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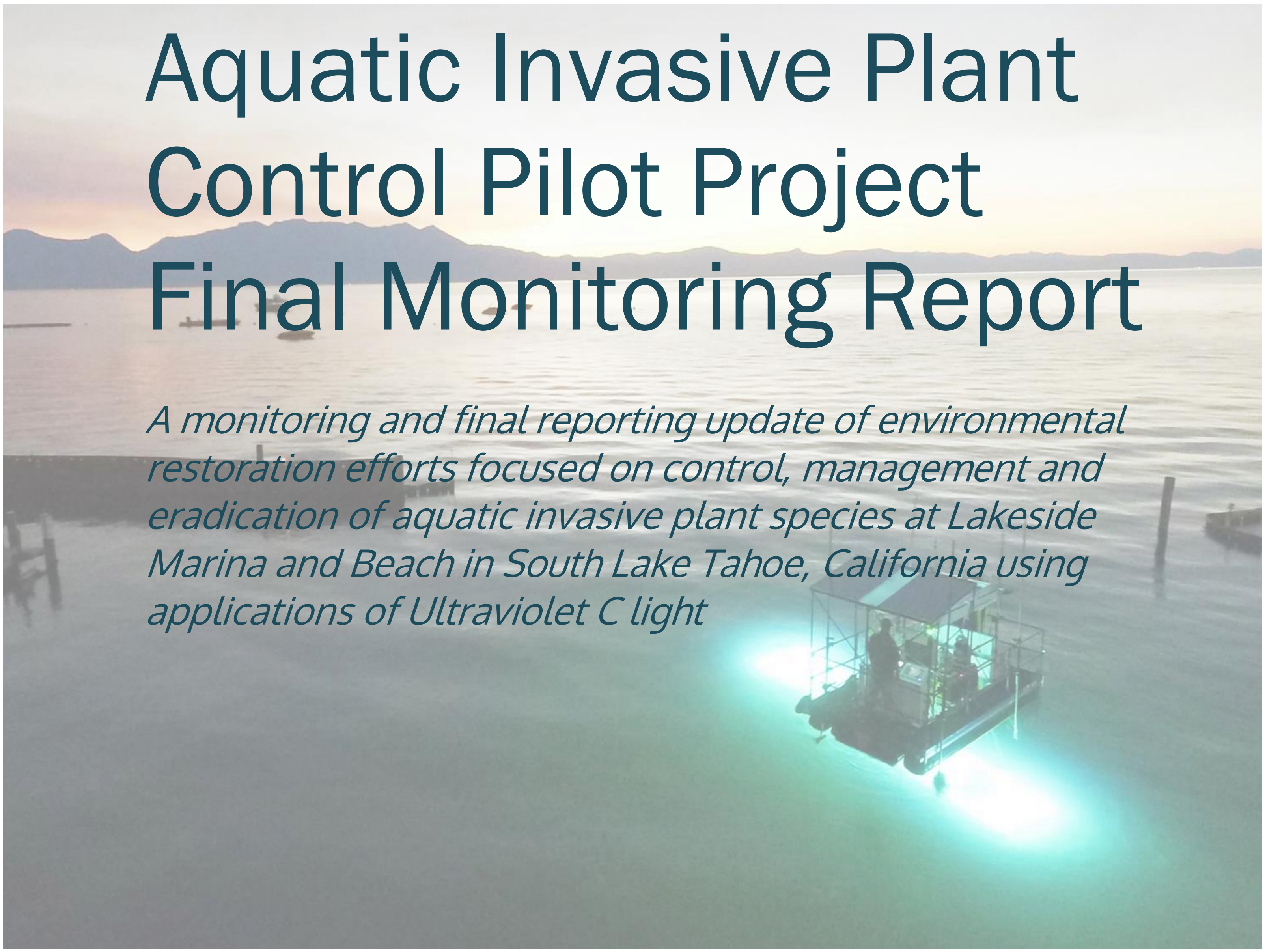

Aquatic Invasive Plant Control Pilot Project Final Monitoring Report

A monitoring and final reporting update of environmental restoration efforts focused on control, management and eradication of aquatic invasive plant species at Lakeside Marina and Beach in South Lake Tahoe, California using applications of Ultraviolet C light

2018 MONITORING REPORT

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Acronym List

ABA	Aquatic Biology Associations, Inc.
AIP	aquatic invasive plants
AIS	aquatic invasive species
BMI	benthic macroinvertebrates
BMP	best management practice
CPW	Curly-leaf pondweed
Conservancy	California Tahoe Conservancy
DDM	degree and decimal minutes
EIP	Environmental Improvement Program
EPA	Environmental Protection Agency
EWM	Eurasian watermilfoil
GPS	Global Positioning System
IRI	Inventive Resources, Inc.
LSB	Lakeside Beach
LSM	Lakeside Marina
mg/L	milligrams per liter
µ S/cm	micro-Siemens/centimeter
MTS	Marine Taxonomic Services, Ltd.
MM	Meeks Bay Marina
(mW/cm2)	megawatt/square centimeter
NDEP	Nevada Division of Environmental Protection
NTU	Nephelometric Turbidity Unit
ppm	parts per million
SB630	State Bond 630
SR	Ski Run Channel
Tahoe RCD	Tahoe Resource Conservation District
TRPA	Tahoe Regional Planning Agency
Water Board	Lahontan Regional Water Quality Control Board
UV-C	Ultraviolet C (shortwave)

Executive Summary

This Final Monitoring Report is submitted to fulfill Contract Number CTA 16031L between the California Tahoe Conservancy (Conservancy) and Tahoe Resource Conservation District (Tahoe RCD) for the Aquatic Invasive Plant Control Pilot Project (Project). This Project tested the effectiveness of ultraviolet light, C wavelength (UV-C) on aquatic invasive plant (AIP) infestations in Lake Tahoe in two lake environments: open water and enclosed water. An interim progress report was submitted to the Conservancy in December 2017 and is available for download on Tahoe RCD's website (https://tahoercd.org/tahoe-aquatic-invasive-species-resources/). The 2017 progress report included:

- A summary of work completed during the 2017 treatment period;
- Draft products, reports and interim findings, including a statement of tasks and milestones and a report of the status on each, including public and agency meetings' outcomes;
- A discussion of any challenges or opportunities encountered in accomplishing the scope of work;
- An assessment of the progress compared to the timeline in the Project Schedule;
- A narrative financial report comparing costs to date and the approved scope of work and budget, and
- Copies of relevant materials produced during the 2017 reporting period under the terms of the agreement.

