |
| Brandy Creek           | WHISWQ18  | 76                        | 3.31                          | 84                                       | 68                          |
| Brandy Creek           | WHISWQ34  | 68                        | 4.98                          | 70                                       | 63                          |
| Clear Creek            | WHISWQ25  | 72                        | 4.01                          | 67                                       | 71                          |
| Crystal Creek          | WHISWQ15  | 54                        | 3.76                          | 79                                       | 81                          |
| Crystal Creek          | WHISWQ23  | 71                        | 3.38                          | 79                                       | 81                          |
| Grizzly Gulch          | WHISWQ06  | 74                        | 3.35                          | 66                                       | 71                          |
| Mill Creek             | WHISWQ09  | 72                        | 3.82                          | 76                                       | 85                          |
| Paige Boulder Creek    | WHISWQ08  | 57                        | 3.43                          | 96                                       | 85                          |
| Paige Boulder Creek    | WHISWQ28  | 65                        | 4.99                          | 76                                       | 73                          |
| Unnamed (Crystal Trib) | WHISWQ03  | 80                        | 3.15                          | 78                                       | 80                          |
| Unnamed (Brandy Trib)  | WHISWQ14  | 68                        | 3.52                          | 79                                       | 73                          |
| Unnamed (Boulder Trib) | WHISWQ22  | 68                        | 4.06                          | 78                                       | 80                          |
| Unnamed (Brandy Trib)  | WHISWQ24  | 80                        | 3.73                          | 77                                       | 74                          |
| Unnamed (Crystal Trib) | WHISWQ35  | 84                        | 3.24                          | 80                                       | 86                          |
| Whiskey Creek          | WHISWQ26  | 64                        | 5.16                          | 77                                       | 69                          |
| Willow Creek           | WHISWQ01  | 50                        | 2.97                          | 53                                       | 64                          |
| Willow Creek           | WHISWQ21  | 48                        | 3.86                          | 73                                       | 75                          |
| <b>Average</b>         |           | 68.5                      | 3.76                          | 77.8                                     | 76.2                        |
| <b>SD</b>              |           | 9.6                       | 0.60                          | 9.2                                      | 7.1                         |
| <b>Median</b>          |           | 69.5                      | 3.68                          | 78.0                                     | 77.0                        |
| <b>Range</b>           |           | 48 - 84                   | 2.97 - 5.16                   | 53 - 96                                  | 63 - 86                     |

### Lassen Volcanic National Park

Sampling began on August 15, 2011 following the arrival of the field crew from Whiskeytown and continued until September 30, 2011 when field activities ceased. A total of 24 sites were sampled on seven streams (Figure 5), with the original target of 25 to 30 sites. Many sites on the original list (Table 10) were unsampleable for a variety of reasons, including that the creeks were dry upon arrival (actual ephemeral streams, and not sampled per the protocol), the site was actually a wetland with no defined stream channel, or that the terrain was too steep to provide safe access (the stream gradient itself may have been acceptable, but steep slopes on the cross-country paths were too steep

to safely access). Particular to Lassen Volcanic, several sites were in geo-thermally influenced streams that were also too hot to access safely. The final 24 sites, however, were concentrated in the western part of the park, with no sampleable sites in the eastern portion. One site, LAVOWQ43 was planned to be sampled later, but the field season ended before we could include it.

The streams of Lassen Volcanic are subalpine streams (average elevation of sampled streams = 1990 m [6529 ft.] above sea level), in both meadow and mixed conifer forest habitats. They are lower gradient streams (average of 2.6%) than those of Whiskeytown. Because a number of the stream reaches traverse meadows, Lassen Volcanic has streams with more open riparian cover than Whiskeytown. Examples of these characteristics in Lassen Volcanic are presented in Figure 6.

**Figure 5.** Stream sites sampled in Lassen Volcanic, 2011.

**Table 10.** Original site list for streams to be sampled in Lassen Volcanic. Sites marked with an \* were not sampled due to a variety of reasons. Sites requiring more than 1.5 hours to access were deemed too far to safely sample in a single day.

| Stream Name         | Site Code | Date Sampled | Reason for not sampling             |
|---------------------|-----------|--------------|-------------------------------------|
| Hat Creek           | LAVOWQ01  | 8/31/2011    |                                     |
| Kings Creek         | LAVOWQ02  | *            | Too steep to safely do              |
| Hot Springs Creek   | LAVOWQ03  | *            | Water too deep for safety           |
| Lost Creek          | LAVOWQ04  | 8/15/2011    |                                     |
| Hat Creek           | LAVOWQ05  | 9/29/2011    |                                     |
| Grassy Swale        | LAVOWQ06  | *            | Wetland, no clear lotic channel     |
| Willow Creek        | LAVOWQ07  | *            | Dry                                 |
| Hat Creek           | LAVOWQ08  | 8/18/2011    |                                     |
| WF Hat Creek        | LAVOWQ09  | 8/17/2011    |                                     |
| NA Rice Creek       | LAVOWQ10  | 9/23/2011    |                                     |
| East Sulphur Creek  | LAVOWQ11  | *            | Too steep to safely do              |
| WF Hat Creek        | LAVOWQ12  | 9/7/2011     |                                     |
| Summit Creek        | LAVOWQ13  | 8/22/2011    |                                     |
| Hot Springs Creek   | LAVOWQ14  | *            | Wetland, no clear lotic channel     |
| Manzanita Creek     | LAVOWQ15  | 9/16/2011    |                                     |
| Warner Valley Creek | LAVOWQ16  | *            | Dry                                 |
| Kings Creek         | LAVOWQ17  | 8/29/2011    |                                     |
| Kings Creek         | LAVOWQ18  | *            | In canyon, too steep for access     |
| West Sulphur Creek  | LAVOWQ19  | *            | Too steep to safely access          |
| Lost Creek          | LAVOWQ20  | 9/21/2011    |                                     |
| WF Hat Creek        | LAVOWQ21  | 8/16/2011    |                                     |
| NA Rice Creek       | LAVOWQ22  | 9/22/2011    |                                     |
| Manzanita Creek     | LAVOWQ23  | 8/25/2011    |                                     |
| WF Hat Creek        | LAVOWQ24  | 9/6/2011     |                                     |
| Kings Creek         | LAVOWQ25  | 8/23/2011    |                                     |
| Hot Springs Creek   | LAVOWQ26  | *            | Hot spring fed, geothermal activity |
| Manzanita Creek     | LAVOWQ27  | 9/1/2011     |                                     |
| Grassy Creek        | LAVOWQ28  | *            | Too distant from vehicle            |
| Hat Creek           | LAVOWQ29  | 9/30/2011    |                                     |
| Kings Creek         | LAVOWQ30  | *            | Too steep to safely access          |
| Kings Creek         | LAVOWQ31  | *            | Too distant from vehicle            |
| Hat Creek           | LAVOWQ32  | 9/13/2011    |                                     |
| Kings Creek         | LAVOWQ33  | 8/30/2011    |                                     |
| Grassy Swale        | LAVOWQ34  | *            | Wetland, no clear lotic channel     |
| East Sulphur Creek  | LAVOWQ35  | *            | Too steep to safely do              |
| Hat Creek           | LAVOWQ36  | 9/8/2011     |                                     |
| Kings Creek         | LAVOWQ37  | 9/27/2011    |                                     |
| Hot Springs Creek   | LAVOWQ38  | *            | Hot spring fed, geothermal activity |
| Bailey Creek        | LAVOWQ39  | *            | Would require crossing private land |
| Hat Creek           | LAVOWQ40  | 9/14/2011    |                                     |
| Grassy Swale        | LAVOWQ41  | *            | Wetland, no clear lotic channel     |
| Hot Springs Creek   | LAVOWQ42  | *            | Wetland, no clear lotic channel     |
| Lost Creek          | LAVOWQ43  | *            | Was planned to be sampled later     |
| Grassy Creek        | LAVOWQ44  | *            | Too distant from vehicle            |
| Hat Creek           | LAVOWQ45  | 9/28/2011    |                                     |

### ***Physical characteristics of Lassen Volcanic streams***

Basic summary statistics of the monitoring streams are presented in Table 11. These are general geomorphological summaries of the streams (e.g., elevation, slope, discharge) and do not impart any conditional information. Summit Creek (LAVOWQ13) was the smallest stream sampled, with the lowest flow ( $0.01 \text{ m}^3/\text{s}$ ) and smallest average width (1.8 m). There was no one largest stream sampled (depending on how “largest” is defined); but Hat Creek (LAVOWQ36) had more than double the instantaneous discharge ( $1.81 \text{ m}^3/\text{s}$ ) of any other site.

### ***Physical condition metrics of Lassen Volcanic streams***

The four EPA physical condition metrics along with substrate size and average embeddedness for Lassen Volcanic are presented in Table 12. The median substrate size for a stream is a more common descriptor, since the average can be influenced by a few, very large pieces of substrate. Overall, coarse gravel (diameter = 38 mm) is the predominant substrate. Several stream sites had a large number of small substrates (Kings Creek [LAVOWQ17, 33] and Lost Creek [LAVOWQ04]). Although perhaps not intuitive, we also provide the median of the median and the average median for the surveyed streams. Coincidental with higher amounts of fine sediments/sand/fine gravel, the average embeddedness was 61.8%.

Due to the nature of these montane and subalpine meadow streams, riparian cover tends to be dominated by shrubs and graminoid (i.e., grasses) vegetation. The limited riparian cover results in eight sites being classified as “Intermediate” using EPA threshold criteria; however, this is likely not a result of degraded or impacted riparian zones, but is the natural character of Lassen Volcanic montane and subalpine streams. In-stream habitat cover was rated “Intermediate” at three smaller, higher elevation stream sites: Kings Creek (LAVOWQ17, 37) and NA Rice Creek (LAVOWQ22). In-stream habitat is also partially composed of boulder substrate, so the overall scarcity of large substrates in Lassen Volcanic streams likely contributes to observed lower ratings. Riparian disturbance was only elevated to “Intermediate” in two sites, Kings Creek (LAVOWQ17) and Manzanita Creek (LAVOWQ27). The Kings Creek site is a roadside stream, and Manzanita Creek is proximal to one of the park’s larger campsites.

The preliminary examination of Relative Bed Stability (RBS) in Lassen Volcanic indicates seven sites rated “Intermediate” in terms of sediment supply relative to expected sediments. Five of the sites were rated “Intermediate” due to smaller than expected sediments being present (silt, fines, sand) and two (both on NA Rice Creek) were “Intermediate” due to larger than expected sediments being present. These are preliminary values based on rapid calculation of RBS, and do not incorporate the effects of woody debris, bankfull characteristics, or residual pool depth on the expected median particle size – these are equations not yet available for analysis.

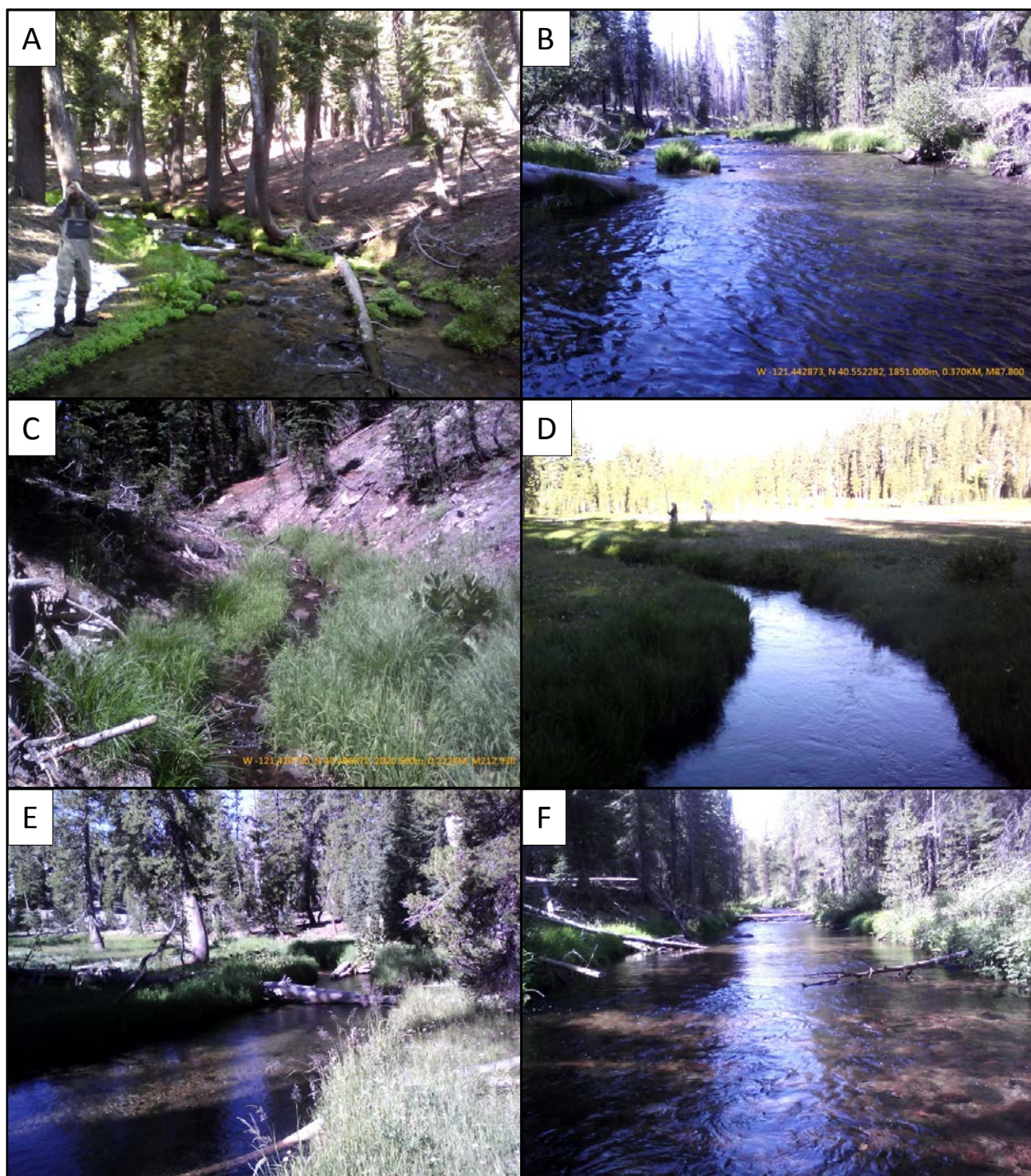


**Figure 6.** Examples of typical stream characteristics in Lassen Volcanic National Park. A = WF Hat Creek (LAVOWQ21), B = Hat Creek (LAVOWQ08), C = Summit Creek (LAVOWQ13), D, E = Kings Creek (LAVOWQ17), F = Hat Creek (LAVOWQ36). Note variety of riparian zone (forest vs. meadow), and prevalence of wide, shallow, low gradient streams.

**Table 11.** Physical characteristics and location of streams sampled in Lassen Volcanic, 2011. UTM = Universal Transverse Mercator, Zone 10N.

| Stream Name     | Site Code | Date Sampled | UTM Coordinates |         | Elevation (m)  | Reach Length (m) | Average Width (m) | Average Depth (cm) | Slope          | Instantaneous Discharge        |                                 |
|-----------------|-----------|--------------|-----------------|---------|----------------|------------------|-------------------|--------------------|----------------|--------------------------------|---------------------------------|
|                 |           |              | X               | Y       |                |                  |                   |                    |                | m <sup>3</sup> s <sup>-1</sup> | ft <sup>3</sup> s <sup>-1</sup> |
| Hat Creek       | LAVOWQ01  | 8/31/2011    | 632630          | 4482923 | 2112           | 150              | 2.6               | 19.6               | 5.7%           | 0.09                           | 3.3                             |
| Hat Creek       | LAVOWQ05  | 9/29/2011    | 631874          | 4484686 | 1999           | 160              | 4.2               | 25.7               | 2.0%           | 0.18                           | 6.3                             |
| Hat Creek       | LAVOWQ08  | 8/18/2011    | 631825          | 4490253 | 1871           | 320              | 7.4               | 53.5               | 0.9%           | 0.89                           | 31.5                            |
| Hat Creek       | LAVOWQ29  | 9/30/2011    | 631418          | 4485035 | 1983           | 200              | 4.2               | 27.2               | 1.2%           | 0.19                           | 6.7                             |
| Hat Creek       | LAVOWQ32  | 9/13/2011    | 631993          | 4488672 | 1883           | 240              | 7.6               | 43.1               | 0.8%           | 0.84                           | 29.7                            |
| Hat Creek       | LAVOWQ36  | 9/8/2011     | 631752          | 4488202 | 1889           | 320              | 7.7               | 42.6               | 0.7%           | 1.81                           | 64.0                            |
| Hat Creek       | LAVOWQ40  | 9/14/2011    | 631301          | 4487852 | 1893           | 280              | 8.4               | 36.5               | 0.7%           | 0.85                           | 30.1                            |
| Hat Creek       | LAVOWQ45  | 9/28/2011    | 632507          | 4484698 | 2010           | 150              | 2.4               | 22.8               | 2.1%           | 0.08                           | 2.8                             |
| Kings Creek     | LAVOWQ17  | 8/29/2011    | 630480          | 4480039 | 2224           | 150              | 2.2               | 56.0               | 0.8%           | 0.56                           | 19.7                            |
| Kings Creek     | LAVOWQ25  | 8/23/2011    | 634293          | 4480665 | 1887           | 200              | 6.0               | 36.5               | 4.1%           | 0.78                           | 27.4                            |
| Kings Creek     | LAVOWQ33  | 8/30/2011    | 631388          | 4479814 | 2184           | 240              | 5.9               | 44.6               | 1.6%           | 0.39                           | 13.8                            |
| Kings Creek     | LAVOWQ37  | 9/27/2011    | 629218          | 4480054 | 2249           | 150              | 2.1               | 28.9               | 2.4%           | 0.25                           | 9.0                             |
| Lost Creek      | LAVOWQ04  | 8/15/2011    | 628042          | 4487334 | 1882           | 150              | 2.0               | 24.4               | 1.0%           | 0.24                           | 8.6                             |
| Lost Creek      | LAVOWQ20  | 9/21/2011    | 627655          | 4489188 | 1828           | 150              | 2.5               | 28.8               | 2.7%           | 0.27                           | 9.4                             |
| Manzanita Creek | LAVOWQ15  | 9/16/2011    | 622055          | 4488111 | 1804           | 160              | 4.2               | 29.0               | 3.9%           | 0.65                           | 23.1                            |
| Manzanita Creek | LAVOWQ23  | 8/25/2011    | 623720          | 4484722 | 2060           | 160              | 3.4               | 27.3               | 5.7%           | 0.39                           | 13.7                            |
| Manzanita Creek | LAVOWQ27  | 9/1/2011     | 621827          | 4488196 | 1798           | 160              | 4.8               | 32.2               | 2.1%           | 0.60                           | 21.1                            |
| NA Rice Creek   | LAVOWQ10  | 9/23/2011    | 629031          | 4477156 | 2075           | 160              | 4.9               | 18.8               | 3.7%           | 0.02                           | 0.9                             |
| NA Rice Creek   | LAVOWQ22  | 9/22/2011    | 629303          | 4476823 | 2059           | 160              | 3.9               | 15.9               | 1.7%           | 0.03                           | 1.2                             |
| Summit Creek    | LAVOWQ13  | 8/22/2011    | 633868          | 4482972 | 2015           | 150              | 1.8               | 17.4               | 5.7%           | 0.01                           | 0.3                             |
| WF Hat Creek    | LAVOWQ09  | 8/17/2011    | 629829          | 4484477 | 1975           | 160              | 3.7               | 31.7               | 4.0%           | 0.28                           | 9.8                             |
| WF Hat Creek    | LAVOWQ12  | 9/7/2011     | 630847          | 4486420 | 1921           | 240              | 7.0               | 45.5               | 1.1%           | 0.84                           | 29.6                            |
| WF Hat Creek    | LAVOWQ21  | 8/16/2011    | 629130          | 4483432 | 2239           | 150              | 5.1               | 21.5               | 6.1%           | 0.20                           | 6.9                             |
| WF Hat Creek    | LAVOWQ24  | 9/6/2011     | 630661          | 4485967 | 1923           | 200              | 5.5               | 33.1               | 1.8%           | 0.56                           | 19.7                            |
| <b>Average</b>  |           |              |                 |         | 1990           | 190              | 4.6               | 31.8               | 2.6%           | 0.46                           | 16.2                            |
| <b>SD</b>       |           |              |                 |         | 137            | 55               | 2.0               | 11.1               | 1.8%           | 0.41                           | 14.5                            |
| <b>Median</b>   |           |              |                 |         | 1979           | 160              | 4.2               | 28.9               | 2.0%           | 0.33                           | 11.7                            |
| <b>Range</b>    |           |              |                 |         | 1798 -<br>2249 | 150 –<br>320     | 1.8 –<br>8.4      | 15.9 –<br>56.0     | 0.7% -<br>6.1% | 0.01 -<br>1.81                 | 0.3 –<br>64.0                   |