This Final Monitoring Report builds upon the data and preliminary findings provided in the 2017 Progress Report by considering long term post-treatment results that were measured during the 2018 growing season between June and September 2018. This report includes:

- A summary of the objectives of the project and how these objectives were accomplished (**Section 3 and Section 7**);
- Summary of public and agency meeting outcomes and work completed for this project (**Table 1 and Appendix B**);
- Findings, conclusions or recommendations for follow-up or ongoing activities that could result from the successful completion of this project (**Sections 9 and 10**);
- Comparison of pre-treatment and post-treatment results for macrophytes, benthic macroinvertebrates (BMI), periphyton, phytoplankton, zooplankton and water quality parameters (**Section 8**);
- Compilation of 2017 and 2018 field photo documentation (**Appendix D**);
- Copies of news articles and educational materials produced as a result of the grant agreement (**Appendix F**); and
- An economic assessment of AIP treatment methods used in Lake Tahoe (**Section 11**).

The results from the Project support initial laboratory findings that the application of UV-C light results in observed mortality of submerged aquatic plants, both in an enclosed waterbody (i.e., marinas) and open waterbody (i.e., beach littoral) systems. Most submerged aquatic plants (i.e., macrophytes) treated with UV-C light exhibited signs of deterioration within 7 to 10 days following treatment. Complete eradication of AIP may not be achieved with only one treatment, but a decrease in plant percent cover, mean plant height, and thus plant density, was observed. For future treatment, macrophytes should be treated with UV-C light early in the growing season (e.g., typically May and June) and treatment conducted several times throughout a season or multiple seasons. This monitoring report provides quantitative information on the physical, chemical, and biological characteristics of lake waters and substrate in the treatment area and comparisons to control sites, which represent comparable AIP infestation sites that were not treated with UV-C light.

The data collected from this Project serves two purposes: 1) to determine the success of the UV-C light treatment method and the efficacy of this method as a useful tool at a lake-wide scale; and 2) to provide information to support future environmental document analysis and permitting needs. Based on observations of UV-C light treatment at Lakeside Marina and Lakeside Beach, UV-C light is a good first line of defense when tackling large, dense areas of aquatic plants, ideally treating in the beginning of the growing season. This technology provides a marked cost advantage and was the least costly method reviewed however, cost should not be the main factor considered when choosing a control method. There is significant interest and support from public and private sectors to further develop this pilot Project and the utility of UV-C light as a technique to treat AIP in Lake Tahoe. It is our recommendation that UV-C light prescription treatments consider the following: project area, treatment frequency, project duration, size of light array, plant species present, desired outcomes, and cost. UV-C technology should be used along with other techniques and technologies in an appropriate and comprehensive manner to be most effective. Additional UV-C light treatment applications and projects should be implemented and monitored for a period of 2-3 years to investigate the full potential of this tool.

Possible constraints:

- Plant height and density is an initial constraint, that may predicate additional rounds of treatment
- Visibility in the water column can obstruct the precision of application to the plant crown
- Site configuration and use need to be addressed through adaptation of the treatment apparatus and treatment timing

1 Introduction

Tahoe Resource Conservation District (Tahoe RCD) leads aquatic invasive plant (AIP) control efforts in the Lake Tahoe Basin and continually seeks innovative technologies and methods to improve treatment efficacy and efficiency. The Aquatic Plant Management Society defines aquatic plant control as techniques used alone or in combination that result in a timely, consistent, and substantial reduction of a target plant population to levels that alleviate an existing or potential impairment to the uses or functions of the water body.

Attempts to locally control or eradicate AIP, specifically Eurasian watermilfoil (*Myriophyllum spicatum*) and curly-leaf pondweed (*Potamogeton crispus*), have been ongoing in Lake Tahoe since 2006. Gas-permeable bottom or benthic barriers and diver-assisted suction removal, when used in combination throughout the growing season (May until November), have proven successful (Shaw et. al. 2016). While this combination of methods is effective in an open water setting such as Emerald Bay, site-specific limitations do exist. Wave action, lake bed morphology, high boater use areas, and high turbidity can impede the effectiveness of these methods. Therefore, additional tools to treat AIP infestations are needed.

New research indicates that using ultraviolet C (UV-C) light, a short-wave electromagnetic radiation light that damages the DNA and cellular structure of aquatic plants and their fragments, could be an effective new method to kill and control AIP species, as laboratory tests resulted in complete mortality when exposure times of more than 5 minutes were applied. This technology was applied in Lake Tahoe to determine the full potential of UV-C light treatment as a new method to enhance and support current efforts in the treatment of AIP.

The UV-C Light Plant Control Pilot Project (Project) is funded by the California Tahoe Conservancy (Conservancy) and Tahoe Fund and managed by Tahoe RCD. UV-C light was applied to three treatment areas: 1) closed marina system (Lakeside Marina or LSM); 2) adjacent open water or littoral environment (Lakeside Beach or LSB-Swim); and 3) an open water environment (immediately adjacent to the Lakeside Marina bulkhead with water taxi use (LSB-Taxi). UV-C light treatment was conducted between June 23, 2017 and September 11, 2017. Associated macrophyte surveys and biomonitoring (i.e., benthic macroinvertebrates, periphyton, zooplankton, phytoplankton and chlorophyll-*a*) were conducted pre-treatment, immediately post-treatment, and long-term post-treatment. Plant response to UV-C light treatment was measured one year after treatment in 2018, and through the 2018 growing season, with the following project milestones:

1. Pre-treatment 2017 to establish baselines; macrophyte surveys and biomonitoring (i.e., benthic macroinvertebrates, periphyton, zooplankton, phytoplankton, and chlorophyll-*a*);
2. Immediate post-treatment 2017 to gauge treatment response and mortality; and

3. Long-term post-treatment 2018 to measure response to UV-C light treatment one year later and through the 2018 growing season.