**Table 12.** Physical condition metrics for Lassen Volcanic streams sampled in 2011. Cells marked in amber are sites meeting EPA threshold criteria for “Intermediate,” whereas sites under “Physical habitat condition metrics” that are uncolored indicate the condition is “Least Disturbed.” Under Relative Bed Stability, italics indicate sites rated Intermediate due to excessively small substrates, and bold is for sites with excessively large substrates.

| Stream Name     | Site Code | Date Sampled | Stream Substrate diameter (mm) |             | Average Embeddedness (%) | Pools (%) | Riffles (%) | Physical Habitat Condition Metrics |                |                        |                      |
|-----------------|-----------|--------------|--------------------------------|-------------|--------------------------|-----------|-------------|------------------------------------|----------------|------------------------|----------------------|
|                 |           |              | Average                        | Median      |                          |           |             | In-Stream habitat cover            | Riparian Cover | Relative Bed Stability | Riparian Disturbance |
| Hat Creek       | LAVOWQ01  | 8/31/2011    | 15.1                           | 38.0        | 56.9                     | 6%        | 42%         | 0.48                               | 0.64           | -0.85                  | 0                    |
| Hat Creek       | LAVOWQ05  | 9/29/2011    | 21.0                           | 38.0        | 57.6                     | 14%       | 33%         | 0.30                               | 0.70           | -0.42                  | 0                    |
| Hat Creek       | LAVOWQ08  | 8/18/2011    | 14.7                           | 38.0        | 65.6                     | 6%        | 29%         | 0.51                               | 0.70           | -0.41                  | 0                    |
| Hat Creek       | LAVOWQ29  | 9/30/2011    | 18.5                           | 38.0        | 69.6                     | 5%        | 30%         | 0.40                               | 0.43           | -0.25                  | 0                    |
| Hat Creek       | LAVOWQ32  | 9/13/2011    | 16.1                           | 38.0        | 68.5                     | 7%        | 43%         | 0.78                               | 0.57           | -0.32                  | 0                    |
| Hat Creek       | LAVOWQ36  | 9/8/2011     | 19.8                           | 38.0        | 63.8                     | 4%        | 48%         | 0.68                               | 0.95           | -0.17                  | 0                    |
| Hat Creek       | LAVOWQ40  | 9/14/2011    | 9.1                            | 38.0        | 73.6                     | 15%       | 44%         | 0.48                               | 1.08           | -0.52                  | 0                    |
| Hat Creek       | LAVOWQ45  | 9/28/2011    | 12.2                           | 38.0        | 58.2                     | 0%        | 46%         | 0.37                               | 0.46           | -0.54                  | 0                    |
| Kings Creek     | LAVOWQ17  | 8/29/2011    | 7.7                            | 4.2         | 70.4                     | 0%        | 11%         | 0.31                               | 0.42           | -0.68                  | 0.45                 |
| Kings Creek     | LAVOWQ25  | 8/23/2011    | 105.2                          | 114.8       | 42.2                     | 9%        | 3%          | 0.65                               | 0.82           | -0.14                  | 0                    |
| Kings Creek     | LAVOWQ33  | 8/30/2011    | 10.6                           | 4.2         | 70.7                     | 1%        | 6%          | 0.45                               | 0.72           | -0.78                  | 0.14                 |
| Kings Creek     | LAVOWQ37  | 9/27/2011    | 15.5                           | 38.0        | 63.5                     | 3%        | 36%         | 0.30                               | 0.57           | -0.60                  | 0                    |
| Lost Creek      | LAVOWQ04  | 8/15/2011    | 2.1                            | 0.5         | 91.6                     | 0%        | 94%         | 0.36                               | 0.88           | -1.00                  | 0                    |
| Lost Creek      | LAVOWQ20  | 9/21/2011    | 20.3                           | 38.0        | 63.8                     | 1%        | 38%         | 0.37                               | 0.63           | -0.53                  | 0                    |
| Manzanita Creek | LAVOWQ15  | 9/16/2011    | 34.9                           | 38.0        | 64.9                     | 0%        | 0%          | 0.33                               | 0.47           | -0.50                  | 0.08                 |
| Manzanita Creek | LAVOWQ23  | 8/25/2011    | 107.8                          | 114.8       | 44.0                     | 9%        | 25%         | 0.93                               | 1.43           | -0.18                  | 0                    |
| Manzanita Creek | LAVOWQ27  | 9/1/2011     | 8.7                            | 38.0        | 69.4                     | 9%        | 34%         | 0.60                               | 0.82           | -0.85                  | 0.36                 |
| NA Rice Creek   | LAVOWQ10  | 9/23/2011    | 103.3                          | 114.8       | 42.2                     | 1%        | 52%         | 0.70                               | 0.90           | 0.20                   | 0                    |
| NA Rice Creek   | LAVOWQ22  | 9/22/2011    | 44.1                           | 38.0        | 39.6                     | 4%        | 54%         | 0.21                               | 0.75           | 0.16                   | 0                    |
| Summit Creek    | LAVOWQ13  | 8/22/2011    | 30.3                           | 38.0        | 64.7                     | 5%        | 62%         | 0.82                               | 0.87           | -0.41                  | 0.07                 |
| WF Hat Creek    | LAVOWQ09  | 8/17/2011    | 33.0                           | 114.8       | 59.8                     | 10%       | 33%         | 0.99                               | 1.17           | -0.55                  | 0                    |
| WF Hat Creek    | LAVOWQ12  | 9/7/2011     | 27.3                           | 38.0        | 60.4                     | 8%        | 35%         | 0.58                               | 1.00           | -0.20                  | 0                    |
| WF Hat Creek    | LAVOWQ21  | 8/16/2011    | 13.3                           | 38.0        | 63.3                     | 10%       | 52%         | 0.34                               | 0.59           | -0.94                  | 0                    |
| WF Hat Creek    | LAVOWQ24  | 9/6/2011     | 46.4                           | 114.8       | 59.3                     | 4%        | 33%         | 0.64                               | 1.05           | -0.10                  | 0.14                 |
| <b>Average</b>  |           |              | 30.7                           | 49.6        | 61.8                     | 5%        | 37%         | 0.52                               | 0.78           | -0.44                  | 0.05                 |
| <b>SD</b>       |           |              | 30.9                           | 36.1        | 11.5                     | 4%        | 20%         | 0.21                               | 0.25           | 0.32                   | 0.12                 |
| <b>Median</b>   |           |              | 19.1                           | 38.0        | 63.6                     | 5%        | 35%         | 0.48                               | 0.74           | -0.46                  | 0.00                 |
| <b>Range</b>    |           |              | 2.1 – 107.8                    | 0.5 – 114.8 | 39.6 – 91.6              | 0 – 15%   | 0 – 94%     | 0.21 – 0.99                        | 0.42 – 1.43    | -1.00 – 0.20           | 0.00 – 0.45          |

### ***Chemical characteristics and condition estimates of Lassen Volcanic streams***

Selected water chemistry results are presented in Table 13. Parameters measured in-situ with a water probe (see methods) are listed under “water quality” and parameters measured in an analytical laboratory or with a stream-side assay (Acid Neutralizing Capacity) are presented as “water chemistry.”

**Dissolved oxygen** data from two sites, Lost Creek (LAVOWQ04) and WF Hat Creek (LAVOWQ21), should be considered estimates and used with caution owing to the results of a mid-season field audit that found the technique used to calibrate the probe was faulty. Post audit data (8/17/2011) meet all protocol standards. All measured dissolved oxygen concentrations attained the water quality criteria in Table 2

**pH** was found to be circum-neutral (pH of 7 = neutral) to slightly alkaline at an average of 7.60. All pH data attained the water quality criteria in Table 2 and the average pH was in the middle of the acceptable range. **Acid Neutralizing Capacities** were all positive, indicating “Least disturbed.”

**Temperature** is presented as a descriptor of conditions during sampling, but varies on a daily, monthly, and seasonal basis. As such, no status or condition should be inferred from temperature readings. Our measurements, taken generally at mid-morning or mid-day in the summer represent near maximal values. All measurements (many under 5 °C [or 41 °F]) are typical for high elevation, montane and subalpine streams. Summit Creek had the highest recorded temperature, at 9.8 °C, almost twice the temperature of other Lassen Volcanic streams, but is also the lowest flow stream sampled (only 0.3 ft<sup>3</sup>/s), so that solar radiation and daily warming would affect it more than neighboring, larger streams.

**Specific conductivity** (used as a surrogate for salinity by the EPA) was uniformly low, and well under EPA threshold criteria for “Least disturbed” at all sites.

All measured **turbidity** readings were well below the NPS threshold of 50 NTU for water quality exceedances. The park-wide average was 3.0 NTU. As mentioned in the Whiskeytown results, some of the Lassen Volcanic turbidity measurements exceed the drinking water criteria, but there is no basis for applying drinking water criteria to these water bodies.

**Anion** and **cation** measurements were all far below any available water quality criteria.

Three sites had elevated **total nitrogen** values: Lost Creek (LAVOWQ04, 20) and Summit Creek (LAVOWQ13). These values are barely above the threshold criterion; however the location of these creeks near park roadways and campgrounds does suggest potential anthropogenic influences.

All but five sites and the overall park average were elevated for **total phosphorous** (two sites on Hat Creek, two sites on NA Rice Creek, and Summit Creek). The widespread distribution of “Intermediate” phosphorus levels suggests a geological or naturally occurring source.

**Table 13.** Water chemistry parameters for streams sampled in Lassen Volcanic, 2011. \* Dissolved oxygen data with \* indicates unverified values due to faulty calibration, and should be seen only as estimates. Data collected with water probe are under “Water Quality,” whereas data from laboratory analyses are under “Water Chemistry.” Cells colored amber indicate EPA condition estimate of “Intermediate.” All other cells not colored indicate “Least disturbed” where EPA thresholds exist.

| Stream Name     | Site Code | Water Quality |            |                               |                          |                 | Water Chemistry |                |                 |                       |                          |                            |        |
|-----------------|-----------|---------------|------------|-------------------------------|--------------------------|-----------------|-----------------|----------------|-----------------|-----------------------|--------------------------|----------------------------|--------|
|                 |           | pH            | Temp. (°C) | Specific Conductivity (µS/cm) | Dissolved Oxygen (mg/L)* | Turbidity (NTU) | Sodium (mg/L)   | Sulfate (mg/L) | Chloride (mg/L) | Total Nitrogen (mg/L) | Total Phosphorous (mg/L) | Acid Neutralizing Capacity |        |
|                 |           |               |            |                               |                          |                 |                 |                |                 |                       |                          | (µeq/L)                    | (mg/L) |
| Hat Creek       | LAVOWQ01  | 7.76          | 3.2        | 50                            | 10.2                     | 0.0             | 1.57            | 0.12           | 0.21            | 0.03                  | 0.011                    | 475                        | 24     |
| Hat Creek       | LAVOWQ05  | 7.25          | 4.1        | 48                            | 10.4                     | 0.0             | 0.94            | 0.06           | 0.14            | 0.06                  | 0.009                    | 420                        | 21     |
| Hat Creek       | LAVOWQ08  | 7.93          | 5.1        | 72                            | 9.7                      | 0.0             | 1.47            | 0.33           | 0.18            | 0.05                  | 0.018                    | 642                        | 32     |
| Hat Creek       | LAVOWQ29  | 7.15          | 4.3        | 48                            | 10.4                     | 0.0             | 1.90            | 0.10           | 0.19            | 0.03                  | 0.005                    | 428                        | 21     |
| Hat Creek       | LAVOWQ32  | 7.84          | 5.3        | 95                            | 10.4                     | 0.6             | 3.35            | 0.76           | 0.39            | 0.04                  | 0.021                    | 910                        | 46     |
| Hat Creek       | LAVOWQ36  | 7.86          | 5.9        | 97                            | 10.3                     | 0.0             | 3.40            | 0.78           | 0.36            | 0.03                  | 0.021                    | 920                        | 46     |
| Hat Creek       | LAVOWQ40  | 8.15          | 5.6        | 97                            | 10.1                     | 0.8             | 3.92            | 0.89           | 0.39            | 0.05                  | 0.022                    | 930                        | 47     |
| Hat Creek       | LAVOWQ45  | 7.23          | 3.3        | 54                            | 11.0                     | 0.0             | 1.75            | 0.13           | 0.28            | 0.04                  | 0.011                    | 533                        | 27     |
| Kings Creek     | LAVOWQ17  | 7.22          | 3.4        | 34                            | 10.3                     | 0.0             | 1.96            | 0.16           | 0.26            | 0.03                  | 0.027                    | 265                        | 13     |
| Kings Creek     | LAVOWQ25  | 7.57          | 4.7        | 35                            | 9.7                      | 2.4             | 1.02            | 0.07           | 0.15            | 0.05                  | 0.022                    | 265                        | 13     |
| Kings Creek     | LAVOWQ33  | 7.46          | 3.7        | 34                            | 10.4                     | 0.0             | 0.83            | 0.08           | 0.12            | 0.04                  | 0.026                    | 232                        | 12     |
| Kings Creek     | LAVOWQ37  | 6.89          | 3.7        | 27                            | 11.0                     | 14.6            | 1.48            | 0.16           | 0.19            | 0.04                  | 0.037                    | 397                        | 20     |
| Lost Creek      | LAVOWQ04  | 7.87          | 5.7        | 84                            | 10.4*                    | 0.0             | 3.97            | 1.26           | 0.46            | 0.15                  | 0.016                    | 850                        | 43     |
| Lost Creek      | LAVOWQ20  | 7.47          | 4.6        | 89                            | 10.5                     | 0.0             | 4.43            | 1.41           | 0.49            | 0.13                  | 0.015                    | 700                        | 35     |
| Manzanita Creek | LAVOWQ15  | 8.19          | 4.5        | 105                           | 10.1                     | 16.6            | 3.60            | 1.07           | 0.30            | 0.04                  | 0.015                    | 960                        | 48     |
| Manzanita Creek | LAVOWQ23  | 7.79          | 4.6        | 69                            | 10.4                     | 0.1             | 3.16            | 0.95           | 0.46            | 0.07                  | 0.018                    | 619                        | 31     |
| Manzanita Creek | LAVOWQ27  | 8.07          | 4.7        | 112                           | 10.5                     | 0.2             | 4.65            | 1.24           | 0.39            | 0.05                  | 0.014                    | 870                        | 44     |
| NA Rice Creek   | LAVOWQ10  | 7.00          | 7.2        | 38                            | 9.6                      | 4.6             | 2.20            | 0.60           | 0.16            | 0.04                  | 0.008                    | 330                        | 17     |
| NA Rice Creek   | LAVOWQ22  | 6.97          | 7.1        | 37                            | 10.5                     | 0.0             | 2.06            | 0.63           | 0.15            | 0.04                  | 0.005                    | 318                        | 16     |
| Summit Creek    | LAVOWQ13  | 7.41          | 9.8        | 26                            | 8.5                      | 0.0             | 1.24            | 0.18           | 0.16            | 0.15                  | 0.009                    | 365                        | 18     |
| WF Hat Creek    | LAVOWQ09  | 7.72          | 4.9        | 109                           | 10.3                     | 0.0             | 4.60            | 1.34           | 0.67            | 0.09                  | 0.033                    | 1030                       | 52     |
| WF Hat Creek    | LAVOWQ12  | 7.78          | 4.8        | 97                            | 9.6                      | 0.0             | 2.71            | 0.65           | 0.27            | 0.04                  | 0.024                    | 940                        | 47     |
| WF Hat Creek    | LAVOWQ21  | 7.56          | 4.3        | 106                           | 12.1*                    | 0.0             | 3.56            | 1.26           | 0.60            | 0.07                  | 0.029                    | 950                        | 48     |
| WF Hat Creek    | LAVOWQ24  | 8.25          | 3.9        | 119                           | 10.0                     | 32.3            | 3.82            | 1.08           | 0.41            | 0.04                  | 0.029                    | 1120                       | 56     |
| <b>Average</b>  |           | 7.60          | 4.9        | 70                            | 10.2                     | 3.0             | 2.65            | 0.64           | 0.31            | 0.06                  | 0.019                    | 645                        | 32     |
| <b>SD</b>       |           | 0.40          | 1.5        | 32                            | 0.5                      | 7.6             | 1.25            | 0.48           | 0.15            | 0.04                  | 0.009                    | 289                        | 14     |
| <b>Median</b>   |           | 7.64          | 4.7        | 71                            | 10.3                     | 0.0             | 2.46            | 0.64           | 0.28            | 0.04                  | 0.018                    | 631                        | 32     |
| <b>Range</b>    |           | 6.89 - 8.25   | 3.2 - 9.8  | 26 - 119                      | 8.5 - 11.0               | 0 - 32.3        | 0.83 - 4.65     | 0.06 - 1.41    | 0.12 - 0.67     | 0.03 - 0.15           | 0.005 - 0.037            | 232 - 1120                 | 20790  |

**Table 14.** Riparian characteristics of Lassen Volcanic streams sampled in 2011. For compositions: D = Deciduous, C = Coniferous, E = Broadleaf Evergreen, N = None, and M = Mixed (10% or more of multiple types).