UV-C light is an effective tool in treating microbes and other living organisms and is currently used in other applications such as food, air and water purification. The Project assists with determining the optimum intensity and duration of UV-C light treatment that is necessary for control of AIP, specifically Eurasian watermilfoil (EWM) and curly-leaf pondweed (CPW). AIP control efforts are anticipated to result in improvements to water quality, native fish habitat, and recreational access for swimming and boating. The Project provides a significant regional benefit by increasing the variety and application of methods available for controlling AIP, potentially at greater efficiencies and less cost.

Pre-treatment monitoring of water quality parameters occurred June 11, 2017 at LSM and July 30, 2017 at LSB to establish baselines. Water quality monitoring occurred daily and weekly during active UV-C light treatments to measure turbidity, total suspended solids, pH, dissolved oxygen and specific conductivity against baseline and to assure that violations of State and Regional water quality objectives did not occur during UV-C light treatment applications. Immediate post-treatment water quality monitoring occurred on October 17, 2017 at LSM and October 29, 2017 at LSB. Long term post-treatment water quality monitoring was not funded as part of this pilot Project.

2 Project Background

2.1 Lake Tahoe AIS Program

In fall 2013, the California Legislature and Governor approved Senate Bill 630 (SB630), establishing the Lake Tahoe Science and Lake Improvement Account (Account) and defining the purposes for expenditure of these funds. The funds deposited into the Account come from rental income collected by the California State Lands Commission for surface uses on Lake Tahoe. These funds are to be expended for establishing a bi-state science- based advisory council, near-shore aquatic invasive species projects or public access projects, and near-shore water quality monitoring. Since 2014, the Conservancy Board has authorized $795,128 in SB630 funding for Lake Tahoe Aquatic Invasive Species (AIS) efforts. This includes control of aquatic invasive plant and aquatic invasive animal species.

SB 630 requires matching funds for projects and monitoring and requires the Conservancy to coordinate the selection of projects to be funded through a collaborative process with agencies, nonprofit organizations, and private landowners who pay the rental income. In 2016, the Conservancy awarded a Proposition 1 grant to Tahoe RCD for AIS control that provides match for the Project.

Currently, there are two known species of AIP in Lake Tahoe, Eurasian watermilfoil (EWM) and curly-leaf pondweed (CPW). These species are considered invasive in Lake Tahoe because of their impacts to recreation, navigation, and ecosystem dynamics. EWM is thought to have been introduced to Lake Tahoe in the 1960s or 1970s and was formally identified along the south shore in the late 1980s and 1990s. There are approximately 20 locations with EWM, including over 150 acres of mixed species in the Tahoe Keys. CPW was first identified in the south shore of Lake Tahoe in 2003. Since its discovery, this species has spread along the south shore and in some areas has outcompeted and replaced infestations of EWM.

AIS control is a high priority for the Lake Tahoe Basin community, agencies and organizations. In 2010, the AIS Management Plan (TRPA 2014) was approved by the Aquatic Nuisance Species Task Force and endorsed by the Governors of Nevada and California and the TRPA executive director. The U.S. Army Corps of Engineers, the Conservancy, and the Lake Tahoe AIS Coordination Committee have worked together to compile this plan. The goals of the AIS Management Plan are to:

- Prevent new introductions of AIS to the Tahoe Region;
- Limit the spread of existing AIS populations in the Tahoe Region, by employing strategies that minimize threats to native species, and extirpate existing AIS populations when possible; and
- Abate harmful ecological, economic, social and public health impacts resulting from AIS.

In 2015, the Lake Tahoe AIS Implementation Plan (Wittmann and Chandra 2015) identified the treatment and control of EWM and CPW as one of the highest priorities for AIS control efforts. In addition, the AIS Implementation Plan ranked LSB and LSM in the top five priority areas for AIP treatment and control. AIS threaten the economic, environmental, and aesthetic value of this important resource to states of California and Nevada.

2.2 Monitoring Plan for UV-C Light Aquatic Invasive Plant Control Project

Appendix A contains the monitoring plan developed by the Advisory Team that was solicited for the Project and directed project monitoring and reporting. The Project assumptions and constraints, as disclosed in the monitoring plan were as follows:

- Overlapping Treatment: Tahoe RCD has used benthic barriers, diver-assisted suction removal and hand pulling to treat AIP at Lakeside Marina and Beach in 2013, 2015, and 2016. In 2017, Tahoe RCD treated the entire marina, with only a portion of the treatment being UV-C light. Close coordination between the two operations is necessary and oversight will be provided by Tahoe RCD.

- UV-C treatment area: This project was designed to test UV-C light technology and will only treat plants in a defined area.

- Scalability: The original vessel and project was designed for a pilot project only. Design and development can be scaled up to fit further lake-wide plant control.

- Complete Treatment: 100 percent of the plant infestation in the project area was treated in 2017 by either UV-C light, or benthic barriers and diver-assisted suction removal.

- Method Success: This project and method is being tested to assess the effectiveness of UV light as another effective method for plant control at Lake Tahoe to be used in combination with existing methods.

2.3 Project Roles and Responsibilities

The following entities have coordinated to plan, fund, implement, monitor and report on the Project.

2.3.1 California Tahoe Conservancy (Conservancy) – Funding

The Conservancy, a state agency, made a recommendation to their Board to authorize a grant to Tahoe RCD for the Project. The Board approved the Project and a grant agreement was signed in March 2017, with Project commencement in spring 2017 and final reporting and completion anticipated by March 31, 2019. Implementation of this Project is consistent with the Conservancy's enabling legislation (Government Code Title 7.42). Specifically, section 66907.7 authorizes the Conservancy to award grants to local public agencies for purposes consistent with its mission. The recommended action is consistent with their 2012-2017 Strategic Plan because it invests in a high priority Environmental Improvement Program (EIP) project (Strategy II).