| Stream Name     | Site Code      | Shading   | Legacy Tree Height (m) | Canopy   |            |                     | Understory |           |                           |
|-----------------|----------------|-----------|------------------------|----------|------------|---------------------|------------|-----------|---------------------------|
|                 |                |           |                        | Big Tree | Small Tree | Composition         | Woody      | Non-woody | Composition               |
| Hat Creek       | LAVOWQ01       | 64%       | 27.7                   | 19%      | 19%        | 95% C, 5% N         | 13%        | 4%        | 77% C, 23%M               |
| Hat Creek       | LAVOWQ05       | 72%       | 11.8                   | 20%      | 7%         | 100% C              | 22%        | 1%        | 91% C, 5% M, 5% N         |
| Hat Creek       | LAVOWQ08       | 32%       | 27.5                   | 13%      | 22%        | 95% C, 5% M         | 19%        | 0%        | 86% C, 9% M, 5% N         |
| Hat Creek       | LAVOWQ29       | 59%       | 21.1                   | 15%      | 4%         | 100% C              | 11%        | 3%        | 64% C, 23% D, 9% M, 5% N  |
| Hat Creek       | LAVOWQ32       | 66%       | 25.4                   | 15%      | 25%        | 95% C, 5% M         | 9%         | 0%        | 86% C, 14% M              |
| Hat Creek       | LAVOWQ36       | 63%       | 38.3                   | 15%      | 24%        | 59% C, 41% M        | 28%        | 0%        | 50% M, 41% C, 9% D        |
| Hat Creek       | LAVOWQ40       | 60%       | 24.4                   | 22%      | 11%        | 59% C, 32% M, 9% N  | 38%        | 0%        | 64% M, 23% D, 14% C       |
| Hat Creek       | LAVOWQ45       | 67%       | 34.3                   | 12%      | 8%         | 86% C, 9% N, 5% D   | 13%        | 8%        | 59% C, 32% D, 9% M        |
| Kings Creek     | LAVOWQ17       | 13%       | 42.6                   | 2%       | 8%         | 41% C, 59% N        | 15%        | 0%        | 55% C, 45% M              |
| Kings Creek     | LAVOWQ25       | 61%       | 14.8                   | 13%      | 17%        | 100% C              | 26%        | 0%        | 100% C                    |
| Kings Creek     | LAVOWQ33       | 44%       | 26.1                   | 16%      | 24%        | 95% C, 5% N         | 19%        | 0%        | 86% C, 14% N              |
| Kings Creek     | LAVOWQ37       | 34%       | 30.7                   | 5%       | 6%         | 68% C, 32% N        | 23%        | 4%        | 68% D, 32% M              |
| Lost Creek      | LAVOWQ04       | 70%       | 33.6                   | 7%       | 8%         | 46% C, 46% N, 4% D  | 41%        | 0%        | 57% D, 21% M, 18% C, 4% N |
| Lost Creek      | LAVOWQ20       | 51%       | 31.5                   | 3%       | 12%        | 100% C              | 22%        | 0%        | 91% C, 5% M, 5% N         |
| Manzanita Creek | LAVOWQ15       | 54%       | 23.1                   | 6%       | 7%         | 91% C, 9% N         | 17%        | 0%        | 75% C, 25% M              |
| Manzanita Creek | LAVOWQ23       | 89%       | 36.9                   | 27%      | 6%         | 100% C              | 58%        | 0%        | 55% M, 36% D, 9% C        |
| Manzanita Creek | LAVOWQ27       | 75%       | 28.8                   | 19%      | 8%         | 50% C, 27% M, 18% D | 31%        | 0%        | 39% C, 34% D, 23% M       |
| NA Rice Creek   | LAVOWQ10       | 52%       | 31.3                   | 11%      | 7%         | 95% C, 5% N         | 37%        | 2%        | 50% C, 50% M              |
| NA Rice Creek   | LAVOWQ22       | 34%       | 28.7                   | 10%      | 8%         | 77% C, 23% N        | 29%        | 9%        | 50% C, 50% M              |
| Summit Creek    | LAVOWQ13       | 69%       | 25.6                   | 17%      | 12%        | 95% C, 5% N         | 30%        | 1%        | 82% C, 18% M              |
| WF Hat Creek    | LAVOWQ09       | 80%       | 24.8                   | 25%      | 8%         | 73% C, 18% N        | 50%        | 1%        | 55% D, 32% C, 14% M       |
| WF Hat Creek    | LAVOWQ12       | 61%       | 27.2                   | 11%      | 36%        | 100% C              | 26%        | 1%        | 86% M, 9% C, 5% D         |
| WF Hat Creek    | LAVOWQ21       | 66%       | 26.5                   | 23%      | 12%        | 91% C, 9% N         | 13%        | 0%        | 74% D, 27% N              |
| WF Hat Creek    | LAVOWQ24       | 66%       | 32.4                   | 10%      | 22%        | 91% C, 9% N         | 39%        | 0%        | 64% M, 23% D, 14% C       |
|                 | <b>Average</b> | 58%       | 28.1                   | 14%      | 13%        |                     | 26%        | 1%        |                           |
|                 | <b>SD</b>      | 17%       | 6.8                    | 7%       | 8%         |                     | 13%        | 2%        |                           |
|                 | <b>Median</b>  | 62%       | 27.6                   | 14%      | 10%        |                     | 24%        | 0%        |                           |
|                 | <b>Range</b>   | 13% - 89% | 11.8 – 42.6            | 2% - 27% | 4% - 36%   |                     | 9% - 58%   | 0% - 9%   |                           |

### ***Riparian characteristics of Lassen Volcanic streams***

The riparian zones of Lassen Volcanic are overall characterized by coniferous trees and a diverse community providing moderate overall shading (58% average, 62% median; Table 14). The site with the least shading was Kings Creek (LAVOWQ17). Both the canopy cover and understory were generally coniferous dominated, with only a few sites having a deciduous canopy cover component.

### ***Vertebrate assemblage and condition of Lassen Volcanic streams***

Results of electrofishing and visual encounters of vertebrate species, along with summaries of abundance, richness, and the EPA Vertebrate MMI are presented in Table 15. A single amphibian species (Pacific Tree Frog, *Pseudacris regilla*), two species of non-native trout (brook trout, *Salvelinus fontinalis*; brown trout, *Salmo trutta*), and one native (but possibly stocked) species of trout (rainbow trout, *Oncorhynchus mykiss*) were observed. Of these, only brook trout, recorded from 15 sites, could be considered wide-spread. Four sites had no detected vertebrate species. All observed vertebrate species have been previously recorded in the park ([KLMN certified species lists](#)).

All but three of the sites with vertebrates were rated as “Intermediate” using the EPA’s Vertebrate MMI threshold criteria; consequently the park-wide average was also in the “Intermediate” range at 48.6 out of 100. This is largely due to low species richness and the presence of non-native fish. Sites with no vertebrates encountered cannot be assessed or assigned scores as streams may be naturally devoid of species. Hence, these sites were not ranked or included in average and median calculations.

### ***Invertebrate assemblage and condition of Lassen Volcanic streams***

A total of 16,261 individual macroinvertebrates were collected, sorted, and identified from Lassen Volcanic streams (A complete taxa list for Lassen Volcanic samples is given in Appendix C). A conservative estimate for the total species richness is 165 separate species (many taxa are only identified to family or genus level, hence the true species richness is likely to be higher; also there are instances where a specific individual was only able to be identified to family, but a separate individual was identified to genus or species, duplicating the “taxonomic units.” See the full protocol [Dinger et al. 2013] or Cuffney et al. 2007 for more detail on ambiguous taxa). Summary statistics (Taxa Richness and measures of biological integrity) for each site are provided in Table 16.

The most diverse site was Hat Creek (LAVOWQ32) with 73 total taxa, and the most depauperate site was Lost Creek (LAVOWQ04) with 39 taxa.

For calculating Hilsenhoff Biotic Index, tolerance values were available for 171 of 191 of the total taxonomic units (including individuals only identified to higher taxonomic units due to poor keys, damaged specimens, or immature lifestages). Taxa with no tolerance value were excluded from HBI calculations. The lowest HBI (indicating a preponderance of intolerant, clean-water indicating organisms) was in the upper watershed of Manzanita Creek (LAVOWQ23). The highest HBI (indicating mostly tolerant organisms) was Hat Creek (LAVOWQ45) at 4.96.

All sites were rated as “Least disturbed” using the EPA Invertebrate MMI, with the lowest recorded index value (75 out of 100) being Manzanita Creek (LAVOWQ15). The highest rated site was NA Rice Creek (LAVOWQ10) at 95 out of 100.

Thirteen sites were rated as “supporting, acceptable” and ten sites as “supporting, intermediate” while one site was rated “not supporting” using the East Sierra MMI. The sole site rated “not supporting” was Lost Creek (LAVOWQ04), the same site had the lowest taxa richness, although it was also rated “Least disturbed” using the EPA MMI criteria. See the discussion for more interpretation of multiple lines of evidence in determining ecological health.

**Table 15.** Vertebrate species and metrics for Lassen Volcanic streams sampled in 2011. Cells colored amber indicate the site meets the numeric value for “Intermediate” condition assessment using EPA threshold values.

| Stream Name     | Site Code | Metrics         |                |                    | Amphibian                                                     | Fish                                                          |                                                |                                                 |  |
|-----------------|-----------|-----------------|----------------|--------------------|---------------------------------------------------------------|---------------------------------------------------------------|------------------------------------------------|-------------------------------------------------|--|
|                 |           | Total Abundance | Total Richness | EPA Vertebrate MMI | Pacific tree frog<br>( <i>Pseudacris regilla</i> )<br>(adult) | Brook trout<br>( <i>Salvelinus fontinalis</i> )<br>Non-native | Brown trout ( <i>Salmo trutta</i> ) Non-native | Rainbow trout<br>( <i>Oncorhynchus mykiss</i> ) |  |
| Hat Creek       | LAVOWQ01  | 1               | 1              | 42.6               | 1                                                             |                                                               |                                                |                                                 |  |
| Hat Creek       | LAVOWQ05  | 4               | 1              | 42.6               |                                                               | 4                                                             |                                                |                                                 |  |
| Hat Creek       | LAVOWQ08  | 5               | 1              | 42.6               |                                                               | 5                                                             |                                                |                                                 |  |
| Hat Creek       | LAVOWQ29  | 5               | 1              | 42.6               |                                                               | 5                                                             |                                                |                                                 |  |
| Hat Creek       | LAVOWQ32  | 5               | 1              | 42.6               |                                                               | 5                                                             |                                                |                                                 |  |
| Hat Creek       | LAVOWQ36  | 5               | 1              | 42.6               |                                                               | 5                                                             |                                                |                                                 |  |
| Hat Creek       | LAVOWQ40  | 6               | 2              | 42.6               |                                                               | 5                                                             | 1                                              |                                                 |  |
| Hat Creek       | LAVOWQ45  | 5               | 1              | 42.6               |                                                               | 5                                                             |                                                |                                                 |  |
| Kings Creek     | LAVOWQ17  | 1               | 1              | 42.6               |                                                               | 1                                                             |                                                |                                                 |  |
| Kings Creek     | LAVOWQ25  | 5               | 2              | 50.1               |                                                               | 4                                                             |                                                | 1                                               |  |
| Kings Creek     | LAVOWQ33  | 4               | 1              | 42.6               |                                                               | 4                                                             |                                                |                                                 |  |
| Kings Creek     | LAVOWQ37  | 0               | 0              | *                  |                                                               |                                                               |                                                |                                                 |  |
| Lost Creek      | LAVOWQ04  | 0               | 0              | *                  |                                                               |                                                               |                                                |                                                 |  |
| Lost Creek      | LAVOWQ20  | 1               | 1              | 71.0               |                                                               |                                                               |                                                | 1                                               |  |
| Manzanita Creek | LAVOWQ15  | 3               | 2              | 60.4               |                                                               |                                                               | 1                                              | 2                                               |  |
| Manzanita Creek | LAVOWQ23  | 0               | 0              | *                  |                                                               |                                                               |                                                |                                                 |  |
| Manzanita Creek | LAVOWQ27  | 8               | 3              | 52.9               |                                                               | 3                                                             | 1                                              | 4                                               |  |
| NA Rice Creek   | LAVOWQ10  | 4               | 1              | 71.0               |                                                               |                                                               |                                                | 4                                               |  |
| NA Rice Creek   | LAVOWQ22  | 3               | 1              | 71.0               |                                                               |                                                               |                                                | 3                                               |  |
| Summit Creek    | LAVOWQ13  | 5               | 1              | 42.6               |                                                               | 5                                                             |                                                |                                                 |  |
| WF Hat Creek    | LAVOWQ09  | 1               | 1              | 42.6               |                                                               | 1                                                             |                                                |                                                 |  |
| WF Hat Creek    | LAVOWQ12  | 4               | 1              | 42.6               |                                                               | 4                                                             |                                                |                                                 |  |
| WF Hat Creek    | LAVOWQ21  | 0               | 0              | *                  |                                                               |                                                               |                                                |                                                 |  |
| WF Hat Creek    | LAVOWQ24  | 3               | 1              | 42.6               |                                                               | 3                                                             |                                                |                                                 |  |
| Average         |           |                 | 1.0            | 48.6               |                                                               |                                                               |                                                |                                                 |  |
| SD              |           |                 | 0.7            | 10.7               |                                                               |                                                               |                                                |                                                 |  |
| Median          |           |                 | 1              | 42.6               |                                                               |                                                               |                                                |                                                 |  |
| Range           |           |                 | 0 - 3          | 42.6 - 71.0        |                                                               |                                                               |                                                |                                                 |  |

**Table 16.** Invertebrate results and metrics for Lassen Volcanic streams, 2011. Cells colored amber indicate values meeting criteria for “Intermediate” condition assessment and red cells indicate “Most disturbed” or equivalent. Cells not colored indicate either “Least disturbed” or no threshold exists for that metric.

| Stream Name     | Site Code | Total<br>Taxa<br>Richness | Hilsenhoff<br>Biotic<br>Index | EPA West-<br>Wide<br>Invertebrate<br>MMI | East<br>Sierra<br>MMI |
|-----------------|-----------|---------------------------|-------------------------------|------------------------------------------|-----------------------|
| Hat Creek       | LAVOWQ01  | 42                        | 3.05                          | 84                                       | 77                    |
| Hat Creek       | LAVOWQ05  | 64                        | 4.84                          | 89                                       | 84                    |
| Hat Creek       | LAVOWQ08  | 50                        | 4.85                          | 87                                       | 75                    |
| Hat Creek       | LAVOWQ29  | 63                        | 3.51                          | 89                                       | 80                    |
| Hat Creek       | LAVOWQ32  | 73                        | 3.08                          | 79                                       | 84                    |
| Hat Creek       | LAVOWQ36  | 71                        | 3.34                          | 90                                       | 86                    |
| Hat Creek       | LAVOWQ40  | 58                        | 4.82                          | 86                                       | 82                    |
| Hat Creek       | LAVOWQ45  | 51                        | 4.96                          | 91                                       | 79                    |
| Kings Creek     | LAVOWQ17  | 43                        | 3.21                          | 89                                       | 80                    |
| Kings Creek     | LAVOWQ25  | 57                        | 3.67                          | 83                                       | 91                    |
| Kings Creek     | LAVOWQ33  | 55                        | 3.84                          | 95                                       | 75                    |
| Kings Creek     | LAVOWQ37  | 48                        | 4.05                          | 83                                       | 88                    |
| Lost Creek      | LAVOWQ04  | 39                        | 4.50                          | 81                                       | 63                    |
| Lost Creek      | LAVOWQ20  | 54                        | 4.20                          | 81                                       | 89                    |
| Manzanita Creek | LAVOWQ15  | 51                        | 4.83                          | 75                                       | 85                    |
| Manzanita Creek | LAVOWQ23  | 49                        | 2.77                          | 80                                       | 86                    |
| Manzanita Creek | LAVOWQ27  | 47                        | 3.92                          | 83                                       | 79                    |
| NA Rice Creek   | LAVOWQ10  | 58                        | 3.38                          | 95                                       | 83                    |
| NA Rice Creek   | LAVOWQ22  | 55                        | 4.08                          | 90                                       | 89                    |
| Summit Creek    | LAVOWQ13  | 57                        | 4.83                          | 79                                       | 93                    |
| WF Hat Creek    | LAVOWQ09  | 46                        | 3.13                          | 85                                       | 78                    |
| WF Hat Creek    | LAVOWQ12  | 70                        | 4.13                          | 87                                       | 80                    |
| WF Hat Creek    | LAVOWQ21  | 45                        | 4.57                          | 84                                       | 70                    |
| WF Hat Creek    | LAVOWQ24  | 45                        | 3.74                          | 80                                       | 84                    |
| <b>Average</b>  |           | 53.8                      | 3.97                          | 85.2                                     | 81.7                  |
| <b>SD</b>       |           | 9.3                       | 0.69                          | 5.1                                      | 6.8                   |
| <b>Median</b>   |           | 52.5                      | 3.99                          | 84.5                                     | 82.5                  |
| <b>Range</b>    |           | 39 - 73                   | 2.77 - 4.96                   | 75 - 95                                  | 63 - 93               |

## Discussion

### General Issues

Although monitoring commenced during the summer of 2011, the KLMN Wadeable Streams protocol did not receive final approval until May 25, 2012. No substantive changes were made to the protocol between 2011 implementation and 2012 approval.

Of primary note, the protocol has a goal of 30 sites sampled per park, but we were unable to meet this goal (22 sites were sampled in Whiskeytown, 24 sites were sampled in Lassen Volcanic). Reasons for this are largely due to the logistical constraints of starting a new monitoring program. Access to remote sites was difficult at both parks, and often the crew would drive/hike several hours only to find that the slope leading down to the stream was hazardous, or that the stream was ephemeral (drying out in the summer months). Ephemeral streams are not covered in this protocol due to the confounding factor that drying has in determining ecological integrity and anthropogenic impact. Future sampling seasons (2014 for Whiskeytown and Lassen Volcanic) will be more efficient and give us a higher probability of achieving our target goals. Additional issues that prevented fully completing the sites were: 1) delays in hiring the field crew, 2) an injury to the field crew leader, and 3) one crew member departing early for other employment. Many of these constraints will be absent in future years (although new obstacles may arise), hopefully increasing the ability to reach 30 sites.

The immediate outcome of sampling fewer than 30 sites is a reduction of precision in the annual status assessments (i.e., increased error bars/standard deviations). Longer-term issues, if follow-up years are unable to increase the sample size, will be a reduction in power to detect trends in park aquatic resources, although a total sample size of 20 is the minimum to achieve the goals of the protocol.

One issue occurred that affected data completeness. The crew responsible for on-site calibration of dissolved oxygen (which according to WRD is susceptible to changes in elevation; the manufacturer, Eureka Environmental, suggests that it is relatively invariant to changes in elevation) checked the level of saturation of the water probe reading in an 100% saturated environment, but neglected to *reset* or *recalibrate* the sensor based on the ambient elevation. Because the technician did record the current reading of saturation, a measure of bias is calculable by comparing the recorded value to the 100% standard. For example, the technician placed the probe in a 100% saturated condition, and measured the current reading – maybe 103%; so the calculated bias is 3% off. On average, the values were off by 4%; suggesting that readings are indicative of the actual stream values but should not be used in any analytical sense. Approximately 29% of the time, the readings were biased to be lower than the actual value, and 61% of the time the values were biased to be higher than the actual value. The readings were unbiased the other 10% of the time. The raw values are presented here, but should be interpreted with caution, and not for regulatory purposes.

This protocol makes use of EPA developed threshold criteria for assigning “condition” to ecological integrity from a diversity array of variable and metrics (physical, chemical, and biological). From a management perspective, three main points should be emphasized:

1. The programmatic goal of the Wadeable Streams Assessment is an assessment of the amount of overall impairment in the sampling frame, and not the identification of site-specific impairment. Hence, within the EPA program, errors in site-specific condition do occur, are recognized to occur, and hopefully minimized; but region-wide averages have still driven the development of threshold criteria. “Intermediate” or “Most disturbed” sites identified by this program should be investigated, but are not an immediate call for “crisis mode.”
2. Threshold criteria are based on region (mountain west-wide models) reference conditions. Localized values based on park reference sites may provide more accurate per-site and park-wide assessment. An example is the threshold criteria used for total phosphorous, where both Whiskeytown and Lassen Volcanic show possible influence of local geology, exhibiting naturally higher phosphorous than the EPA derived values. When a majority of park sites show increased values in a single metric, and the park can conclusively show that these sites should be rated as “Least disturbed,” the creation of park-specific thresholds may be necessary through research programs or research partners.
3. The use of multiple indices allow for the potential of some indices to rate a stream condition as “least disturbed” whereas others might rate it as “Most disturbed” – creating a perceived paradox of a stream condition. Indeed, most sites in Whiskeytown had one or more “flags” (“Intermediate or Most disturbed”). Rather than view this as a paradox, managers should consider two points; (a) a weight of evidence approach, and (b) a specificity of impact approach. In the weight of evidence approach, a stream site that has multiple “flags” across multiple categories (e.g., biological, chemical, and biological) would suggest a truly imperiled stream. In the specificity of impact approach, a stream that is “intermediate” in one category and not the others can be used to help pinpoint what the impact is that might be affecting water quality. As an example, a stream or lake that has elevated phosphorous and low nitrogen may be indicative of a system impacted by agriculture, whereas a system with low phosphorous and high nitrogen may be indicative of a system impacted by depositional pollution (although nitrogen is also associated with fertilizer run-off).

### **Whiskeytown National Recreation Area**

Two primary patterns emerged in the Whiskeytown data. One, the preliminary Relative Bed Stability (RBS – measure of observed sediments versus expected sediments) was higher than expected, so that bed substrates were dominated by large substrates with a paucity of smaller sediments. Two, a majority of sites had elevated Total Phosphorous levels above the “least disturbed” threshold.