The Project is consistent with the authority given to the Conservancy through SB630 pursuant to section 6717.6.1(a) of the Public Resources Code. The Conservancy coordinated selection of this Project through a collaborative process that included participation of a stakeholder group consisting of public agencies, nonprofit organizations, and private landowners.

2.3.2 Tahoe Resource Conservation District (Tahoe RCD) – Planning, Environmental Clearance, and Project Management

Tahoe RCD, a local special district, provided project oversight and management for planning implementation, monitoring and reporting for the Project. Pursuant to State CEQA Guidelines (Cal. Code Regs., tit. 14, § 15000 et seq.), certain classes of activities are statutorily exempt from CEQA or are exempt because they have been determined by the Secretary for Natural Resources to have no significant effect on the environment. Pursuant to Public Resources Code sections 21001(f) and 21082, the Conservancy has also adopted regulations to implement, interpret, and make specific the provisions of CEQA (Cal. Code Regs., tit. 14, § 12100 et seq.). Tahoe RCD staff has evaluated this Project and found it to be exempt under CEQA. This Project qualifies for a categorical exemption under State CEQA Guidelines section 15306 (information collection), and the Conservancy's CEQA regulations, section 12102.6. A Notice of Exemption (NOE) was prepared and submitted for the Project (included as Attachment C of the 2017 Progress Report).

Through the SB 630 grant, the Conservancy funded Tahoe RCD $260,128 to implement and monitor the Project at Lakeside Marina and Beach.

2.3.3 Inventive Resources, Inc. (IRI) – UV-C Light Plant Control Implementation

Inventive Resources Inc. (IRI), a design, invention and patent development business, has developed a patented treatment method and vessel that uses UV-C to treat AIP. IRI was contracted to treat specific areas of Lakeside Marina and Lakeside Beach as part of this Project to confirm AIP mortality results that were achieved in laboratory testing, and to better define treatment duration and AIP regrowth responses. UV-C light treatment applications are also being studied to determine feasibility and cost effectiveness for larger scale AIP management program applications. Considerable effort has been invested in laboratory testing, Quality Assurance/Quality Control (QA/QC), fabrication, and beta testing of the UV-C light treatment method and treatment vessel.

IRI mobilized the UV-C light treatment vessel to the treatment areas, recorded existing treatment area conditions, and submitted the treatment schedule to the Advisory Team. IRI technicians conducted UV-C light treatment, testing treatment durations and intensities. IRI submitted monthly progress summary reports and other pertinent data, including the underwater camera video and photo documentation, which captured visual plant mortality and decomposition. IRI has submitted technical memorandums and assisted in data analysis and recommendations towards the final monitoring report.

2.3.4 Marine Taxonomic Services (MTS) – Pre-and Post-Project Biomonitoring

Marine Taxonomic Services, Ltd. (MTS), an environmental consulting firm, was contracted to bring sampling design expertise and to provide insight towards project-level survey and sampling plans. Technical expertise in underwater sampling of any type is rare and difficult to employ, but it is imperative to properly document progress towards the goals in this pilot Project. MTS was employed to administer the parameters of mobilization and monitoring efforts for periphyton, zooplankton, phytoplankton, benthic macro-invertebrates, chlorophyll-a, and AIP in addition to other macrophytes. In addition, MTS provided data and methods for report deliverables regarding survey and sampling methods.

2.3.5 Green(e) Consulting – Quality Control/Quality Assurance Monitoring and Reporting

Melanie Greene, AICP, CPESC, QSP/QSD, a hydrologist and principal planner with Green(e) Consulting, was contracted to participate on the Advisory Team and conduct third party water quality monitoring pre-treatment, during active treatment, and immediately post-treatment. Data collected included turbidity, dissolved oxygen, pH, conductivity and temperature. Ms. Greene compiled water quality monitoring data and provided data analysis for post-project effectiveness. Ms. Greene was the primary author of the 2017 interim progress report and facilitated data analysis and reporting with the Advisory Team in 2018 to author and produce this 2018 final project monitoring report.

2.3.6 Advisory Team

In addition to IRI, MTS and Green(e) consulting, the following individuals also participated on the Advisory Team, which prepared the Monitoring Plan (Appendix A), reviewed the monitoring results, and contributed to the content or review of the final monitoring report:

- Ravi Jain, Dean Emeritus, School of Engineering and Computer Science, University of the Pacific (Section 11.0);
- Dennis Zabaglo, TRPA Aquatic Species Prevention Coordinator;
- Dan Shaw, California Department of Parks and Recreation; and
- Whitney Brennen, California Tahoe Conservancy.

3 Project Objectives

This Project is designed to obtain quantitative information on the physical, chemical, and biological characteristics of Lake Tahoe waters and substrate within the treatment area to evaluate potential impacts from using UV-C light to control aquatic plants. The data collected from this project serves two purposes, 1) documents success of this treatment method and 2) determines the potential use of UV-C light treatment as a tool for plant control on a lake-wide scale. If UV-C light treatment is proposed for lake-wide application, this pilot data will provide information to support future programmatic-level environmental document analysis and permitting needs. For example, biological parameters such as benthic macroinvertebrates (BMI), periphyton, and plankton are being monitored because they are an important food source for fish. Additionally, turbidity levels are monitored to determine if the UV-C light treatment method can adhere to the 3 NTU (Nephelometric Turbidity Unit) turbidity threshold of TRPA, Lahontan Regional Water Quality Control Board (Water Board) and Nevada Department of Environmental Protection (NDEP).

Questions that are to be answered by this Project include:

- Does UV-C Light kill aquatic invasive plant species?
- How far will UV-C light penetrate sediment on the lakebed?
- How do benthic macroinvertebrates (BMI) respond to UV-C light treatment methods?
- How does UV-C light affect water temperature?
- What are the effects of the UV-C light treatment method to dissolved oxygen levels in the treatment area?
- How do plankton (phytoplankton or zooplankton) or periphyton respond to UV-C light treatment methods?
- What are the regrowth rates for AIP within the treatment areas?