As a management concern, high RBS values indicate stable, armored streambeds. Typical examples of impacted streams with high RBS values fall into two categories: (1) streams below dams where the dam interrupts the sediment supply and (2) streams with their channels artificially manipulated for flood control (e.g., lined with concrete). Neither example applies to the streams of Whiskeytown, where streams with higher RBS values occur across the landscape, and in both sites near roads/trails and isolated sites far from any apparent anthropogenic disturbance. One hypothesis is that recent high water spates from the 2010-11 winter flushed sediments and no recent erosion has occurred to replace flushed sediments. Another consideration is that the granitic pluton that comprises Shasta

Bally is naturally a low producer of fine sediments so that the streams of Whiskeytown are naturally dominated by larger substrates (leading to streams being named “Boulder Creek,” for example).

Elevated total phosphorous in Whiskeytown streams has two potential explanations. First, higher phosphorous concentrations may be a natural state for the streams of Whiskeytown, owing to the volcanic history of the region. Second, there is concern that illicit marijuana plantations in Whiskeytown may be using artificial fertilizers, with run-off into Whiskeytown streams that will manifest as high nutrient levels, potentially causing nuisance algal blooms. Nitrogen levels remained low at all sites across the park landscape and logically if there were an enrichment occurring due to marijuana plantations, we would logically expect increases in both nitrogen and phosphorous. Additionally, it seems unlikely that large enough marijuana operations to produce a signal in phosphorous are occurring unnoticed in eight different watersheds across the park landscape.

Very little concern was detected in vertebrate monitoring. Although the KLMN procedures for amphibian and fish monitoring are a “rapid” assessment of the vertebrate assemblages, the overall diversity of the park was high with five species of amphibians, and six species of fish (one of which was the non-native brook trout). Total abundance of vertebrates is a highly variable assessment, dependent on the total reach length and total time spent shocking the stream. Additionally, crews used a light touch on most amphibians, so that the total numbers may be much higher than those counted. The EPA vertebrate MMI indicated that most sites were in the “least disturbed” category, and appeared to accurately reflect the condition of the site. Two sites that were “Intermediate” were Clear Creek, which was typified by larger, deeper, slower water than most of the steep, cascading streams of the park (and so had less fish characteristic of cold-water streams); and one site on Brandy Creek with multiple specimens of brook trout.

Invertebrate monitoring showed a single site, Willow Creek (WHISWQ01) that met criteria for “Most disturbed.” Willow Creek is recognized by the state of California as Clean Water Act 303(d) impaired for acid mine drainage, zinc, and copper. WHISWQ01 was also characterized by low diversity (relative to other streams in the park) at only 50; the lowest was 48 at a site also on Willow Creek). Of note, the HBI for this site (WHISWQ01) was the lowest in the park (2.97 – indicating an intolerant, clean water assemblage); however this was the result of a large number of *Lepidostoma* caddisflies (Trichoptera:Lepidostomatidae), and Willow Creek was generally depauperate – collections only had two taxa of mayflies (Ephemeroptera) and two taxa of stoneflies (Plecoptera). The California State North Coast MMI rated this site as “good,” but was near the threshold of being rated as only “fair.” We sampled a second site (WHISWQ21) further downstream on Willow Creek in the 303(d) impaired section, but both the EPA MMI and the North Coast IBI were distinctly improved and not rated as “Most disturbed” (although still characterized by lower diversity). Based on the location of WHISWQ21, we suggest that the tributary Crystal Creek has a mitigating effect on the water quality conditions, particularly for the aquatic macroinvertebrates.

The low diversity and low ecological integrity scores in the 303(d) impacted stretch are likely a lasting legacy of the mining practices in the Willow Creek watershed (from the Greenhorn Mine), where water run-off through mine tailings creates sulfuric acid, degrading the streams by acidification and increasing heavy metal toxicity to the stream biota. Other ecological indicators

(physical, chemical, and vertebrate assemblages) show high integrity of stream condition in Willow Creek. However, a recently published USGS stream survey ([Wulff et al. 2012](#)) indicated that water samples from 2004 and 2005 in Willow Creek were still high in strontium, lithium, manganese, barium, aluminum, and copper. Although the pH and Acid Neutralizing Capacity of Willow Creek are now in “Least disturbed” reference condition, the high concentrations of heavy metals are still manifest. California is expected to produce a TMDL (total maximum daily load) plan for Willow Creek by 2019 that will quantify the maximum amount of pollutants that Willow Creek can receive and allocate those pollutant loads among point and non-point sources in the watershed to enable the creek to attain its state-designated beneficial uses.

Overall estimation of potentially problematic water quality sites should be looked at using a weight of evidence approach, using information from all the available metrics (Table 17). Table 17 shows the summation of “flags,” each time a condition score was rated as “Intermediate” or “Most disturbed,” but in this instance there is no weighting of “Most disturbed” or “Intermediate” – they are treated as equal flags. There are 11 total metrics used, so maximally disturbed sites would be “11.” Most sites in Whiskeytown are limited to 1 or 2 flags; mostly from the elevated phosphorous and elevated RBS scores already discussed. However, one site stands out with 6 flags, Clear Creek (WHISWQ25).

**Table 17.** Condition summary for Whiskeytown streams, 2011. Flags indicate each incidence of “Intermediate” or “Most disturbed” condition.

| Stream Name            | Site Code | Number of Flags |          |            | Sum |
|------------------------|-----------|-----------------|----------|------------|-----|
|                        |           | Physical        | Chemical | Biological |     |
| Boulder Creek          | WHISWQ02  | 1               | 0        | 0          | 1   |
| Boulder Creek          | WHISWQ17  | 1               | 0        | 0          | 1   |
| Boulder Creek          | WHISWQ30  | 0               | 0        | 0          | 0   |
| Boulder Creek          | WHISWQ33  | 0               | 1        | 0          | 1   |
| Brandy Creek           | WHISWQ12  | 0               | 1        | 0          | 1   |
| Brandy Creek           | WHISWQ18  | 0               | 0        | 1          | 1   |
| Brandy Creek           | WHISWQ34  | 1               | 1        | 0          | 2   |
| Clear Creek            | WHISWQ25  | 3               | 1        | 2          | 6   |
| Crystal Creek          | WHISWQ15  | 0               | 1        | 0          | 1   |
| Crystal Creek          | WHISWQ23  | 2               | 0        | 0          | 2   |
| Grizzly Gulch          | WHISWQ06  | 1               | 0        | 1          | 2   |
| Mill Creek             | WHISWQ09  | 0               | 1        | 0          | 1   |
| Paige Boulder Creek    | WHISWQ08  | 1               | 1        | 0          | 2   |
| Paige Boulder Creek    | WHISWQ28  | 1               | 0        | 0          | 1   |
| Unnamed (Crystal Trib) | WHISWQ03  | 0               | 1        | 0          | 1   |
| Unnamed (Brandy Trib)  | WHISWQ14  | 1               | 0        | 0          | 1   |
| Unnamed (Boulder Trib) | WHISWQ22  | 1               | 0        | 0          | 1   |
| Unnamed (Brandy Trib)  | WHISWQ24  | 1               | 0        | 0          | 1   |
| Unnamed (Crystal Trib) | WHISWQ35  | 0               | 1        | 0          | 1   |
| Whiskey Creek          | WHISWQ26  | 2               | 0        | 0          | 2   |
| Willow Creek           | WHISWQ01  | 0               | 1        | 1          | 2   |
| Willow Creek           | WHISWQ21  | 2               | 1        | 0          | 3   |

This section of Clear Creek sampled was in the stretch above Whiskeytown Lake, and not below Whiskeytown Dam (the crew found that attempted sites below the dam were too deep to sample). The site was characterized by being the widest (average 11.4 m), deepest (average 54.5 cm), and most instantaneous discharge (51.5 ft<sup>3</sup>/s) of any sampled stream. Some of these “flags” can be attributed to these geomorphological features; however it is also a roadside stream with indicators of high riparian disturbance.

Although 2011 was the first year of monitoring, recently published reports on Whiskeytown aquatic chemistry and biota surveys from 2004 and 2005 (Wulff et al. 2012, [Brown et al. 2012](#)) offer an opportunity for comparing some aspects of our monitoring to the inventory efforts of the USGS. Both the USGS project and KLMN monitoring protocols are broad in scope, measuring physical, chemical, and biological aspects of Whiskeytown streams. A primary difference is that KLMN monitoring used a probabilistic selection of sites (GRTS) to allow park-wide inference (within the sampling frame) of condition and the USGS study appears to have used a non-random selection of sites, including sites outside the park boundary. This non-random selection of sites may have led the USGS to encounter a larger number of fish species than the KLMN sampling (USGS recorded 11 fish species versus the KLMN recording 6 species); however the KLMN recorded 5 species of amphibians versus the 4 recorded by the USGS). Additionally, we recorded 256 taxa of macroinvertebrates, whereas the USGS recorded 224 (despite the USGS collecting a total of 76 samples versus the 24 samples collected by the KLMN). A full comparison and integration of USGS results with the current monitoring results is beyond the scope of this annual report, but will be explored in future Analysis and Synthesis reports for integrating methods and trends.

### **Lassen Volcanic National Park**

Several patterns were observed in the stream data for Lassen Volcanic National Park. First, the montane and subalpine nature of several streams led to some observations of lower amounts of riparian vegetation. Second, as with Whiskeytown, there was a high occurrence of elevated phosphorous levels. Third, the naturally depauperate fish fauna, coupled with a high prevalence of non-native trout in the streams, qualifies the interpretation of the EPA Vertebrate MMI. Fourth, the streams of Lassen Volcanic generally do not have an amphibian presence. Finally, the Eastern Sierra MMI initially proposed to provide a regionally relevant condition assessment may not be appropriate.

Although eight sites in Lassen Volcanic were rated as “Intermediate” for riparian cover, this is likely due to prevalence of montane and subalpine meadow systems along the park streams. As a high elevation stream meanders in a grassy meadow, a perceived paucity of woody overstory vegetation will drive the riparian cover metric down, suggesting an “Intermediate” condition. However, this is certainly a natural state for some of the streams of Lassen Volcanic and does not indicate impairment.

As with Whiskeytown, the streams of Lassen Volcanic were characterized by elevated phosphorous levels at 19 of 24 sites. In the absence of any identifiable anthropogenic pollution, and with the geologic influences and geothermal activity, the “Intermediate” ratings are likely natural and do not indicate any sort of impairment.

Only one species of native fish was encountered in the streams of Lassen Volcanic: rainbow trout. Two additional non-native salmonids were encountered, a remnant of fish stocking in the region (brook and brown trout). Although several of the fish species on the certified species list are potential stream dwellers (at least as migrants) we did not encounter them in our sampling. It is likely that the high elevation nature of the streams, along with occasional natural downstream barriers such as waterfalls, have limited the fish populations. This limitation, along with two species of non-native trout, resulted in low EPA Vertebrate MMI scores. The consideration of whether these scores and “Intermediate” condition assessment are valid is open to interpretation. They should be considered preliminary at this time. In the interpretation that the ecosystem is “impaired” or “imperiled” the presence of non-native trout does not signal an extrinsic threat or degradation; rather it is an indication of the legacy of non-native trout stocking for the region. Viewing the entire stream ecosystem, however, the presence on non-native trout can negatively impact the native biota. Notably, the EPA Vertebrate MMI index differs from the other condition assessments provided: the other indicators are symptomatic of the external impacts (e.g., anthropogenic disturbances), but for Lassen Volcanic the Vertebrate MMI signals the actual impact (non-native fish).

Only one site recorded the presence of an amphibian species (Hat Creek, LAVOWQ01), where the Pacific tree frog was observed. While there are four other confirmed amphibian species within the park (including the recently unobserved and possibly extirpated Cascades frog, *Rana cascadae*), none of these are generally found in stream environments, and are more likely to be found in mountain ponds, lakes, and wetlands. Hence, the scarcity of amphibians in these particular surveys is not a cause of concern. Threats to amphibians in Lassen Volcanic remain a real concern, owing to the lack of Cascades frog sightings ([Fellers et al. 2008](#)) and to the presence of ranavirus ([Dinger 2009](#)).

Condition based on the Eastern Sierra MMI provided contrasting results when compared to the EPA Invertebrate MMI. Whereas the EPA results showed all sites being rated “least disturbed,” the Eastern Sierra MMI rated 10 sites as “Intermediate” and one as “Most disturbed.” This contrast could be due to two potential reasons: (1) The invertebrate assemblage in Lassen Volcanic is different enough from the Eastern Sierra so that individual metrics respond to disturbance differently, yielding inaccurate conditions scoring and (2) the individual scoring thresholds that make up the metric need to be calibrated to the Lassen ecoregion based on local reference sites. Under either of these two scenarios, the current designated condition using the Eastern Sierra MMI is likely spurious and the use of this metric needs either recalibration or more research.

Overall estimation of potentially problematic Lassen Volcanic water quality sites should be looked at using a weight of evidence approach, using information from all the available metrics (Table 18). Table 18 shows the summation of “flags,” each time a condition score was rated as “Intermediate” or “Most disturbed,” but in this instance there is no weighting of “Most disturbed” or “Intermediate” – they are treated as equal flags. There are 11 total metrics used, so maximally disturbed sites would be “11.” Most sites in Lassen Volcanic are limited to 2 or 3 flags; mostly from the elevated phosphorous, EPA Vertebrate MMI scores, and the low ratings from the Eastern Sierra MMI already discussed. Three sites, however, stand out: Kings Creek (LAVOWQ17) with six flags and Manzanita Creek (LAVOWQ27) and Hat Creek (LAVOWQ01) with five flags. The site on Manzanita Creek is

proximal to a heavily used campground (Manzanita Lake) in the northwest portion of the park, and is likely exposed to more anthropogenic disturbance. The site on Hat Creek is also near a heavily used campground (Summit Lake), but is 400 meters or more from nearby trails and roads. The site on Kings Creek is proximal to park roads and a nearby trailhead to the Kings Creek Falls, and also likely experiences increased visitor use.

To our knowledge, no widespread survey of Lassen Streams has been done prior to the current survey. Most previous aquatic studies have focused on lentic (lakes and ponds) ecosystems ([Hoffman et al. 2005](#)). Accordingly, this report provides current condition and also serves as a baseline for assessing future change.

**Table 18.** Condition summary for Lassen Volcanic streams, 2011. Flags indicate each incidence of “Intermediate” or “Most disturbed” condition.

| Stream Name     | Site Code | Number of Flags |          |            | Sum |
|-----------------|-----------|-----------------|----------|------------|-----|
|                 |           | Physical        | Chemical | Biological |     |
| Hat Creek       | LAVOWQ01  | 2               | 1        | 2          | 5   |
| Hat Creek       | LAVOWQ05  | 0               | 0        | 1          | 1   |
| Hat Creek       | LAVOWQ08  | 0               | 1        | 2          | 3   |
| Hat Creek       | LAVOWQ29  | 1               | 0        | 2          | 3   |
| Hat Creek       | LAVOWQ32  | 1               | 1        | 1          | 3   |
| Hat Creek       | LAVOWQ36  | 0               | 1        | 1          | 2   |
| Hat Creek       | LAVOWQ40  | 0               | 1        | 1          | 2   |
| Hat Creek       | LAVOWQ45  | 1               | 1        | 2          | 4   |
| Kings Creek     | LAVOWQ17  | 3               | 1        | 2          | 6   |
| Kings Creek     | LAVOWQ25  | 0               | 1        | 1          | 2   |
| Kings Creek     | LAVOWQ33  | 1               | 1        | 2          | 4   |
| Kings Creek     | LAVOWQ37  | 2               | 1        | 0          | 3   |
| Lost Creek      | LAVOWQ04  | 1               | 2        | 1          | 4   |
| Lost Creek      | LAVOWQ20  | 1               | 1        | 0          | 2   |
| Manzanita Creek | LAVOWQ15  | 1               | 1        | 1          | 3   |
| Manzanita Creek | LAVOWQ23  | 0               | 1        | 0          | 1   |
| Manzanita Creek | LAVOWQ27  | 2               | 1        | 2          | 5   |
| NA Rice Creek   | LAVOWQ10  | 1               | 0        | 0          | 1   |
| NA Rice Creek   | LAVOWQ22  | 2               | 0        | 0          | 2   |
| Summit Creek    | LAVOWQ13  | 0               | 1        | 1          | 2   |
| WF Hat Creek    | LAVOWQ09  | 0               | 1        | 2          | 3   |
| WF Hat Creek    | LAVOWQ12  | 0               | 1        | 2          | 3   |
| WF Hat Creek    | LAVOWQ21  | 1               | 1        | 1          | 3   |
| WF Hat Creek    | LAVOWQ24  | 0               | 1        | 1          | 2   |



## Conclusions

This was the first year of monitoring streams in the Klamath Network. Overall stream conditions in both parks surveyed appear to be mostly good, with specific concerns identified. No indications of water quality criteria exceedances were observed. Criteria set forth by the EPA Wadeable Streams Assessment provide some guidance and assessment for stream condition, but may need regional calibration owing to natural, localized reference conditions. Sampling will continue in 2014, with annual reports and more comprehensive Analysis and Synthesis reports completed thereafter.

In general, the application of broadly developed multi-metric indices should be approached cautiously in the early years such as this. Site-specific characteristics or distinctive disturbance histories may yield conflicting results. Interpretation should be cautious. In future years, a better understanding of the unique characteristics of the stream reaches in each park will hopefully allow us to better differentiate anthropogenic impacts from natural variation.

Additionally, two refinements will be made in the future as we incorporate more EPA reporting tools: (1) Future RBS values will incorporate woody debris and pool depth in calculating expected substrate size [current reported values are based on “rapid, quick assessment”], and (2) Observed/Expected ratios of biodiversity loss (for macroinvertebrates) will be calculated.



## Literature Cited

- Brousseau, C. M., and R. G. Randall. 2008. Assessment of long-term trends in the littoral fish community of Hamilton Harbour using and Index of Biotic Integrity. Great Lakes Laboratory for Fisheries and Aquatic Sciences. Canadian Technical Report of Fisheries and Aquatic Sciences 2811. Burlington, Ontario, Canada.
- Brown, L. R., J. T. May, and M. Wulff. 2012. Associations of benthic macroinvertebrate assemblages with environmental variables in the upper Clear Creek watershed, California. *Western North American Naturalist* 72:473-494.
- Bury, G. W. 2009. Temperature-dependent biogeography and sensitive stream amphibians: Patterns of adaptation and challenges of climate change. Third Conference on Klamath-Siskiyou Ecology, Selma, Oregon, May 28-30, 2009.
- California Environmental Protection Agency State Water Resources Control Board. 2010. 2010 Integrated Report (Clean Water Act Section 303(d) List / 305(b) Report) – Statewide. Online report available at: [http://www.waterboards.ca.gov/water\\_issues/programs/tmdl/integrated2010.shtml](http://www.waterboards.ca.gov/water_issues/programs/tmdl/integrated2010.shtml) (accessed 22 April 2012).
- de Vlaming, V. L., and R. B. Bury. 1970. Thermal selection in tadpoles of the tailed-frog, *Ascaphus truei*. *Journal of Herpetology* 4:179-189.
- Dinger, E. C. 2009. Ranavirus confirmed in a population of long-toed salamanders (*Ambystoma macrodactylum*) in Lassen Volcanic National Park. Resource Brief.
- Dinger, E. C., D. A. Sarr, S. R. Mohren, and R. L. Hoffman. 2012. Integrated aquatic community and water quality monitoring of mountain ponds and lakes in the Klamath Network. Natural Resource Report NPS/KLMN/NRR—2012/484. National Park Service, Fort Collins, Colorado.
- Dinger, E. C., D. A. Sarr, S. R. Mohren, C. E. Stanley, and K.M. Irvine. 2013. Integrated aquatic community and water quality monitoring of wadeable streams in the Klamath Network. Natural Resource Report NPS/KLMN/NRR—2013/669. National Park Service, Fort Collins, Colorado.
- Environmental Protection Agency (USEPA). 2006. Wadeable streams assessment: A collaborative survey of the nation's streams. EPA 841-B-06-002. Office of Research and Development, Office of Water, Washington D.C.
- Environmental Protection Agency (USEPA). 2008. EPA's 2008 report on the environment. EPA/600/R-07/045F. National Center for Environmental Assessment, Washington, D.C.
- Environmental Protection Agency (USEPA). 2009. National rivers and streams assessment: Field operation manual. EPA-841-B-07-009. Washington, D.C.