4 Project Area Location

UV-C light treatment occurred at three locations in 2017: Lakeside Marina (LSM), a closed marina system, and at portions of the water taxi and swim area of Lakeside Beach (LSB), an adjacent open water beach environment. **Figure 1** depicts the project area location and vicinity. Lakeside Marina and Beach are located in the vicinity of the California-Nevada Stateline area in South Lake Tahoe, California. The project area can be accessed from Lakeshore Boulevard between Park Avenue and Stateline Avenue.

The littoral zone is the near shore area where sunlight penetrates all the way to the sediment and allows aquatic plants (macrophytes) to grow. Two different types of littoral environments, an open water and closed marina system, with known AIP infestations were chosen to receive treatment to see the effects of UV-C light on two different nearshore lake environments. Marinas can be defined as establishments providing water-oriented services that has had man-made alterations to a littoral zone. These alterations typically result in localized change to aquatic ecology and littoral drift. The pilot Project does not compare the two different littoral sites to each other but evaluates them individually as an open water site and a closed marina system by comparing them to representative control site. The control sites were selected based on comparable littoral location and known AIP infestation but received no UV-C light treatment in 2017.

The LSM treatment area is approximately 11,800 square feet (0.27 acres) and is compared to Meeks Bay Marina (MM), the closed marina system control site. Macrophyte survey transect locations are depicted in **Figure 2**, while **Figure 3** illustrates the biomonitoring sampling points for the closed marina sites.

The LSB treatment areas, which includes the water taxi (LSB-Taxi) and the swim beach (LSB-Swim) areas, totals approximately 7,600 square feet (0.18 acres) and is compared to Ski Run channel (SR), the open water control site. Macrophyte survey transect locations are depicted in **Figure 4**, while **Figure 5** illustrates the biomonitoring sampling point locations for the open water sites.

Lake levels averaged above 6228 feet Lake Tahoe Datum (LTD) throughout project implementation in 2017 with water column depths maintained at 8 to 10 feet. Comparable lake levels persisted during 2018 post-project monitoring.

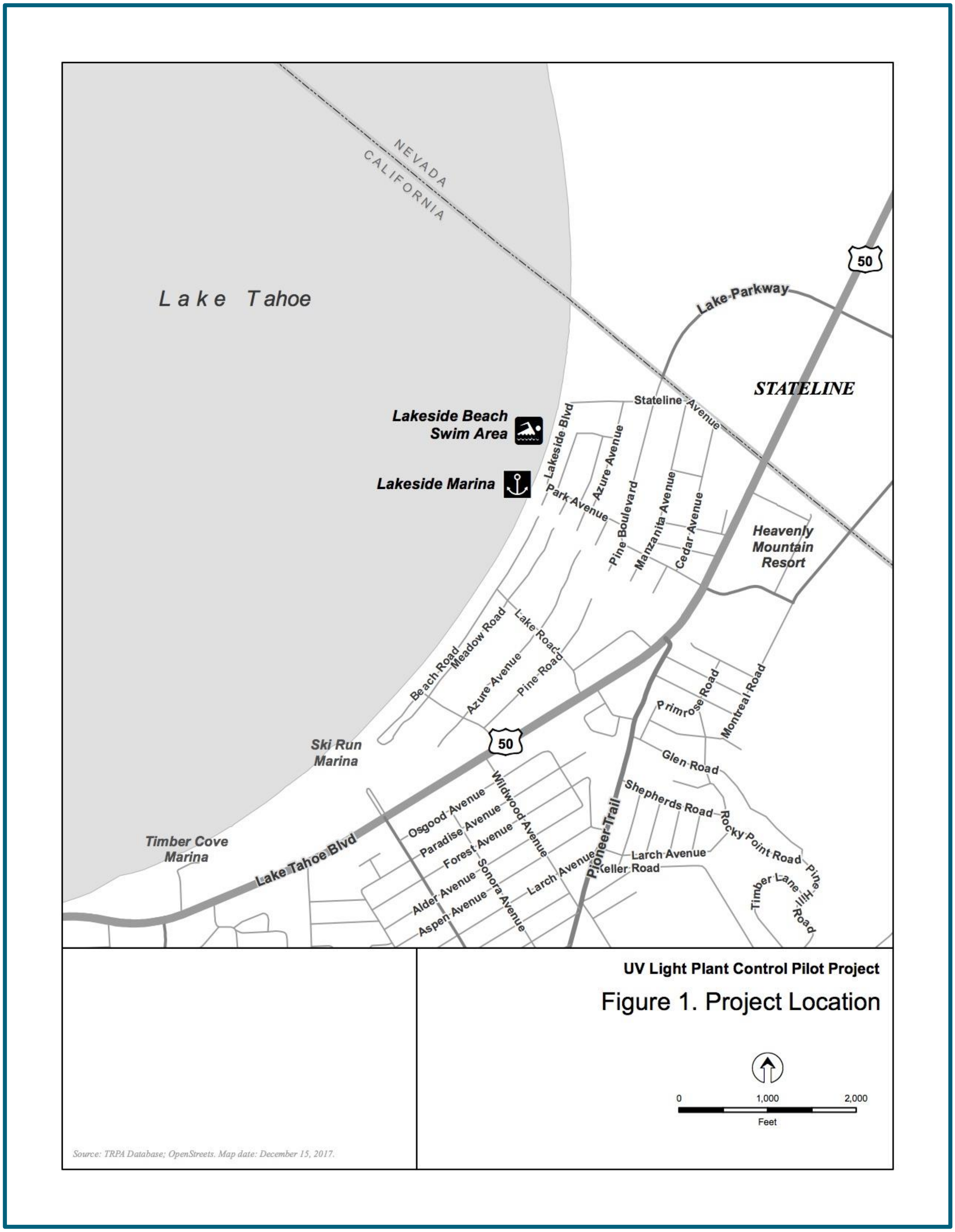

Figure 1. Project area location

Figure 2. LSM (treatment site) and MM (control site) macrophyte transect locations

Figure 3. LSM (treatment site) and MM (control site) biomonitoring sample locations

Figure 4. LSB (treatment site), the LSB-Taxi in transect is green and the LSB-Swim transect is pink, and SR (control site) macrophyte transect locations

Figure 5. LSB (Taxi and Swim treatment sites) and SR (control site) biomonitoring sampling locations

5 Project Scope and Schedule

Attachment A contains the Monitoring Plan for UV-C Light Aquatic Invasive Plant Control Pilot Project (Monitoring Plan). The Monitoring Plan outlines the following components:

- Introduction
- Objectives
- Assumptions and Constraints
- Sampling Parameters
- Monitoring Parameters and Time-frame Definitions
- Field Sampling Plan and Schedule
- Field Logbook and Forms
- Data Management and Reporting

Table 1 details the Project timeline through December 2018. The Project was implemented according to the Project Schedule. **Table 1** identifies by date the project tasks, milestones, public and agency meetings, general notations, and reports status and results, when applicable.