- Fellers, G. M., K. L. Pope, J. E. Stead, M. S. Koo, and H. H. Welsh, Jr. 2008. Turning population trend monitoring into active conservation: Can we save the Cascades Frog in the Lassen region of California? *Herpetological Conservation and Biology* 3:28-39.
- Fetscher, A. E., L. Busse, and P. R. Ode. 2010. Standard operating procedures for collecting stream algae samples and associated physical habitat and chemical data for ambient bioassessments in California. California State Water Resources Control Board, Surface Water Ambient Monitoring Program (SWAMP), Bioassessment SOP 002.
- Herbst, D. B., and E. L. Silldorff. 2009. Development of a benthic macroinvertebrate index of biological integrity (IBI) for stream assessment in the eastern Sierra Nevada of California. Final Technical Report. Surface Water Ambient Monitoring Program. Department of Fish and Game Aquatic Bioassessment Laboratory, Rancho Cordova, California.
- Hilsenhoff, W. L. 1987. An improved biotic index of organic stream pollution. *Great Lakes Entomology* 20:31-39.
- Hilsenhoff, W. L. 1988. Rapid field assessment of organic pollution with a family-level biotic index. *Journal of the North American Benthological Society* 7:65-68.
- Hoffman, R. L., C. R. Currens, and M. A. Madej. 2005. Klamath Network water quality report (phase II). Klamath Inventory and Monitoring Network, Ashland, Oregon.
- Karr, J.R. and E.W. Chu. 1999. Restoring life in running waters: Better biological monitoring. Island Press, Washington D.C.
- Kaufmann, P. R., P. Levine, E. G. Robison, C. Seeliger, and D. V. Peck. 1999. Quantifying physical habitat in wadeable streams. EPA/620/R-99/003. U.S. Environmental Protection Agency, Washington D.C.
- Kincaid, T. M. 2012. User guide for spsurvey, Version 2.4 – Probability survey design and analysis function. Available online at: [http://www.epa.gov/nheerl/arm/documents/design\\_doc/UserGuide.pdf](http://www.epa.gov/nheerl/arm/documents/design_doc/UserGuide.pdf) (accessed 27 February 2013).
- Omernik, J. M. 1987. Ecoregions of the conterminous United States. Map (Scale 1:7,500,000). *Annals of the association of American Geographers* 77(1):118-125.
- Rehn, A. C., P. R. Ode, and J. T. May. 2005. Development of a Benthic Index of Biotic Integrity (B-IBI) for wadeable streams in northern coastal California and its application to regional 305(b) assessment. Final Technical Report. Surface Water Ambient Monitoring Program. California Department of Fish and Game Aquatic Bioassessment Laboratory, Rancho Cordova, CA.
- Rosenberg, D. M., and V. H Resh, editors. 1993. Freshwater biomonitoring and benthic macroinvertebrates. Chapman and Hall, New York, New York.

- Sarr, D. A., D. C. Odion, S. R. Mohren, E. E. Perry, R. L. Hoffman, L. K. Bridy, and A. A. Merton. 2007. Klamath Network vital signs monitoring plan. Natural Resource Report NPS/KLMN/NRR—2007/016. National Park Service, Fort Collins, Colorado.
- Stevens Jr., D. L., and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. *Journal of American Statistical Association* 99:262-278.
- Stoddard, J. L., D. V. Peck, S. G. Paulsen, J. Van Sickle, C. P. Hawkins, A. T. Herlihy, R. M. Hughes, P. R. Kaufmann, D. P. Larsen, G. Lomnický, and others. 2005a. An ecological assessment of western streams and rivers. EPA/620/R-05/005. U.S. Environmental Protection Agency, Washington, D.C.
- Stoddard, J. L., D. V. Peck, A. R. Olsen, D. P. Larsen, J. Van Sickle, C. P. Hawkins, R. M. Hughes, T. R. Whittier, G. Lomnický, A. T. Herlihy, and others. 2005b. Environmental Monitoring and Assessment Program (EMAP) western streams and rivers statistical summary. U.S. Environmental Protection Agency EPA 620/R-05/006. Washington, D.C.
- Wulff, M. L., J. T. May, and L. R. Brown. 2012. Upper Clear Creek watershed aquatic chemistry and biota surveys, 2004-5, Whiskeytown National Recreation Area, Shasta County, California: U.S. Geological Survey Open-File Report 2012-1173.



## Appendix A. Example of MMI calculation and scoring

To facilitate understanding of MMIs, below is an exposition on how a representative MMI, the California Northern Coastal Region Benthic Index of Biotic Integrity (Rehn et al. 2005), is calculated using data collected from Boulder Creek in Whiskeytown (WHISWQ02). Metric calculations begin using the species list provided by the contractor, Rhithron Associates, Inc.

| Taxon                                           | Count | Unique? | Taxon                                             | Count | Unique? |
|-------------------------------------------------|-------|---------|---------------------------------------------------|-------|---------|
| <b>Non-insect taxa</b>                          |       |         | <b>Trichoptera (Cont.)</b>                        |       |         |
| <i>Turbellaria</i>                              | 1     |         | <i>Polycentropus</i>                              | 1     |         |
| <i>Sphaeriidae</i> - immature                   | 1     |         | <i>Rhyacophila</i> - early instar or damaged      | 4     |         |
| <i>Lebertia</i>                                 | 1     |         | <i>Rhyacophila</i> Betteni Gr.                    | 9     |         |
| <i>Torrenticola</i>                             | 15    |         | <i>Gumaga</i>                                     | 18    |         |
| <i>Mesenchytraeus</i>                           | 2     |         | <i>Sericostomatidae</i> - pupa                    | 5     |         |
| <i>Lumbriculidae</i> - damaged                  | 1     |         | <i>Neophylax splendens</i>                        | 9     |         |
| <i>Spirosperma</i>                              | 4     |         | <b>Coleoptera</b>                                 |       |         |
| <b>Ephemeroptera</b>                            |       |         | <i>Ampumixis dispar</i>                           | 3     |         |
| <i>Ameletus</i>                                 | 16    |         | <i>Cleptelmis addenda</i>                         | 1     |         |
| <i>Baetis tricaudatus</i>                       | 23    |         | <i>Elmidae</i> - early instar or damaged          | 5     | no      |
| <i>Dipheter hageni</i>                          | 43    |         | <i>Optioservus</i>                                | 2     |         |
| <i>Caudatella</i> - early instar or damaged     | 4     | no      | <i>Zaitzevia parvula</i>                          | 1     |         |
| <i>Caudatella heterocaudata</i>                 | 7     |         | <i>Eubrianax edwardsi</i>                         | 72    |         |
| <i>Drunella</i> - early instar                  | 7     | no      | <b>Diptera</b>                                    |       |         |
| <i>Drunella doddsii</i>                         | 4     |         | <i>Ceratopogoninae</i> - early instar             | 3     |         |
| <i>Drunella flavilinea</i>                      | 3     |         | <i>Empididae</i> - early instar, damaged, or pupa | 1     |         |
| <i>Drunella pelosa</i>                          | 1     |         | <i>Antocha monticola</i>                          | 3     |         |
| <i>Ephemerella excrucians</i>                   | 5     |         | <i>Cryptolabis</i>                                | 14    |         |
| <i>Ephemerellidae</i> - early instar or damaged | 4     | no      | <i>Dicranota</i>                                  | 3     |         |
| <i>Epeorus</i>                                  | 42    |         | <i>Hexatoma</i>                                   | 1     |         |
| <i>Ironodes</i>                                 | 2     |         | <i>Tipulidae</i> - damaged or pupa                | 2     | no      |
| <i>Rhithrogena</i>                              | 1     |         | <b>Diptera (Chironomidae)</b>                     |       |         |
| <i>Paraleptophlebia</i>                         | 3     |         | <i>Brillia</i>                                    | 4     |         |
| <b>Plecoptera</b>                               |       |         | <i>Cricotopus (Nostococladus) nostocicola</i>     | 3     |         |
| <i>Suwallia</i>                                 | 4     |         | <i>Cryptochironomus</i>                           | 1     |         |
| <i>Moselia infuscata</i>                        | 1     |         | <i>Demicryptochironomus</i>                       | 6     |         |
| <i>Zapada cinctipes</i>                         | 2     |         | <i>Eukiefferiella Brevicalcar</i> Gr.             | 1     |         |
| <i>Calineuria californica</i>                   | 2     |         | <i>Lopescladius</i>                               | 1     |         |
| <i>Perlidae</i> - early instar                  | 1     | no      | <i>Micropsectra</i>                               | 5     |         |
| <b>Trichoptera</b>                              |       |         | <i>Monodiamesa</i>                                | 2     |         |
| <i>Amiocentrus aspilus</i>                      | 1     |         | <i>Pagastia</i>                                   | 5     |         |
| <i>Micrasema</i>                                | 5     |         | <i>Paratendipes</i>                               | 3     |         |
| <i>Heteroplectron californicum</i>              | 4     |         | <i>Polypedilum</i>                                | 10    |         |
| <i>Glossosoma</i>                               | 3     |         | <i>Prodiamesa</i>                                 | 2     |         |
| <i>Glossosomatidae</i> - damaged or pupa        | 9     | no      | <i>Rheotanytarsus</i>                             | 5     |         |
| <i>Helicopsyche</i>                             | 140   |         | <i>Stempellinella</i>                             | 7     |         |
| <i>Hydropsyche</i>                              | 14    |         | <i>Tanypodinae</i> - early instar or damaged      | 1     | no      |
| <i>Parapsyche</i>                               | 6     |         | <i>Tanytarsini</i> - early instar or damaged      | 3     | no      |
| <i>Lepidostoma</i>                              | 9     |         | <i>Tanytarsus</i>                                 | 2     |         |
| <i>Allocosmoecus partitus</i>                   | 1     |         | <i>Thienemannimyia</i> Gr.                        | 6     |         |
| <i>Limnephilidae</i> - early instar or damaged  | 5     |         | <i>Tvetenia Bavarica</i> Gr.                      | 1     |         |

The values for the eight metrics that comprise the MMI are then calculated. The first metric is EPT taxa richness (Ephemeroptera, Plecoptera, and Trichoptera). In this example, a quick count of the number of taxa in these three insect orders is 37; but this must be adjusted for non-unique taxa. There are often incomplete taxonomic determinations by the taxonomist, but who can determine that they do not represent other unique taxa. For EPT, there are 5 non-unique taxa, so the final EPT taxa richness is 32. Once the values for each eight metrics are calculated, they are scored according to the metric creation (either on a scale from the original authors or linearly interpreted):

| <b>Component Metric</b>    | <b>Boulder Creek Value</b> | <b>Score</b> |
|----------------------------|----------------------------|--------------|
| EPT Richness               | 32                         | 10           |
| Coleoptera Richness        | 6                          | 10           |
| Diptera Richness           | 6                          | 6            |
| % Intolerant Individuals   | 63.90%                     | 10           |
| %Non-gastropod Individuals | 35%                        | 10           |
| % Predator Individuals     | 7.1%                       | 3            |
| % Shredder Taxa            | 13.4%                      | 8            |
| % Non-insect Taxa          | 6.0%                       | 10           |
|                            | Sum                        | 67           |
|                            | Scaled to 100              | 83.75        |

The final step is to scale it to a 0 – 100 range for interpretation. In this example, the summed score is multiplied by 1.25 for a final score of “83.75.”

Interpretation is then based on a traditional scale; 100 = pristine; 10 = severely degraded. Furthermore, scores from 10 to 20 can be considered “very poor,” 20 – 40 are “poor,” 40 – 60 are “fair,” 60 – 80 are “good,” and 80 – 100 are “very good.” Secondly, scores below 52 are considered “impaired.”

## **Appendix B. Benthic Macroinvertebrates of Whiskeytown National Recreation Area**

The following table is an accounting of all macroinvertebrate taxonomic units reported by the contract laboratory. The Interagency Taxonomic Information System (ITIS) Serial Number is provided for each taxa when available.

Note that due to taxonomic ambiguity, taxa used in analyses may differ from the taxa presented here. See the full protocol for more on dealing with taxonomic ambiguity.

**Table 1.** Taxonomic units of Benthic Macroinvertebrates encountered in Whiskeytown National Recreation Area, 2011. TSN = Taxonomic Serial Number; see [www.itis.gov](http://www.itis.gov) for full taxonomy. \* indicates cases where no TSN exists, either due to it being a “species group,” or a recently redescribed taxon with no number yet designated. Total number of sites sampled was 22.

| Order (or higher)   | Family           | Taxon (Lowest unit IDed)                                    | TSN    | Total No. | No. of sites | Percent of sites |
|---------------------|------------------|-------------------------------------------------------------|--------|-----------|--------------|------------------|
| Turbellaria (Class) |                  | Turbellaria                                                 | 53964  | 78        | 13           | 59%              |
| Nemata (Phylum)     |                  | Nemata                                                      | 563956 | 81        | 13           | 59%              |
| Veneroida           | Pisidiidae       | Pisidiidae - immature                                       | 81388  | 8         | 6            | 27%              |
| Basommatophora      | Physidae         | <i>Physa</i> - immature                                     | 76677  | 6         | 1            | 5%               |
| Basommatophora      | Physidae         | <i>Physa gyrina</i>                                         | 76678  | 1         | 1            | 5%               |
| Neotaenioglossa     | Pleuroceridae    | <i>Juga</i> - immature                                      | 71570  | 102       | 2            | 9%               |
| Amphipoda           |                  | Amphipoda - damaged                                         | 93294  | 1         | 1            | 5%               |
| Amphipoda           | Crangonyctidae   | Crangonyctidae - damaged                                    | 95080  | 1         | 1            | 5%               |
| Trombidiformes      | Hygrobatidae     | <i>Atractides</i>                                           | 83282  | 9         | 5            | 23%              |
| Trombidiformes      | Hydrodromidae    | <i>Hydrodroma</i>                                           | 83225  | 2         | 1            | 5%               |
| Trombidiformes      | Hygrobatidae     | <i>Hygrobatas</i>                                           | 83297  | 52        | 7            | 32%              |
| Trombidiformes      | Hygrobatidae     | Hygrobatidae - damaged                                      | 83281  | 1         | 1            | 5%               |
| Trombidiformes      | Lebertiidae      | <i>Lebertia</i>                                             | 83034  | 21        | 10           | 45%              |
| Trombidiformes      | Mideopsidae      | <i>Mideopsis</i>                                            | 83479  | 8         | 4            | 18%              |
| Trombidiformes      | Hydryphantidae   | <i>Protzia</i>                                              | 83170  | 5         | 3            | 14%              |
| Trombidiformes      | Sperchontidae    | <i>Sperchon</i>                                             | 83006  | 25        | 10           | 45%              |
| Trombidiformes      | Sperchontidae    | <i>Sperchonopsis</i>                                        | 83029  | 13        | 8            | 36%              |
| Trombidiformes      | Torrenticolide   | <i>Torrenticola</i>                                         | 83254  | 206       | 21           | 95%              |
| Oligochaeta         | Enchytraeidae    | <i>Enchytraeus</i>                                          | 68531  | 20        | 5            | 23%              |
| Haplotaxida         | Enchytraeidae    | <i>Fridericia</i>                                           | 204785 | 161       | 15           | 68%              |
| Haplotaxida         | Enchytraeidae    | <i>Mesenchytraeus</i>                                       | 68544  | 134       | 13           | 59%              |
| Haplotaxida         | Lumbriculidae    | Lumbriculidae - damaged                                     | 68440  | 4         | 3            | 14%              |
| Haplotaxida         | Lumbriculidae    | <i>Stylodrilus</i>                                          | 68450  | 1         | 1            | 5%               |
| Haplotaxida         | Tubificidae      | <i>Limnodrilus</i>                                          | 68638  | 3         | 1            | 5%               |
| Haplotaxida         | Naididae         | Naididae (Tubificinae) - with capillary setae - immature    | 68509  | 18        | 4            | 18%              |
| Haplotaxida         | Naididae         | Naididae (Tubificinae) - without capillary setae - immature | 68509  | 28        | 2            | 9%               |
| Haplotaxida         | Naididae         | <i>Nais</i>                                                 | 68946  | 25        | 6            | 27%              |
| Haplotaxida         | Naididae         | <i>Pristina</i>                                             | 68876  | 4         | 4            | 18%              |
| Haplotaxida         | Tubificidae      | <i>Spirosperma</i>                                          | 68780  | 4         | 1            | 5%               |
| Odonata             | Aeshnidae        | Aeshnidae - early instar                                    | 101596 | 5         | 2            | 9%               |
| Odonata             | Cordulegastridae | <i>Cordulegaster</i> - early instar                         | 102027 | 6         | 3            | 14%              |
| Odonata             | Cordulegastridae | <i>Cordulegaster dorsalis</i>                               | 593042 | 4         | 4            | 18%              |
| Odonata             | Gomphidae        | Gomphidae - early instar                                    | 101664 | 72        | 13           | 59%              |
| Odonata             | Gomphidae        | <i>Octogomphus specularis</i>                               | 101737 | 14        | 7            | 32%              |
| Odonata             | Coenagrionidae   | <i>Argia</i> - damaged                                      | 102139 | 2         | 2            | 9%               |
| Ephemeroptera       | Ameletidae       | <i>Ameletus</i>                                             | 100996 | 179       | 14           | 64%              |
| Ephemeroptera       | Baetidae         | <i>Baetis</i> - early instar or damaged                     | 100800 | 55        | 5            | 23%              |
| Ephemeroptera       | Baetidae         | <i>Baetis tricaudatus</i>                                   | 100817 | 839       | 21           | 95%              |
| Ephemeroptera       | Baetidae         | <i>Dipheter hageni</i>                                      | 568598 | 170       | 17           | 77%              |
| Ephemeroptera       | Ephemerellidae   | <i>Attenella</i> - early instar                             | 101338 | 3         | 1            | 5%               |
| Ephemeroptera       | Ephemerellidae   | <i>Attenella margarita</i>                                  | 101343 | 4         | 2            | 9%               |

**Table 1.** Taxonomic units of Benthic Macroinvertebrates encountered in Whiskeytown National Recreation Area, 2011. TSN = Taxonomic Serial Number; see [www.itis.gov](http://www.itis.gov) for full taxonomy. \* indicates cases where no TSN exists, either due to it being a “species group,” or a recently redescribed taxon with no number yet designated. Total number of sites sampled was 22. (Continued).