Table 1. Project Timeline & Summary of Work Completed During the Reporting Period	
Date	**Project Action/Status**
12/9/15	Nearshore Aquatic Weed Working Group (NAWWG) Meeting with initial Project proposal presentation
6/14/16	NAWWG Meeting with Project feasibility discussions prior to funding and contractual agreements
9/13/16	NAWWG Meeting with Project feasibility discussions prior to funding and contractual agreements
12/13/16	NAWWG Meeting with Project feasibility discussions prior to funding and contractual agreements
3/14/17	NAWWG Meeting with project and funding updates provided by Tahoe RCD Staff
3/17/17	Funding agreement signed between Conservancy and Tahoe RCD
5/30/17	Kickoff Meeting with Tahoe RCD and Advisory Group; Review and Finalize Monitoring Plan; Images of preexisting conditions taken in LSM
6/11/17	LSM Pre-treatment Water Quality Monitoring Conducted (Hourly Turbidity, DO, Conductivity; pH, TDS, Temperature)
6/12/17	LSM Pre-treatment Surveys for Macrophytes, Benthic Macroinvertebrate, Chlorophyll, Periphyton, Zooplankton and Phytoplankton
6/13/17	MM (Control Site) Pre-treatment Surveys for Macrophytes, Benthic Macroinvertebrate, Chlorophyll, Periphyton, Zooplankton and Phytoplankton; NAWWG Meeting Project funding, contracting and project update provided by Tahoe RCD Staff
6/21/17	Mobilization of treatment vessel complete; UV-C light Vessel is onsite at LSM; Completion of preexisting images in LSM
6/22/17	Pre-treatment Aquatic Invasive Plant Surveys (Macrophytes); Subsurface Cameras Installed by Contractor; LSM Active Treatment Walkways 1 through 19; Operational and equipment testing

Table 1. Project Timeline & Summary of Work Completed During the Reporting Period	
Date	Project Action/Status
6/23/17	LSM Active Treatment Walkway Points 1, 2 and 3 (Grids A6-A10, B6-B10, C6-C10, D6-D10, E6-E10, F6-F10)
6/24/17	LSM Active Treatment Walkway Points 3, 4 and 5 (Grids G6-G10, H6-H10, I6-I10, J6-J10)
6/25/17	No treatment conducted; Cleaning of UV-C light treatment array and photo documentation conducted
6/26/17	LSM Active Treatment Walkway Points 5 and 6 (Grids K6-K10, L6-L10) and sampled discretionary Points 21, 22, 23 outside the LSM treatment area
6/27/17	LSM Active Treatment Walkway 1, 6 and Point 20; Treatment was suspended due to safety concerns with increased winds. Winds on this day were approximately 8 mph with gusts reaching up to 20 mph at times
6/28/17	LSM Active-treatment Water Quality Monitoring Conducted (Hourly Turbidity, DO, Conductivity; pH, TDS, Temperature); LSM Active Treatment Walkway Points 6, 7 (Grids M6-M10, N5-N10)
6/29/17	LSM Active Treatment Walkway Point 8 (Grids O6, O7)
6/30/17	UV-C light treatment array cleaning conducted
7/1/17	No treatment conducted (holiday weekend)
7/2/17	No treatment conducted (holiday weekend)
7/3/17	No treatment conducted (holiday weekend)
7/4/17	No treatment conducted (holiday weekend)
7/5/17	No treatment conducted (holiday weekend); IRI staff remobilizes and maintains treatment and monitoring equipment
7/6/17	Media Day with local news outlets and publications. LSM Active treatment Weekly Water Quality Monitoring Conducted (Hourly Turbidity, DO, Conductivity; pH, TSS, Temperature); LSM Active Treatment 9 (Grids A1-A5 and B1-B5); About one-half of the LSM treatment area has been treated
7/7/17	LSM Active Treatment Point 9 (Grids C1-C5)
7/8/17	LSM Active Treatment Points 10-11 (Grids D1-D5, E1-E5, F1-F5)
7/9/17	LSM Active Treatment Points 11-12 (Grids G1-G5, H1-H5)
7/10/17	LSM Active Treatment Points 12-13 (Grids I1-I5, J2-J5)
7/11/17	LSM Active Treatment Point 14 (Grids L1-L5)
7/12/17	LSM Active treatment Weekly Water Quality Monitoring Conducted (Hourly Turbidity, DO, Conductivity; pH, TDS, Temperature); LSM Active Treatment Point 13 (Grids K1-K5, J1)
7/13/17	LSM Active Treatment Points 14-16 (Grids M1-M4, Q3-Q7)
7/14/17	LSM Active Treatment Points 15-16 (Grids M5, N5, O5, P1-P3, P6, P7); LSM Phase 1 treatment is complete
7/15/17	No treatment conducted. LSB Pre-treatment surveys for Macrophytes, Benthic Macroinvertebrate, Chlorophyll, Periphyton, Zooplankton and Phytoplankton
7/16/17	No treatment conducted. SR (Control Site) Pre-treatment Surveys for Macrophytes, Benthic Macroinvertebrate, Chlorophyll, Periphyton, Zooplankton and Phytoplankton. Sacramento ABC news station Channel 10 came on July 18th and interviewed key people on the project
7/17/17	No treatment conducted
7/18/17	No treatment conducted; Sacramento ABC news station Channel 10 onsite interview of IRI technicians
7/30/17	LSB (Swim and Taxi) Pre-treatment Water Quality Monitoring Conducted (Hourly Turbidity, DO, Conductivity; pH, TSS, Temperature)

Table 1. Project Timeline & Summary of Work Completed During the Reporting Period	
Date	**Project Action/Status**
8/7/17	LSB pre-treatment photo documentation conducted. LSB-Taxi and LSB-Swim were surveyed for preexisting conditions and obstructions that may delay or change treatment plans; New field designed skid added to treatment array
8/8/17	LSB pre-treatment photo documentation conducted. LSB-Taxi and LSB-Swim were surveyed for preexisting conditions and obstructions that may delay or change treatment plans. LSB-Swim Active Treatment conducted at Grids B-C1 through B-C6 and B-D1 through B-D6 and B-E1 through B-E6
8/9/17	LSB Active treatment Weekly Water Quality Monitoring Conducted (Hourly Turbidity, DO, Conductivity; pH, TDS, Temperature); LSB-Taxi Active Treatment at T-B1 through T-B18 and T-C1 through T-C18
8/10/17	LSB-Taxi Active Treatment at T-A1 through T-A9.
8/11/17	LSB-Swim Active Treatment conducted at Grids B-F1 through B-F6 and B-G1 through B-G6 and B-H1 through B-H6
8/12/17	No treatment conducted
8/13/17	No treatment conducted
8/14/17	LSB-Swim Active Treatment at Grids B-I1 through B-I6
8/15/17	LSB-Swim Active Treatment at Grids B-B3 through B-B6
8/16/17	LSB-Swim Active-treatment Weekly Water Quality Monitoring Conducted (Hourly Turbidity, DO, Conductivity; pH, TDS, Temperature); LSB-Swim Active Treatment at Grids B-A5, B-A6. Phase 1 of LSB-Swim complete
8/17/17	LSB-Taxi Active Treatment at Grids T-D1 through T-D18
8/18/17	LSB-Taxi Active Treatment at Grids A10 through T-A18; Phase 1 of treatment at LSB-Taxi complete
8/28/17	MTS roped off the water taxi area and swim beach area for visual markers. LSM Active Treatment Points 1, 2 and 3 (Grids A6 -A10, B6-B10, C6-C10, D6-D10, E6-E10, F6-F10
8/29/17	LSM Active Treatment Points 11, 12 and 13 (Grids G6-G10, H6-H10, I6-I10, J6-J10)
8/30/17	LSM Active treatment Weekly Water Quality Monitoring Conducted (Hourly Turbidity, DO, Conductivity; pH, TSS, Temperature); LSM Active Treatment Points 5, 6 and 7 (Grids K6-K10, L6-L10, M6-M10, N6-N10)
8/31/17	LSM Active Treatment Point 2 (Grids D6-D10)
9/1/17	LSM Active Treatment Points 5, 6, 7, 8
9/2/17	No treatment conducted (holiday weekend)
9/3/17	No treatment conducted (holiday weekend)
9/4/17	No treatment conducted (holiday weekend)
9/5/17	LSM Active Treatment Points 12, 13 and 14 (Grids H1-H5, I1-I5, J1-J5, K1-K5, L1-L5) and LSB-Taxi Points T-A1 through T-A16; Phase 2 of treatment at LSM complete
9/6/17	No treatment conducted
9/7/17	No treatment conducted
9/8/17	LSB Active-treatment Weekly Water Quality Monitoring Conducted (Hourly Turbidity, DO, Conductivity; pH, TSS, Temperature); LSB-Taxi Active Treatment
9/9/17	LSB-Taxi Active Treatment and Points 4, 5, 6, 7, 8, 9, 10 and 11
9/10/17	LSB-Taxi Active Treatment a and Points B-I1, B-I3, B-I6
9/11/17	LSB-Taxi Active Treatment; Phase 2 of treatment at LSB (Swim and Taxi) completed
9/12/17	NAWWG Meeting, Project update provided by IRI and Tahoe RCD Staff

Table 1. Project Timeline & Summary of Work Completed During the Reporting Period	
Date	**Project Action/Status**
9/16/17	LSM and LSB Macrophytes surveys, Benthic Macroinvertebrate, Chlorophyll, Periphyton, Zooplankton and Phytoplankton
9/18/17	Immediate post-treatment photo documentation completed at LSM and LSB
10/1/17	Immediate post-treatment photo documentation completed at LSM and LSB
10/8/17	LSB (Swim and Taxi) Immediate Post-treatment Macrophyte Surveys
10/9/17	Advisory Group Meeting at TRCD offices; Immediate post-treatment photo documentation completed at LSM and LSB
10/10/17	UV-C light treatment vessel demobilized and moved off site
10/13/17	Progress Report Outline due to the Advisory Group
10/17/17	LSM and LSB Immediate Post-treatment Water Quality Monitoring Conducted (Hourly Turbidity, DO, Conductivity; pH, TSS, Temperature)
10/27/17	Sub-consultants provide data, reports and grant deliverables to Green(e) Consulting
10/28/17	Immediate post-treatment photo documentation completed at LSM and LSB-Taxi
10/29/17	LSB Immediate Post-treatment Weekly Water Quality Monitoring Conducted (Hourly Turbidity, DO, Conductivity; pH, TSS, Temperature); Immediate post-treatment photo documentation completed at LSB-Swim
11/21/17	Immediate post-treatment photo documentation completed at LSM and LSB
12/1/17	Draft Progress Report provided to Tahoe RCD for review; Immediate post-treatment photo documentation using a new remotely-operated vehicle for underwater images completed at LSM and LSB
12/4/17	Draft Progress Report provided to Advisory Group for Internal Review
12/13/17	Advisory Group provides comments and edits to Green(e) Consulting for preparation of the Final Draft Progress Report
12/15/17	Final Draft Progress Report delivered to Tahoe RCD
12/31/17	Deliverable date of Final Progress Report per grant guidelines
04/13/18	Advisory Group kickoff meeting for 2018 post-treatment monitoring
05/11/18	IRI monthly photo monitoring
06/01/18	IRI monthly photo monitoring
06/20/18	LSM long term post-treatment Surveys for Macrophytes, Benthic Macroinvertebrate, Chlorophyll, Periphyton, Zooplankton and Phytoplankton
06/21/18	LSB long term post-treatment Surveys for Macrophytes, Benthic Macroinvertebrate, Chlorophyll, Periphyton, Zooplankton and Phytoplankton; MM (Control Site) Long-term post-treatment Surveys for Macrophytes, Benthic Macroinvertebrate, Chlorophyll, Periphyton, Zooplankton and Phytoplankton
06/22/18	SR (Control Site) long term post-treatment Surveys for Macrophytes, Benthic Macroinvertebrate, Chlorophyll, Periphyton, Zooplankton and Phytoplankton
07/26/18	IRI monthly photo monitoring
08/01/18	IRI site visit and photo monitoring
08/10/18	IRI monthly photo monitoring
09/10/18	IRI monthly photo monitoring
08/13/18	LSM and LSB (Swim and Taxi) long term post-treatment Macrophyte surveys
10/03/18	Advisory Group meeting - Final Monitoring Report directives and review of preliminary data graphs