| Order (or higher) | Family          | Taxon (Lowest unit IDed)                        | TSN    | Total No. | No. of sites | Percent of sites |
|-------------------|-----------------|-------------------------------------------------|--------|-----------|--------------|------------------|
| Ephemeroptera     | Ephemerellidae  | <i>Caudatella</i> - early instar or damaged     | 101347 | 45        | 7            | 32%              |
| Ephemeroptera     | Ephemerellidae  | <i>Caudatella columbiella</i>                   | *      | 6         | 2            | 9%               |
| Ephemeroptera     | Ephemerellidae  | <i>Caudatella edmundsi</i>                      | 568631 | 1         | 1            | 5%               |
| Ephemeroptera     | Ephemerellidae  | <i>Caudatella heterocaudata</i>                 | 101351 | 31        | 6            | 27%              |
| Ephemeroptera     | Ephemerellidae  | <i>Caudatella hystrix</i>                       | 101348 | 9         | 4            | 18%              |
| Ephemeroptera     | Ephemerellidae  | <i>Drunella</i> - early instar                  | 101365 | 42        | 13           | 59%              |
| Ephemeroptera     | Ephemerellidae  | <i>Drunella coloradensis</i>                    | 101389 | 49        | 11           | 50%              |
| Ephemeroptera     | Ephemerellidae  | <i>Drunella doddsii</i>                         | 101368 | 202       | 14           | 64%              |
| Ephemeroptera     | Ephemerellidae  | <i>Drunella flavilinea</i>                      | 101392 | 4         | 2            | 9%               |
| Ephemeroptera     | Ephemerellidae  | <i>Drunella grandis</i>                         | 101370 | 13        | 1            | 5%               |
| Ephemeroptera     | Ephemerellidae  | <i>Drunella pelosa</i>                          | 568634 | 1         | 1            | 5%               |
| Ephemeroptera     | Ephemerellidae  | <i>Drunella spinifera</i>                       | 101385 | 2         | 2            | 9%               |
| Ephemeroptera     | Ephemerellidae  | <i>Ephemerella excrucians</i>                   | 101276 | 24        | 5            | 23%              |
| Ephemeroptera     | Ephemerellidae  | <i>Ephemerella tibialis</i>                     | 101401 | 109       | 12           | 55%              |
| Ephemeroptera     | Ephemerellidae  | <i>Ephemerellidae</i> - early instar or damaged | 101232 | 37        | 8            | 36%              |
| Ephemeroptera     | Ephemerellidae  | <i>Matriella teresa</i>                         | 776979 | 94        | 13           | 59%              |
| Ephemeroptera     | Ephemerellidae  | <i>Serratella micheneri</i>                     | 568639 | 2         | 1            | 5%               |
| Ephemeroptera     | Heptageniidae   | <i>Cinygma</i>                                  | 100598 | 118       | 11           | 50%              |
| Ephemeroptera     | Heptageniidae   | <i>Epeorus</i>                                  | 100626 | 383       | 16           | 73%              |
| Ephemeroptera     | Heptageniidae   | <i>Heptageniidae</i> - early instar or damaged  | 100504 | 35        | 8            | 36%              |
| Ephemeroptera     | Heptageniidae   | <i>Ironodes</i>                                 | 100666 | 84        | 15           | 68%              |
| Ephemeroptera     | Heptageniidae   | <i>Nixe</i>                                     | 100692 | 2         | 1            | 5%               |
| Ephemeroptera     | Heptageniidae   | <i>Rhithrogena</i>                              | 100572 | 2         | 2            | 9%               |
| Ephemeroptera     | Leptophlebiidae | <i>Paraleptophlebia</i>                         | 101187 | 197       | 17           | 77%              |
| Ephemeroptera     | Leptohyphidae   | <i>Tricorythodes</i>                            | 101405 | 15        | 2            | 9%               |
| Plecoptera        | Capniidae       | <i>Capniidae</i> - early instar or damaged      | 102643 | 1         | 1            | 5%               |
| Plecoptera        | Chloroperlidae  | <i>Chloroperlidae</i> - early instar or damaged | 103202 | 13        | 7            | 32%              |
| Plecoptera        | Chloroperlidae  | <i>Paraperla</i>                                | 103233 | 1         | 1            | 5%               |
| Plecoptera        | Chloroperlidae  | <i>Suwallia</i>                                 | 103254 | 21        | 5            | 23%              |
| Plecoptera        | Chloroperlidae  | <i>Sweltsa</i>                                  | 103273 | 64        | 6            | 27%              |
| Plecoptera        | Leuctridae      | <i>Leuctridae</i> - early instar or damaged     | 102840 | 25        | 5            | 23%              |
| Plecoptera        | Leuctridae      | <i>Moselia infuscata</i>                        | 102910 | 182       | 9            | 41%              |
| Plecoptera        | Nemouridae      | <i>Malenka</i>                                  | 102567 | 265       | 16           | 73%              |
| Plecoptera        | Nemouridae      | <i>Nemouridae</i> - early instar or damaged     | 102517 | 63        | 13           | 59%              |
| Plecoptera        | Nemouridae      | <i>Soyedina</i>                                 | 102556 | 1         | 1            | 5%               |
| Plecoptera        | Nemouridae      | <i>Visoka cataractae</i>                        | 102615 | 17        | 5            | 23%              |
| Plecoptera        | Nemouridae      | <i>Zapada</i> - damaged                         | 102591 | 3         | 1            | 5%               |

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| Order (or higher) | Family          | Taxon (Lowest unit IDed)                              | TSN    | Total No. | No. of sites | Percent of sites |
|-------------------|-----------------|-------------------------------------------------------|--------|-----------|--------------|------------------|
| Plecoptera        | Nemouridae      | <i>Zapada cinctipes</i>                               | 102594 | 44        | 6            | 27%              |
| Plecoptera        | Nemouridae      | <i>Zapada columbiana</i>                              | 102596 | 3         | 1            | 5%               |
| Plecoptera        | Nemouridae      | <i>Zapada frigida</i>                                 | 102601 | 3         | 1            | 5%               |
| Plecoptera        | Nemouridae      | <i>Zapada Oregonensis</i> Gr.                         | 102597 | 18        | 4            | 18%              |
| Plecoptera        | Peltoperlidae   | <i>Peltoperlidae</i> - damaged                        | 102488 | 1         | 1            | 5%               |
| Plecoptera        | Peltoperlidae   | <i>Sierraperla cora</i>                               | 102515 | 2         | 1            | 5%               |
| Plecoptera        | Peltoperlidae   | <i>Soliperla</i>                                      | 103142 | 1         | 1            | 5%               |
| Plecoptera        | Peltoperlidae   | <i>Yoraperla</i> - early instar or damaged            | 102510 | 5         | 4            | 18%              |
| Plecoptera        | Peltoperlidae   | <i>Yoraperla nigrisoma</i>                            | 568730 | 130       | 10           | 45%              |
| Plecoptera        | Perlidae        | <i>Calineuria californica</i>                         | 102986 | 86        | 12           | 55%              |
| Plecoptera        | Perlidae        | <i>Doroneuria</i> - early instar                      | 103121 | 3         | 1            | 5%               |
| Plecoptera        | Perlidae        | <i>Doroneuria baumanni</i>                            | 103123 | 28        | 7            | 32%              |
| Plecoptera        | Perlidae        | <i>Perlidae</i> - early instar                        | 102914 | 94        | 13           | 59%              |
| Plecoptera        | Perlodidae      | <i>Isoperla</i>                                       | 102995 | 6         | 1            | 5%               |
| Plecoptera        | Perlodidae      | <i>Megarcys</i>                                       | 103110 | 2         | 1            | 5%               |
| Plecoptera        | Perlodidae      | <i>Perlodidae</i> - early instar or damaged           | 102994 | 36        | 8            | 36%              |
| Plecoptera        | Pteronarcyidae  | <i>Pteronarcys</i> - early instar                     | 102471 | 17        | 4            | 18%              |
| Plecoptera        | Pteronarcyidae  | <i>Pteronarcys californica</i>                        | 102473 | 1         | 1            | 5%               |
| Plecoptera        | Pteronarcyidae  | <i>Pteronarcys princeps</i>                           | 102484 | 6         | 4            | 18%              |
| Megaloptera       |                 | <i>Megaloptera</i> - damaged                          | 115000 | 1         | 1            | 5%               |
| Megaloptera       | Corydalidae     | <i>Corydalidae</i> - damaged                          | 115023 | 2         | 1            | 5%               |
| Megaloptera       | Corydalidae     | <i>Orohermes crepusculus</i>                          | 115045 | 79        | 12           | 55%              |
| Megaloptera       | Sialidae        | <i>Sialis</i>                                         | 115002 | 2         | 1            | 5%               |
| Trichoptera       | Apataniidae     | <i>Apatania</i>                                       | 115935 | 27        | 6            | 27%              |
| Trichoptera       | Apataniidae     | <i>Pedomoecus sierra</i>                              | 115973 | 22        | 5            | 23%              |
| Trichoptera       | Brachycentridae | <i>Amiocentrus aspilus</i>                            | 116934 | 2         | 2            | 9%               |
| Trichoptera       | Brachycentridae | <i>Brachycentrus americanus</i>                       | 116912 | 38        | 4            | 18%              |
| Trichoptera       | Brachycentridae | <i>Micrasema</i>                                      | 116958 | 181       | 15           | 68%              |
| Trichoptera       | Calmoceratidae  | <i>Heteroplectron californicum</i>                    | 116538 | 160       | 16           | 73%              |
| Trichoptera       | Glossosomatidae | <i>Agapetus</i>                                       | 117121 | 11        | 3            | 14%              |
| Trichoptera       | Glossosomatidae | <i>Anagapetus</i>                                     | 117154 | 20        | 5            | 23%              |
| Trichoptera       | Glossosomatidae | <i>Glossosoma</i>                                     | 117159 | 449       | 20           | 91%              |
| Trichoptera       | Glossosomatidae | <i>Glossosomatidae</i> - damaged or pupa              | 117120 | 28        | 7            | 32%              |
| Trichoptera       | Helicosychidae  | <i>Helicopsyche</i>                                   | 117016 | 371       | 10           | 45%              |
| Trichoptera       | Hydropsychidae  | <i>Arctopsychinae</i> - early instar                  | 568763 | 15        | 1            | 5%               |
| Trichoptera       | Hydropsychidae  | <i>Hydropsyche</i>                                    | 115453 | 156       | 16           | 73%              |
| Trichoptera       | Hydropsychidae  | <i>Hydropsychidae</i> - early instar or pupa          | 115398 | 97        | 8            | 36%              |
| Trichoptera       | Hydropsychidae  | <i>Parapsyche</i>                                     | 115556 | 148       | 16           | 73%              |
| Trichoptera       | Hydroptilidae   | <i>Hydroptila</i>                                     | 115641 | 4         | 2            | 9%               |
| Trichoptera       | Hydroptilidae   | <i>Hydroptilidae</i> - early instar, damaged, or pupa | 115629 | 4         | 3            | 14%              |
| Trichoptera       | Hydroptilidae   | <i>Neotrichia</i>                                     | 115833 | 14        | 1            | 5%               |

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| Order (or higher) | Family           | Taxon (Lowest unit IDed)                        | TSN    | Total No. | No. of sites | Percent of sites |
|-------------------|------------------|-------------------------------------------------|--------|-----------|--------------|------------------|
| Trichoptera       | Lepidostomatidae | <i>Lepidostoma</i>                              | 116794 | 1266      | 21           | 95%              |
| Trichoptera       | Leptoceridae     | <i>Leptoceridae - early instar or pupa</i>      | 116547 | 3         | 2            | 9%               |
| Trichoptera       | Leptoceridae     | <i>Oecetis</i>                                  | 116607 | 2         | 1            | 5%               |
| Trichoptera       | Limnephilidae    | <i>Allocosmoecus partitus</i>                   | 115970 | 1         | 1            | 5%               |
| Trichoptera       | Limnephilidae    | <i>Dicosmoecus atripes</i>                      | 116266 | 1         | 1            | 5%               |
| Trichoptera       | Limnephilidae    | <i>Dicosmoecus gilvipes</i>                     | 116268 | 1         | 1            | 5%               |
| Trichoptera       | Limnephilidae    | <i>Dicosmoecus pallicornis</i>                  | 116272 | 1         | 1            | 5%               |
| Trichoptera       | Limnephilidae    | <i>Ecclisomyia</i>                              | 116025 | 9         | 2            | 9%               |
| Trichoptera       | Limnephilidae    | <i>Hydatophylax hesperus</i>                    | 115998 | 1         | 1            | 5%               |
| Trichoptera       | Limnephilidae    | <i>Limnephilidae - early instar or damaged</i>  | 115933 | 13        | 3            | 14%              |
| Trichoptera       | Limnephilidae    | <i>Onocosmoecus</i>                             | 116315 | 5         | 3            | 14%              |
| Trichoptera       | Limnephilidae    | <i>Psychoglypha</i>                             | 115975 | 2         | 2            | 9%               |
| Trichoptera       | Odontoceridae    | <i>Marilia</i>                                  | 116514 | 20        | 1            | 5%               |
| Trichoptera       | Philopotamidae   | <i>Dolophilodes</i>                             | 115319 | 3         | 2            | 9%               |
| Trichoptera       | Philopotamidae   | <i>Philopotamidae - early instar or damaged</i> | 115257 | 5         | 3            | 14%              |
| Trichoptera       | Philopotamidae   | <i>Wormaldia</i>                                | 115258 | 25        | 7            | 32%              |
| Trichoptera       | Polycentropidae  | <i>Polycentropodidae - damaged</i>              | 117043 | 6         | 5            | 23%              |
| Trichoptera       | Polycentropidae  | <i>Polycentropus</i>                            | 117044 | 12        | 4            | 18%              |
| Trichoptera       | Psychomyidae     | <i>Tinodes</i>                                  | 115350 | 8         | 4            | 18%              |
| Trichoptera       | Rhyacophilidae   | <i>Himalopsyche phryganea</i>                   | 608146 | 1         | 1            | 5%               |
| Trichoptera       | Rhyacophilidae   | <i>Rhyacophila - early instar or damaged</i>    | 115097 | 59        | 16           | 73%              |
| Trichoptera       | Rhyacophilidae   | <i>Rhyacophila Angelita Gr.</i>                 | *      | 9         | 8            | 36%              |
| Trichoptera       | Rhyacophilidae   | <i>Rhyacophila Betteni Gr.</i>                  | *      | 155       | 20           | 91%              |
| Trichoptera       | Rhyacophilidae   | <i>Rhyacophila Brunnea Gr.</i>                  | *      | 41        | 10           | 45%              |
| Trichoptera       | Rhyacophilidae   | <i>Rhyacophila Grandis Gr.</i>                  | *      | 2         | 2            | 9%               |
| Trichoptera       | Rhyacophilidae   | <i>Rhyacophila Hyalinata Gr.</i>                | *      | 6         | 3            | 14%              |
| Trichoptera       | Rhyacophilidae   | <i>Rhyacophila Sibirica Gr.</i>                 | *      | 17        | 3            | 14%              |
| Trichoptera       | Rhyacophilidae   | <i>Rhyacophila Verrula Gr.</i>                  | *      | 1         | 1            | 5%               |
| Trichoptera       | Rhyacophilidae   | <i>Rhyacophila Visor Gr.</i>                    | *      | 5         | 3            | 14%              |
| Trichoptera       | Rhyacophilidae   | <i>Rhyacophilidae - pupa</i>                    | 115097 | 11        | 8            | 36%              |
| Trichoptera       | Sericoctenidae   | <i>Gumaga</i>                                   | 117003 | 291       | 19           | 86%              |
| Trichoptera       | Sericoctenidae   | <i>Sericoctenidae - pupa</i>                    | 116982 | 6         | 2            | 9%               |
| Trichoptera       | Uenoidae         | <i>Neophylax rickeri</i>                        | 116054 | 4         | 2            | 9%               |
| Trichoptera       | Uenoidae         | <i>Neophylax splendens</i>                      | 116063 | 61        | 10           | 45%              |
| Trichoptera       | Uenoidae         | <i>Uenoidae - early instar</i>                  | 568757 | 1         | 1            | 5%               |
| Coleoptera        | Dytiscidae       | <i>Agabus</i>                                   | 111966 | 2         | 1            | 5%               |
| Coleoptera        | Dytiscidae       | <i>Dytiscidae - early instar or damaged</i>     | 111963 | 5         | 4            | 18%              |
| Coleoptera        | Dytiscidae       | <i>Oreodytes - damaged or larva</i>             | 112314 | 3         | 3            | 14%              |
| Coleoptera        | Dytiscidae       | <i>Sanfilippodytes - damaged</i>                | 728253 | 12        | 2            | 9%               |
| Coleoptera        | Elmidae          | <i>Ampumixis dispar</i>                         | 114197 | 141       | 16           | 73%              |
| Coleoptera        | Elmidae          | <i>Bryelmis siskiyou</i>                        | *      | 1         | 1            | 5%               |
| Coleoptera        | Elmidae          | <i>Cleptelmis addenda</i>                       | 114166 | 47        | 8            | 36%              |

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| Order (or higher) | Family          | Taxon (Lowest unit IDed)                                | TSN    | Total No. | No. of sites | Percent of sites |
|-------------------|-----------------|---------------------------------------------------------|--------|-----------|--------------|------------------|
| Coleoptera        | Elmidae         | <i>Dubiraphia</i>                                       | 114126 | 1         | 1            | 5%               |
| Coleoptera        | Elmidae         | <i>Elmidae - early instar or damaged</i>                | 114093 | 42        | 7            | 32%              |
| Coleoptera        | Elmidae         | <i>Heterolimnius corpulentus</i>                        | 114169 | 164       | 8            | 36%              |
| Coleoptera        | Elmidae         | <i>Lara</i>                                             | 114137 | 29        | 10           | 45%              |
| Coleoptera        | Elmidae         | <i>Narpus concolor</i>                                  | 114144 | 37        | 11           | 50%              |
| Coleoptera        | Elmidae         | <i>Optioservus</i>                                      | 114177 | 141       | 14           | 64%              |
| Coleoptera        | Elmidae         | <i>Ordobrevia nubifera</i>                              | 114236 | 149       | 17           | 77%              |
| Coleoptera        | Elmidae         | <i>Zaitzevia - larva</i>                                | 114205 | 29        | 9            | 41%              |
| Coleoptera        | Elmidae         | <i>Zaitzevia parvula</i>                                | 114206 | 30        | 9            | 41%              |
| Coleoptera        | Hydraenidae     | <i>Hydraena</i>                                         | 112757 | 26        | 10           | 45%              |
| Coleoptera        | Hydrophilidae   | <i>Anacaena</i>                                         | 112878 | 2         | 2            | 9%               |
| Coleoptera        | Hydrophilidae   | <i>Cymbiodyta pacifica</i>                              | 113020 | 1         | 1            | 5%               |
| Coleoptera        | Hydrophilidae   | <i>Hydrophilidae - early instar or damaged</i>          | 112811 | 8         | 6            | 27%              |
| Coleoptera        | Amphizoidae     | <i>Amphizoa</i>                                         | 111953 | 1         | 1            | 5%               |
| Coleoptera        | Psephenidae     | <i>Acneus</i>                                           | 114082 | 2         | 2            | 9%               |
| Coleoptera        | Psephenidae     | <i>Eubrianax edwardsi</i>                               | 708467 | 228       | 14           | 64%              |
| Coleoptera        | Psephenidae     | <i>Psephenus</i>                                        | 114070 | 11        | 2            | 9%               |
| Coleoptera        | Eulichadidae    | <i>Stenocolus scutellaris</i>                           | 114269 | 14        | 5            | 23%              |
| Diptera           | Blephariceridae | <i>Blephariceridae - early instar, damaged, or pupa</i> | 121227 | 4         | 2            | 9%               |
| Diptera           | Ceratopogonidae | <i>Atrichopogon</i>                                     | 127113 | 3         | 2            | 9%               |
| Diptera           | Ceratopogonidae | <i>Ceratopogoninae - early instar</i>                   | 127338 | 62        | 17           | 77%              |
| Diptera           | Ceratopogonidae | <i>Mallochohelea</i>                                    | 127702 | 3         | 2            | 9%               |
| Diptera           | Ceratopogonidae | <i>Probezzia</i>                                        | 127729 | 2         | 1            | 5%               |
| Diptera           | Ceratopogonidae | <i>Sphaeromias</i>                                      | 127761 | 1         | 1            | 5%               |
| Diptera           | Dixidae         | <i>Dixa</i>                                             | 125810 | 4         | 2            | 9%               |
| Diptera           | Dixidae         | <i>Dixidae - pupa</i>                                   | 125809 | 1         | 1            | 5%               |
| Diptera           | Dixidae         | <i>Meringodixa</i>                                      | 125874 | 2         | 2            | 9%               |
| Diptera           | Empididae       | <i>Chelifera</i>                                        | 136305 | 11        | 4            | 18%              |
| Diptera           | Empididae       | <i>Clinocera</i>                                        | 135849 | 4         | 3            | 14%              |
| Diptera           | Empididae       | <i>Empididae - early instar, damaged, or pupa</i>       | 135830 | 12        | 9            | 41%              |
| Diptera           | Empididae       | <i>Empididae sp. (RAI Taxon # 0001)</i>                 | *      | 1         | 1            | 5%               |
| Diptera           | Empididae       | <i>Hemerodromia</i>                                     | 136327 | 1         | 1            | 5%               |
| Diptera           | Empididae       | <i>Neoplasta</i>                                        | 136352 | 18        | 9            | 41%              |
| Diptera           | Empididae       | <i>Oreogeton</i>                                        | 136377 | 6         | 2            | 9%               |
| Diptera           | Empididae       | <i>Wiedemannia</i>                                      | 135920 | 3         | 1            | 5%               |
| Diptera           | Ephydriidae     | <i>Ephydriidae</i>                                      | 146893 | 2         | 2            | 9%               |
| Diptera           | Pelecorynchidae | <i>Glutops</i>                                          | 130915 | 15        | 4            | 18%              |
| Diptera           | Psychodidae     | <i>Maruina</i>                                          | 125392 | 5         | 3            | 14%              |
| Diptera           | Psychodidae     | <i>Pericoma / Telmatoscopus</i>                         | *      | 12        | 5            | 23%              |
| Diptera           | Simuliidae      | <i>Helodon</i>                                          | *      | 1         | 1            | 5%               |
| Diptera           | Simuliidae      | <i>Prosimulium</i>                                      | 126703 | 1         | 1            | 5%               |
| Diptera           | Simuliidae      | <i>Simulium</i>                                         | 126774 | 361       | 14           | 64%              |

**Table 1.** Taxonomic units of Benthic Macroinvertebrates encountered in Whiskeytown National Recreation Area, 2011. TSN = Taxonomic Serial Number; see [www.itis.gov](http://www.itis.gov) for full taxonomy. \* indicates cases where no TSN exists, either due to it being a “species group,” or a recently redescribed taxon with no number yet designated. Total number of sites sampled was 22. (Continued).

| Order (or higher) | Family        | Taxon (Lowest unit IDed)                        | TSN    | Total No. | No. of sites | Percent of sites |
|-------------------|---------------|-------------------------------------------------|--------|-----------|--------------|------------------|
| Diptera           | Stratiomyidae | <i>Caloparyphus</i>                             | 625843 | 2         | 2            | 9%               |
| Diptera           | Stratiomyidae | <i>Stratiomyidae - damaged</i>                  | 130150 | 1         | 1            | 5%               |
| Diptera           | Thaumaleidae  | <i>Thaumaleidae</i>                             | 126624 | 1         | 1            | 5%               |
| Diptera           | Tipulidae     | <i>Antocha monticola</i>                        | 119660 | 44        | 12           | 55%              |
| Diptera           | Tipulidae     | <i>Cryptolabis</i>                              | 120488 | 44        | 11           | 50%              |
| Diptera           | Tipulidae     | <i>Dicranota</i>                                | 121027 | 97        | 17           | 77%              |
| Diptera           | Tipulidae     | <i>Hexatoma</i>                                 | 120094 | 9         | 4            | 18%              |
| Diptera           | Tipulidae     | <i>Limnophila</i>                               | 120164 | 1         | 1            | 5%               |
| Diptera           | Tipulidae     | <i>Limonia</i>                                  | 119704 | 1         | 1            | 5%               |
| Diptera           | Tipulidae     | <i>Molophilus</i>                               | 120758 | 2         | 1            | 5%               |
| Diptera           | Tipulidae     | <i>Rhabdomastix</i>                             | 120968 | 3         | 2            | 9%               |
| Diptera           | Tipulidae     | <i>Tipula</i>                                   | 119037 | 4         | 2            | 9%               |
| Diptera           | Tipulidae     | <i>Tipulidae - damaged or pupa</i>              | 118840 | 19        | 8            | 36%              |
| Diptera           | Chironomidae  | <i>Ablabesmyia</i>                              | 128079 | 10        | 3            | 14%              |
| Diptera           | Chironomidae  | <i>Boreochlus</i>                               | 127954 | 1         | 1            | 5%               |
| Diptera           | Chironomidae  | <i>Brillia</i>                                  | 128477 | 303       | 21           | 95%              |
| Diptera           | Chironomidae  | <i>Brundiniella eumorpha</i>                    | 128028 | 12        | 3            | 14%              |
| Diptera           | Chironomidae  | <i>Chaetocladius</i>                            | 128520 | 36        | 9            | 41%              |
| Diptera           | Chironomidae  | <i>Chironomini - early instar or damaged</i>    | 129229 | 3         | 3            | 14%              |
| Diptera           | Chironomidae  | <i>Cladotanyarsus</i>                           | 129873 | 29        | 1            | 5%               |
| Diptera           | Chironomidae  | <i>Conchapelopia</i>                            | 128130 | 1         | 1            | 5%               |
| Diptera           | Chironomidae  | <i>Corynoneura</i>                              | 128563 | 27        | 7            | 32%              |
| Diptera           | Chironomidae  | <i>Cricotopus</i>                               | 128575 | 23        | 7            | 32%              |
| Diptera           | Chironomidae  | <i>Cricotopus (Nostococcladius) nostocicola</i> | 128628 | 89        | 8            | 36%              |
| Diptera           | Chironomidae  | <i>Cricotopus Trifascia Gr.</i>                 | 568521 | 1         | 1            | 5%               |
| Diptera           | Chironomidae  | <i>Cryptochironomus</i>                         | 129368 | 6         | 5            | 23%              |
| Diptera           | Chironomidae  | <i>Demicryptochironomus</i>                     | 129421 | 10        | 3            | 14%              |
| Diptera           | Chironomidae  | <i>Diamesa</i>                                  | 128355 | 7         | 4            | 18%              |
| Diptera           | Chironomidae  | <i>Eukiefferiella - early instar or pupa</i>    | 128689 | 34        | 12           | 55%              |
| Diptera           | Chironomidae  | <i>Eukiefferiella Brehmi Gr.</i>                | *      | 23        | 6            | 27%              |
| Diptera           | Chironomidae  | <i>Eukiefferiella Brevicalcar Gr.</i>           | *      | 6         | 5            | 23%              |
| Diptera           | Chironomidae  | <i>Eukiefferiella Claripennis Gr.</i>           | *      | 48        | 13           | 59%              |
| Diptera           | Chironomidae  | <i>Eukiefferiella Devonica Gr.</i>              | *      | 29        | 10           | 45%              |
| Diptera           | Chironomidae  | <i>Eukiefferiella Gracei Gr.</i>                | *      | 101       | 15           | 68%              |
| Diptera           | Chironomidae  | <i>Euryhapsis</i>                               | 128707 | 1         | 1            | 5%               |
| Diptera           | Chironomidae  | <i>Heleniella</i>                               | 128730 | 14        | 7            | 32%              |
| Diptera           | Chironomidae  | <i>Heterotrissoccladius Marcidus Gr.</i>        | *      | 4         | 2            | 9%               |
| Diptera           | Chironomidae  | <i>Krenosmittia</i>                             | 128771 | 11        | 3            | 14%              |
| Diptera           | Chironomidae  | <i>Larsia</i>                                   | 128183 | 1         | 1            | 5%               |
| Diptera           | Chironomidae  | <i>Lauterborniella agrayloides</i>              | 129526 | 11        | 3            | 14%              |
| Diptera           | Chironomidae  | <i>Limnophyes</i>                               | 128776 | 6         | 4            | 18%              |
| Diptera           | Chironomidae  | <i>Lopescladius</i>                             | 128811 | 40        | 6            | 27%              |
| Diptera           | Chironomidae  | <i>Metriocnemus</i>                             | 128821 | 2         | 2            | 9%               |

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| Order (or higher) | Family       | Taxon (Lowest unit IDed)                        | TSN    | Total No. | No. of sites | Percent of sites |
|-------------------|--------------|-------------------------------------------------|--------|-----------|--------------|------------------|
| Diptera           | Chironomidae | <i>Micropsectra</i>                             | 129890 | 686       | 20           | 91%              |
| Diptera           | Chironomidae | <i>Microtendipes</i>                            | 129535 | 1         | 1            | 5%               |
| Diptera           | Chironomidae | <i>Microtendipes Pedellus Gr.</i>               | *      | 407       | 12           | 55%              |
| Diptera           | Chironomidae | <i>Microtendipes Rydalis Gr.</i>                | *      | 69        | 5            | 23%              |
| Diptera           | Chironomidae | <i>Monodiamesa</i>                              | 128440 | 2         | 1            | 5%               |
| Diptera           | Chironomidae | <i>Nanocladius</i>                              | 128844 | 3         | 3            | 14%              |
| Diptera           | Chironomidae | <i>Natarsia</i>                                 | 128070 | 5         | 4            | 18%              |
| Diptera           | Chironomidae | <i>Nilotanytus</i>                              | 128202 | 10        | 5            | 23%              |
| Diptera           | Chironomidae | <i>Odontomesa</i>                               | 128446 | 4         | 2            | 9%               |
| Diptera           | Chironomidae | <i>Orthocladiinae - early instar or damaged</i> | 128457 | 13        | 5            | 23%              |
| Diptera           | Chironomidae | <i>Orthocladius</i>                             | 568523 | 149       | 21           | 95%              |
| Diptera           | Chironomidae | <i>Orthocladius lignicola</i>                   | 128913 | 11        | 7            | 32%              |
| Diptera           | Chironomidae | <i>Pagastia</i>                                 | 128401 | 51        | 14           | 64%              |
| Diptera           | Chironomidae | <i>Parachaetocladius</i>                        | 128951 | 14        | 6            | 27%              |
| Diptera           | Chironomidae | <i>Paracladopelma alphaeus</i>                  | 129598 | 12        | 5            | 23%              |
| Diptera           | Chironomidae | <i>Parakiefferiella</i>                         | 128968 | 5         | 2            | 9%               |
| Diptera           | Chironomidae | <i>Paramerina</i>                               | 128207 | 29        | 8            | 36%              |
| Diptera           | Chironomidae | <i>Parametriocnemus</i>                         | 128978 | 137       | 19           | 86%              |
| Diptera           | Chironomidae | <i>Paratanytarsus</i>                           | 129935 | 2         | 1            | 5%               |
| Diptera           | Chironomidae | <i>Paratendipes</i>                             | 129623 | 21        | 7            | 32%              |
| Diptera           | Chironomidae | <i>Pentaneura</i>                               | 128215 | 15        | 9            | 41%              |
| Diptera           | Chironomidae | <i>Phaenopsectra</i>                            | 129637 | 100       | 7            | 32%              |
| Diptera           | Chironomidae | <i>Polypedilum</i>                              | 129657 | 144       | 16           | 73%              |
| Diptera           | Chironomidae | <i>Potthastia - pupa</i>                        | 128408 | 2         | 2            | 9%               |
| Diptera           | Chironomidae | <i>Potthastia Gaedii Gr.</i>                    | *      | 58        | 3            | 14%              |
| Diptera           | Chironomidae | <i>Prodiamesa</i>                               | 128452 | 22        | 4            | 18%              |
| Diptera           | Chironomidae | <i>Pseudochironomus</i>                         | 129851 | 1         | 1            | 5%               |
| Diptera           | Chironomidae | <i>Reomyia</i>                                  | *      | 14        | 4            | 18%              |
| Diptera           | Chironomidae | <i>Rheocricotopus</i>                           | 129086 | 5         | 5            | 23%              |
| Diptera           | Chironomidae | <i>Rheosmittia</i>                              | 129107 | 5         | 2            | 9%               |
| Diptera           | Chironomidae | <i>Rheotanytarsus</i>                           | 129952 | 351       | 20           | 91%              |
| Diptera           | Chironomidae | <i>Robackia - pupa</i>                          | 129730 | 1         | 1            | 5%               |
| Diptera           | Chironomidae | <i>Robackia demeijerei</i>                      | 129733 | 17        | 3            | 14%              |
| Diptera           | Chironomidae | <i>Smittia</i>                                  | 129110 | 1         | 1            | 5%               |
| Diptera           | Chironomidae | <i>Stempellina</i>                              | 129962 | 4         | 1            | 5%               |
| Diptera           | Chironomidae | <i>Stempellinella</i>                           | 129969 | 109       | 11           | 50%              |
| Diptera           | Chironomidae | <i>Stenochironomus</i>                          | 129746 | 6         | 4            | 18%              |
| Diptera           | Chironomidae | <i>Stilocladius</i>                             | 129152 | 1         | 1            | 5%               |
| Diptera           | Chironomidae | <i>Synorthocladius</i>                          | 129161 | 2         | 1            | 5%               |
| Diptera           | Chironomidae | <i>Tanytarsinae - early instar or damaged</i>   | 127994 | 5         | 5            | 23%              |
| Diptera           | Chironomidae | <i>Tanytarsini - early instar or damaged</i>    | 129872 | 37        | 5            | 23%              |
| Diptera           | Chironomidae | <i>Tanytarsus</i>                               | 129872 | 170       | 19           | 86%              |

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| Order (or higher) | Family       | Taxon (Lowest unit IDed)     | TSN    | Total No. | No. of sites | Percent of sites |
|-------------------|--------------|------------------------------|--------|-----------|--------------|------------------|
| Diptera           | Chironomidae | <i>Thienemanniella</i>       | 129182 | 46        | 11           | 50%              |
| Diptera           | Chironomidae | <i>Thienemannimyia</i> Gr.   | 128236 | 160       | 22           | 100%             |
| Diptera           | Chironomidae | <i>Tvetenia</i> - pupa       | 129197 | 4         | 3            | 14%              |
| Diptera           | Chironomidae | <i>Tvetenia Bavarica</i> Gr. | *      | 110       | 19           | 86%              |



## **Appendix C. Benthic Macroinvertebrates of Lassen Volcanic National Park**

The following table is an accounting of all macroinvertebrate taxonomic units reported by the contract laboratory. The Interagency Taxonomic Information System (ITIS) Serial Number is provided for each taxa when available.

Note that due to taxonomic ambiguity, taxa used in analyses may differ from the taxa presented here. See the full protocol for more on dealing with taxonomic ambiguity.

**Table 1.** Taxonomic units of Benthic Macroinvertebrates encountered in Lassen Volcanic National Park, 2011. TSN = Taxonomic Serial Number; see [www.itis.gov](http://www.itis.gov) for full taxonomy. \* indicates cases where no TSN exists, either due to it being a “species group,” or a recently redescribed taxon with no number yet designated. Total number of sites sampled was 24.

| Order (or higher)   | Family         | Taxon (Lowest unit IDed)                                    | TSN    | Total No. | No. of sites | Percent of sites |
|---------------------|----------------|-------------------------------------------------------------|--------|-----------|--------------|------------------|
| Turbellaria (Class) |                | Turbellaria                                                 | 53964  | 337       | 22           | 92%              |
| Nemata (Phylum)     |                | Nemata                                                      | 563956 | 133       | 19           | 79%              |
| Veneroida           | Pisidiidae     | Pisidiidae - immature                                       | 81388  | 152       | 14           | 58%              |
| Veneroida           | Pisidiidae     | <i>Sphaerium</i>                                            | 81391  | 19        | 1            | 4%               |
| Trombidiformes      |                | Acari - damaged                                             | 82769  | 3         | 2            | 8%               |
| Trombidiformes      | Hygrobatidae   | <i>Atractides</i>                                           | 83282  | 5         | 3            | 13%              |
| Trombidiformes      | Aturidae       | <i>Aturus</i>                                               | 82974  | 3         | 2            | 8%               |
| Trombidiformes      | Lebertiidae    | <i>Estelloxus californiensis</i>                            | 83049  | 1         | 1            | 4%               |
| Trombidiformes      | Hydrovolziidae | <i>Hydrovolzia</i>                                          | 83119  | 1         | 1            | 4%               |
| Trombidiformes      | Hygrobatidae   | <i>Hygrobates</i>                                           | 83297  | 7         | 4            | 17%              |
| Trombidiformes      | Lebertiidae    | <i>Lebertia</i>                                             | 83034  | 157       | 21           | 88%              |
| Trombidiformes      | Mideopsidae    | <i>Mideopsis</i>                                            | 83479  | 1         | 1            | 4%               |
| Trombidiformes      | Hydryphantidae | <i>Protzia</i>                                              | 83170  | 6         | 5            | 21%              |
| Trombidiformes      | Sperchontidae  | <i>Sperchon</i>                                             | 83006  | 97        | 15           | 63%              |
| Trombidiformes      | Sperchontidae  | <i>Sperchonopsis</i>                                        | 83029  | 17        | 5            | 21%              |
| Trombidiformes      | Torrenticolide | <i>Testudacarus</i>                                         | 83250  | 1         | 1            | 4%               |
| Trombidiformes      | Hydryphantidae | <i>Parathyas</i>                                            | 895840 | 3         | 2            | 8%               |
| Trombidiformes      | Torrenticolide | <i>Torrenticola</i>                                         | 83254  | 12        | 3            | 13%              |
| Oligochaeta         | Enchytraeidae  | <i>Enchytraeus</i>                                          | 68531  | 22        | 8            | 33%              |
| Haplotaxida         | Enchytraeidae  | <i>Fridericia</i>                                           | 204785 | 47        | 15           | 63%              |
| Haplotaxida         | Enchytraeidae  | <i>Mesenchytraeus</i>                                       | 68544  | 791       | 23           | 96%              |
| Haplotaxida         | Naididae       | Naididae (Tubificinae) - with capillary setae - immature    | 68509  | 1         | 1            | 4%               |
| Haplotaxida         | Naididae       | Naididae (Tubificinae) - without capillary setae - immature | 68509  | 4         | 1            | 4%               |
| Haplotaxida         | Naididae       | <i>Nais</i>                                                 | 68946  | 3         | 1            | 4%               |
| Haplotaxida         | Tubificidae    | <i>Telmatodrilus vej dovskyi</i>                            | 68760  | 1         | 1            | 4%               |
| Ephemeroptera       | Ameletidae     | <i>Ameletus</i>                                             | 100996 | 129       | 19           | 79%              |
| Ephemeroptera       | Baetidae       | Baetidae - damaged                                          | 100755 | 160       | 1            | 4%               |
| Ephemeroptera       | Baetidae       | <i>Baetis</i> - early instar or damaged                     | 100800 | 221       | 9            | 38%              |
| Ephemeroptera       | Baetidae       | <i>Baetis bicaudatus</i>                                    | 100823 | 1521      | 21           | 88%              |
| Ephemeroptera       | Baetidae       | <i>Baetis tricaudatus</i>                                   | 100817 | 255       | 10           | 42%              |
| Ephemeroptera       | Baetidae       | <i>Dipheter hageni</i>                                      | 568598 | 56        | 6            | 25%              |
| Ephemeroptera       | Ephemerellidae | <i>Attenella delantala</i>                                  | 101345 | 16        | 2            | 8%               |
| Ephemeroptera       | Ephemerellidae | <i>Caudatella</i> - early instar or damaged                 | 101347 | 152       | 10           | 42%              |
| Ephemeroptera       | Ephemerellidae | <i>Caudatella heterocaudata</i>                             | 101351 | 4         | 1            | 4%               |
| Ephemeroptera       | Ephemerellidae | <i>Caudatella hystrix</i>                                   | 101348 | 44        | 9            | 38%              |
| Ephemeroptera       | Ephemerellidae | <i>Drunella</i> - early instar                              | 101365 | 14        | 3            | 13%              |
| Ephemeroptera       | Ephemerellidae | <i>Drunella coloradensis</i>                                | 101389 | 222       | 20           | 83%              |
| Ephemeroptera       | Ephemerellidae | <i>Drunella doddsii</i>                                     | 101368 | 95        | 12           | 50%              |
| Ephemeroptera       | Ephemerellidae | <i>Drunella spinifera</i>                                   | 101385 | 37        | 8            | 33%              |
| Ephemeroptera       | Ephemerellidae | <i>Ephemerella</i> - early instar or damaged                | 101233 | 61        | 5            | 21%              |
| Ephemeroptera       | Ephemerellidae | <i>Ephemerella excrucians</i>                               | 101276 | 10        | 2            | 8%               |

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| Order (or higher) | Family          | Taxon (Lowest unit IDed)                        | TSN    | Total No. | No. of sites | Percent of sites |
|-------------------|-----------------|-------------------------------------------------|--------|-----------|--------------|------------------|
| Ephemeroptera     | Ephemerellidae  | <i>Ephemerella tibialis</i>                     | 101401 | 38        | 4            | 17%              |
| Ephemeroptera     | Ephemerellidae  | Ephemerellidae - early instar or damaged        | 101232 | 63        | 9            | 38%              |
| Ephemeroptera     | Ephemerellidae  | <i>Serratella</i> - damaged                     | 101395 | 8         | 1            | 4%               |
| Ephemeroptera     | Heptageniidae   | <i>Cinygma</i>                                  | 100598 | 3         | 1            | 4%               |
| Ephemeroptera     | Heptageniidae   | <i>Cinygmula</i>                                | 100557 | 241       | 19           | 79%              |
| Ephemeroptera     | Heptageniidae   | <i>Epeorus</i>                                  | 100626 | 474       | 22           | 92%              |
| Ephemeroptera     | Heptageniidae   | <i>Heptageniidae</i> - early instar or damaged  | 100504 | 36        | 2            | 8%               |
| Ephemeroptera     | Heptageniidae   | <i>Rhithrogena</i>                              | 100572 | 152       | 15           | 63%              |
| Ephemeroptera     | Leptophlebiidae | <i>Paraleptophlebia</i>                         | 101187 | 100       | 10           | 42%              |
| Plecoptera        | Capniidae       | <i>Capniidae</i> - early instar or damaged      | 102643 | 19        | 10           | 42%              |
| Plecoptera        | Chloroperlidae  | <i>Chloroperlidae</i> - early instar or damaged | 103202 | 33        | 5            | 21%              |
| Plecoptera        | Chloroperlidae  | <i>Kathroperla perdita</i>                      | 103237 | 4         | 2            | 8%               |
| Plecoptera        | Chloroperlidae  | <i>Paraperla</i>                                | 103233 | 6         | 4            | 17%              |
| Plecoptera        | Chloroperlidae  | <i>Paraperlinae</i> - early instar              | 609856 | 21        | 3            | 13%              |
| Plecoptera        | Chloroperlidae  | <i>Suwallia</i>                                 | 103254 | 29        | 6            | 25%              |
| Plecoptera        | Chloroperlidae  | <i>Sweltsa</i>                                  | 103273 | 351       | 20           | 83%              |
| Plecoptera        | Chloroperlidae  | <i>Utaerla sopladora</i>                        | 103299 | 1         | 1            | 4%               |
| Plecoptera        | Leuctridae      | <i>Leuctridae</i> - early instar or damaged     | 102840 | 41        | 13           | 54%              |
| Plecoptera        | Leuctridae      | <i>Moselia infuscata</i>                        | 102910 | 150       | 19           | 79%              |
| Plecoptera        | Nemouridae      | <i>Malenka</i>                                  | 102567 | 39        | 3            | 13%              |
| Plecoptera        | Nemouridae      | <i>Nemouridae</i> - early instar or damaged     | 102517 | 3         | 1            | 4%               |
| Plecoptera        | Nemouridae      | <i>Soyedina</i>                                 | 102556 | 1         | 1            | 4%               |
| Plecoptera        | Nemouridae      | <i>Visoka cataractae</i>                        | 102615 | 40        | 11           | 46%              |
| Plecoptera        | Nemouridae      | <i>Zapada cinctipes</i>                         | 102594 | 37        | 4            | 17%              |
| Plecoptera        | Nemouridae      | <i>Zapada columbiana</i>                        | 102596 | 412       | 18           | 75%              |
| Plecoptera        | Nemouridae      | <i>Zapada frigida</i>                           | 102601 | 63        | 10           | 42%              |
| Plecoptera        | Nemouridae      | <i>Zapada Oregonensis Gr.</i>                   | 102597 | 333       | 23           | 96%              |
| Plecoptera        | Peltoperlidae   | <i>Sierraperla cora</i>                         | 102515 | 41        | 6            | 25%              |
| Plecoptera        | Peltoperlidae   | <i>Yoraperla brevis</i>                         | 102512 | 122       | 9            | 38%              |
| Plecoptera        | Peltoperlidae   | <i>Yoraperla nigrisoma</i>                      | 568730 | 752       | 15           | 63%              |
| Plecoptera        | Perlidae        | <i>Calineuria californica</i>                   | 102986 | 15        | 2            | 8%               |
| Plecoptera        | Perlidae        | <i>Doroneuria baumanni</i>                      | 103123 | 11        | 5            | 21%              |
| Plecoptera        | Perlidae        | <i>Perlidae</i> - early instar                  | 102914 | 16        | 5            | 21%              |
| Plecoptera        | Perlodidae      | <i>Isoperla</i>                                 | 102995 | 63        | 11           | 46%              |
| Plecoptera        | Perlodidae      | <i>Kogotus nonus</i>                            | 103150 | 22        | 8            | 33%              |
| Plecoptera        | Perlodidae      | <i>Megarcys</i>                                 | 103110 | 13        | 6            | 25%              |
| Plecoptera        | Perlodidae      | <i>Perlodidae</i> - early instar or damaged     | 102994 | 80        | 14           | 58%              |
| Plecoptera        | Pteronarcyidae  | <i>Pteronarcys princeps</i>                     | 102484 | 3         | 2            | 8%               |

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| Order (or higher) | Family           | Taxon (Lowest unit IDed)                       | TSN    | Total No. | No. of sites | Percent of sites |
|-------------------|------------------|------------------------------------------------|--------|-----------|--------------|------------------|
| Plecoptera        | Taeniopterygidae | <i>Taeniopterygidae - early instar</i>         | 102788 | 9         | 5            | 21%              |
| Megaloptera       |                  | <i>Megaloptera - damaged</i>                   | 115000 | 4         | 2            | 8%               |
| Megaloptera       | Sialidae         | <i>Sialis</i>                                  | 115002 | 3         | 3            | 13%              |
| Trichoptera       |                  | <i>Trichoptera - damaged</i>                   | 115095 | 1         | 1            | 4%               |
| Trichoptera       | Apataniidae      | <i>Apatania</i>                                | 115935 | 56        | 8            | 33%              |
| Trichoptera       | Apataniidae      | <i>Apataniidae - early instar</i>              | 598182 | 3         | 3            | 13%              |
| Trichoptera       | Apataniidae      | <i>Pedomoecus sierra</i>                       | 115973 | 51        | 10           | 42%              |
| Trichoptera       | Brachycentridae  | <i>Amiocentrus aspilus</i>                     | 116934 | 3         | 1            | 4%               |
| Trichoptera       | Brachycentridae  | <i>Brachycentrus americanus</i>                | 116912 | 2         | 2            | 8%               |
| Trichoptera       | Brachycentridae  | <i>Micrasema</i>                               | 116958 | 87        | 14           | 58%              |
| Trichoptera       | Glossosomatidae  | <i>Glossosoma</i>                              | 117159 | 6         | 3            | 13%              |
| Trichoptera       | Hydropsychidae   | <i>Hydropsyche</i>                             | 115453 | 1         | 1            | 4%               |
| Trichoptera       | Hydropsychidae   | <i>Hydropsychidae - early instar or pupa</i>   | 115398 | 1         | 1            | 4%               |
| Trichoptera       | Hydropsychidae   | <i>Parapsyche</i>                              | 115556 | 19        | 11           | 46%              |
| Trichoptera       | Lepidostomatidae | <i>Lepidostoma</i>                             | 116794 | 1         | 1            | 4%               |
| Trichoptera       | Limnephilidae    | <i>Ecclisomyia</i>                             | 116025 | 348       | 13           | 54%              |
| Trichoptera       | Limnephilidae    | <i>Limnephilidae - early instar or damaged</i> | 115933 | 61        | 13           | 54%              |
| Trichoptera       | Limnephilidae    | <i>Psychoglypha</i>                            | 115975 | 7         | 2            | 8%               |
| Trichoptera       | Philopotamidae   | <i>Dolophilodes</i>                            | 115319 | 4         | 2            | 8%               |
| Trichoptera       | Rhyacophilidae   | <i>Rhyacophila - early instar or damaged</i>   | 115097 | 5         | 3            | 13%              |
| Trichoptera       | Rhyacophilidae   | <i>Rhyacophila Alberta Gr.</i>                 | *      | 1         | 1            | 4%               |
| Trichoptera       | Rhyacophilidae   | <i>Rhyacophila Angelita Gr.</i>                | *      | 5         | 1            | 4%               |
| Trichoptera       | Rhyacophilidae   | <i>Rhyacophila arnaudi</i>                     | 115165 | 23        | 6            | 25%              |
| Trichoptera       | Rhyacophilidae   | <i>Rhyacophila Betteni Gr.</i>                 | *      | 101       | 20           | 83%              |
| Trichoptera       | Rhyacophilidae   | <i>Rhyacophila Brunnea Gr.</i>                 | *      | 19        | 10           | 42%              |
| Trichoptera       | Rhyacophilidae   | <i>Rhyacophila Grandis Gr.</i>                 | *      | 1         | 1            | 4%               |
| Trichoptera       | Rhyacophilidae   | <i>Rhyacophila Hyalinata Gr.</i>               | *      | 1         | 1            | 4%               |
| Trichoptera       | Rhyacophilidae   | <i>Rhyacophila Nevadensis Gr.</i>              | *      | 19        | 3            | 13%              |
| Trichoptera       | Rhyacophilidae   | <i>Rhyacophila Sibirica Gr.</i>                | *      | 45        | 14           | 58%              |
| Trichoptera       | Rhyacophilidae   | <i>Rhyacophila Vagrita Gr.</i>                 | *      | 13        | 5            | 21%              |
| Trichoptera       | Rhyacophilidae   | <i>Rhyacophila Verrula Gr.</i>                 | *      | 75        | 10           | 42%              |
| Trichoptera       | Rhyacophilidae   | <i>Rhyacophila Vofixa Gr.</i>                  | *      | 64        | 9            | 38%              |
| Trichoptera       | Rhyacophilidae   | <i>Rhyacophilidae - pupa</i>                   | 115097 | 20        | 7            | 29%              |
| Trichoptera       | Uenoidae         | <i>Neothremma</i>                              | 116388 | 124       | 9            | 38%              |
| Trichoptera       | Uenoidae         | <i>Oligophlebodes</i>                          | 116039 | 13        | 3            | 13%              |
| Coleoptera        | Dytiscidae       | <i>Dytiscidae - early instar or damaged</i>    | 111963 | 1         | 1            | 4%               |
| Coleoptera        | Dytiscidae       | <i>Oreodytes - damaged or larva</i>            | 112314 | 2         | 2            | 8%               |
| Coleoptera        | Dytiscidae       | <i>Oreodytes crassulus</i>                     | 728440 | 16        | 2            | 8%               |
| Coleoptera        | Elmidae          | <i>Cleptelmis addenda</i>                      | 114166 | 155       | 4            | 17%              |
| Coleoptera        | Elmidae          | <i>Heterolimnius corpulentus</i>               | 114169 | 217       | 11           | 46%              |
| Coleoptera        | Hydraenidae      | <i>Hydraena</i>                                | 112757 | 1         | 1            | 4%               |
| Diptera           | Ceratopogonidae  | <i>Bezzia / Palpomyia</i>                      | *      | 21        | 5            | 21%              |

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|-------------------|------------------|---------------------------------------------------|--------|-----------|--------------|------------------|
| Diptera           | Ceratopogonidae  | <i>Ceratopogoninae - early instar</i>             | 127338 | 12        | 3            | 13%              |
| Diptera           | Ceratopogonidae  | <i>Forcipomyia</i>                                | 127152 | 10        | 4            | 17%              |
| Diptera           | Ceratopogonidae  | <i>Mallochohelea</i>                              | 127702 | 4         | 2            | 8%               |
| Diptera           | Empididae        | <i>Chelifera</i>                                  | 136305 | 16        | 4            | 17%              |
| Diptera           | Empididae        | <i>Clinocera</i>                                  | 135849 | 22        | 6            | 25%              |
| Diptera           | Empididae        | <i>Empididae - early instar, damaged, or pupa</i> | 135830 | 16        | 4            | 17%              |
| Diptera           | Empididae        | <i>Neoplasta</i>                                  | 136352 | 41        | 9            | 38%              |
| Diptera           | Empididae        | <i>Oreogeton</i>                                  | 136377 | 4         | 3            | 13%              |
| Diptera           | Empididae        | <i>Roederiodes</i>                                | 135893 | 1         | 1            | 4%               |
| Diptera           | Empididae        | <i>Wiedemannia</i>                                | 135920 | 5         | 3            | 13%              |
| Diptera           | Ephydriidae      | <i>Ephydriidae</i>                                | 146893 | 1         | 1            | 4%               |
| Diptera           | Pelecorynichidae | <i>Glutops</i>                                    | 130915 | 225       | 16           | 67%              |
| Diptera           | Psychodidae      | <i>Pericoma / Telmatoscopus</i>                   | *      | 1         | 1            | 4%               |
| Diptera           | Simuliidae       | <i>Helodon</i>                                    | *      | 453       | 22           | 92%              |
| Diptera           | Simuliidae       | <i>Simuliidae - early instar or damaged</i>       | 126640 | 4         | 3            | 13%              |
| Diptera           | Simuliidae       | <i>Simulium</i>                                   | 126774 | 57        | 9            | 38%              |
| Diptera           | Tabanidae        | <i>Tabanidae - damaged</i>                        | 130934 | 1         | 1            | 4%               |
| Diptera           | Tipulidae        | <i>Antocha monticola</i>                          | 119660 | 7         | 4            | 17%              |
| Diptera           | Tipulidae        | <i>Dicranota</i>                                  | 121027 | 13        | 2            | 8%               |
| Diptera           | Tipulidae        | <i>Hesperoconopa</i>                              | 120732 | 36        | 3            | 13%              |
| Diptera           | Tipulidae        | <i>Hexatoma</i>                                   | 120094 | 41        | 8            | 33%              |
| Diptera           | Tipulidae        | <i>Limnophila</i>                                 | 120164 | 5         | 5            | 21%              |
| Diptera           | Tipulidae        | <i>Pedicia</i>                                    | 121118 | 2         | 2            | 8%               |
| Diptera           | Tipulidae        | <i>Rhabdomastix</i>                               | 120968 | 1         | 1            | 4%               |
| Diptera           | Tipulidae        | <i>Tipulidae - damaged or pupa</i>                | 118840 | 7         | 1            | 4%               |
| Diptera           | Chironomidae     | <i>Apsectrotanytus</i>                            | 128021 | 2         | 1            | 4%               |
| Diptera           | Chironomidae     | <i>Brillia</i>                                    | 128477 | 49        | 15           | 63%              |
| Diptera           | Chironomidae     | <i>Chaetocladius</i>                              | 128520 | 55        | 8            | 33%              |
| Diptera           | Chironomidae     | <i>Conchapelopia</i>                              | 128130 | 1         | 1            | 4%               |
| Diptera           | Chironomidae     | <i>Corynoneura</i>                                | 128563 | 46        | 16           | 67%              |
| Diptera           | Chironomidae     | <i>Cricotopus</i>                                 | 128575 | 9         | 4            | 17%              |
| Diptera           | Chironomidae     | <i>Cricotopus (Nostococladius) nostocicola</i>    | 128628 | 229       | 14           | 58%              |
| Diptera           | Chironomidae     | <i>Diamesa</i>                                    | 128355 | 98        | 14           | 58%              |
| Diptera           | Chironomidae     | <i>Diplocladius cultriger</i>                     | 128671 | 447       | 18           | 75%              |
| Diptera           | Chironomidae     | <i>Eukiefferiella - early instar or pupa</i>      | 128689 | 19        | 10           | 42%              |
| Diptera           | Chironomidae     | <i>Eukiefferiella Brehmi Gr.</i>                  | *      | 26        | 5            | 21%              |
| Diptera           | Chironomidae     | <i>Eukiefferiella Claripennis Gr.</i>             | *      | 48        | 18           | 75%              |
| Diptera           | Chironomidae     | <i>Eukiefferiella Devonica Gr.</i>                | *      | 29        | 21           | 88%              |
| Diptera           | Chironomidae     | <i>Eukiefferiella Gracei Gr.</i>                  | *      | 101       | 20           | 83%              |
| Diptera           | Chironomidae     | <i>Heleniella</i>                                 | 128730 | 6         | 4            | 17%              |
| Diptera           | Chironomidae     | <i>Heterotrissocladius</i>                        | 128737 | 2         | 2            | 8%               |
| Diptera           | Chironomidae     | <i>Heterotrissocladius Marcidus Gr.</i>           | *      | 9         | 3            | 13%              |

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| Order (or higher) | Family       | Taxon (Lowest unit IDed)                        | TSN    | Total No. | No. of sites | Percent of sites |
|-------------------|--------------|-------------------------------------------------|--------|-----------|--------------|------------------|
| Diptera           | Chironomidae | <i>Hydrobaenus</i>                              | 128750 | 837       | 14           | 58%              |
| Diptera           | Chironomidae | <i>Krenosmittia</i>                             | 128771 | 19        | 10           | 42%              |
| Diptera           | Chironomidae | <i>Limnophyes</i>                               | 128776 | 7         | 5            | 21%              |
| Diptera           | Chironomidae | <i>Meropelopia</i>                              | 128130 | 1         | 1            | 4%               |
| Diptera           | Chironomidae | <i>Micropsectra</i>                             | 129890 | 317       | 23           | 96%              |
| Diptera           | Chironomidae | <i>Monodiamesa</i>                              | 128440 | 27        | 5            | 21%              |
| Diptera           | Chironomidae | <i>Orthocladiinae - early instar or damaged</i> | 128457 | 16        | 10           | 42%              |
| Diptera           | Chironomidae | <i>Orthocladus</i>                              | 568523 | 906       | 23           | 96%              |
| Diptera           | Chironomidae | <i>Orthocladus lignicola</i>                    | 128913 | 1         | 1            | 4%               |
| Diptera           | Chironomidae | <i>Pagastia</i>                                 | 128401 | 308       | 23           | 96%              |
| Diptera           | Chironomidae | <i>Parachaetocladus</i>                         | 128951 | 4         | 2            | 8%               |
| Diptera           | Chironomidae | <i>Parakiefferiella</i>                         | 128968 | 3         | 3            | 13%              |
| Diptera           | Chironomidae | <i>Parametriocnemus</i>                         | 128978 | 68        | 15           | 63%              |
| Diptera           | Chironomidae | <i>Paraphaenocladus</i>                         | 128989 | 17        | 7            | 29%              |
| Diptera           | Chironomidae | <i>Parochlus kiefferi</i>                       | 127989 | 1         | 1            | 4%               |
| Diptera           | Chironomidae | <i>Parorthocladus</i>                           | 129011 | 24        | 8            | 33%              |
| Diptera           | Chironomidae | <i>Polypedilum</i>                              | 129657 | 12        | 4            | 17%              |
| Diptera           | Chironomidae | <i>Pseudodiamesa</i>                            | 128416 | 28        | 12           | 50%              |
| Diptera           | Chironomidae | <i>Rheocricotopus</i>                           | 129086 | 31        | 12           | 50%              |
| Diptera           | Chironomidae | <i>Rheotanytarsus</i>                           | 129952 | 2         | 1            | 4%               |
| Diptera           | Chironomidae | <i>Stempellinella</i>                           | 129969 | 111       | 11           | 46%              |
| Diptera           | Chironomidae | <i>Stilocladus</i>                              | 129152 | 21        | 10           | 42%              |
| Diptera           | Chironomidae | <i>Tanypodinae - early instar or damaged</i>    | 127994 | 1         | 1            | 4%               |
| Diptera           | Chironomidae | <i>Tanytarsus</i>                               | 129872 | 1         | 1            | 4%               |
| Diptera           | Chironomidae | <i>Thienemanniella</i>                          | 129182 | 14        | 2            | 8%               |
| Diptera           | Chironomidae | <i>Thienemannimyia Gr.</i>                      | 128236 | 38        | 9            | 38%              |
| Diptera           | Chironomidae | <i>Tvetenia - pupa</i>                          | 129197 | 56        | 13           | 54%              |
| Diptera           | Chironomidae | <i>Tvetenia Bavarica Gr.</i>                    | *      | 781       | 24           | 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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**National Park Service**  
**U.S. Department of the Interior**



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**Natural Resource Stewardship and Science**

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