Table 1. Project Timeline & Summary of Work Completed During the Reporting Period	
Date	**Project Action/Status**
11/8/18	Draft Macrophyte, Benthic Macroinvertebrate and periphyton results provided to Advisory Group for review and feedback
12/03/18	Draft Final Monitoring Report to Advisory Group for review
12/15/18	Draft Final Monitoring Report submitted to TRCD for review, Board review, approval and submittal
12/31/18	Draft Final Monitoring Report due to Tahoe RCD
03/31/19	Final Monitoring Report due to Conservancy

6 Project Permitting and Approvals

Project permits and approvals are provided in **Appendix E**.

6.1 Tahoe Regional Planning Agency

TRPA issued permit, EIPC2017-008, for UV Light Pilot Project for the Control of Aquatic Invasive Plants, Project number 570-000-00.

6.2 Lahontan Regional Water Quality Control Board

No permit was required; however, input was provided towards the monitoring plan to incorporate specific monitoring parameters that the Water Board desired (Email correspondence from March 3 to April 20, 2017).

6.3 California Department of Fish and Wildlife

CDFW determined that because of the small size of the pilot Project (approximately 0.22 Acres or treated area) that neither a 1600 agreement nor CEQA would be required by the CDFW, as documented in an email from Mr. Bob Hosea on March 22, 2017. Monitoring for potential effects to periphyton, plankton and benthic macroinvertebrates were requested, and this biomonitoring was included in the pilot Project.

6.4 United State Army Corps of Engineers

USACE issued a letter dated April 27, 2017 authorizing the project under Nationwide Permit Number 27: Aquatic Habitat Restoration, Establishment and Enhancement Activities, Regulatory Division (SPK-2012-00564).

6.5 California State Lands Commission

California State lands Commission issued a letter of non-objection on March 15, 2017 (file reference PRC 8994.9).

7 Approach and Methodology

This section details the field methods used for UV-C plant control applications, biomonitoring (BMI, chlorophyll, periphyton, phytoplankton, and zooplankton), and water quality monitoring. Laboratory methods and reporting are also presented.

Environmental factors were observed and documented during active treatment and monitoring activities but are considered to be uncontrolled variables and are outside of the scope of the analyses conducted for this pilot Project. Such factors included: variable lake levels, greater vulnerability to increased temperature from climate change, air temperatures and wind speed, impacts from nearshore recreation (i.e. boat activity and other water sport recreation traffic), domestic animal and wildlife activity, nearshore structures and habitat (seasonal stream runoff) and wave action.

7.1 UV-C Plant Control Application

Inventive Resources Inc. (IRI) has developed a patented treatment method and vessel that uses ultraviolet light (UV-C) to treat AIP. IRI was contracted to test specific areas of Lakeside Marina and Lakeside Beach as part of this 2017 Pilot Project to confirm AIP mortality results achieved in laboratory testing and to better define treatment duration and AIP regrowth responses. UV-C light treatment applications are also being studied to determine feasibility and cost effectiveness for larger scale AIP management program applications. Considerable effort has been invested in laboratory testing, QA/QC, fabrication, and beta testing of the UV-C light treatment method and treatment vessel by IRI outside the scope of this Project.

IRI designed and manufactured proprietary UV-C lamps designed specifically for treatment of aquatic plants. These lights are assembled into a chamber. The UV-C treatment device has a drop chamber that contains UV-C lamps arranged so they are within six (6) inches (i.e., 15 cm) of aquatic plants. The UV-C light chamber deflects the taller plant downward and consolidates them under the chamber for treatment. The most lethal range of ultraviolet light wavelength for plants is in the spectrum of 200 to 280 nanometers (nm). This is known in the industry as the Germicidal Spectrum. The peak germicidal wavelength is 254 nm and is the selected wavelength for this project. When plant cells are exposed to the high energy associated with UV-C short wavelength light at 254 nm the energy is absorbed by plant DNA structure, causing cellular damage. This energy absorption forms new bonds between adjacent nucleotides, creating dimers. The dimers form and prevent replication. The affected cell is neutralized and is then unable to reproduce. High intensity light (mW/cm^2) and exposure time (minutes) determined how quickly a susceptible cell was disabled by UV-C light. Ultraviolet light energy breaks organic molecular bonds. This bond breakage results in cellular damage and the eventual destruction and decomposition of the plant.

IRI mobilized the UV-C light treatment vessel to LSM, recorded existing treatment area conditions, and submitted the treatment plan (i.e., proposed schedule and treatment regime) to the Advisory Team. **Photo 1** illustrates the IRI treatment vessel and IRI technicians conducting UV-C light treatment at LSM in June 2017. IRI technicians conducted UV-C light treatment as described in **Table 1**. IRI submitted monthly progress summary reports and other pertinent data, including underwater camera video and photo documentation, which captured plant mortality and decomposition throughout 2017 and documented post-treatment conditions through September 2018.

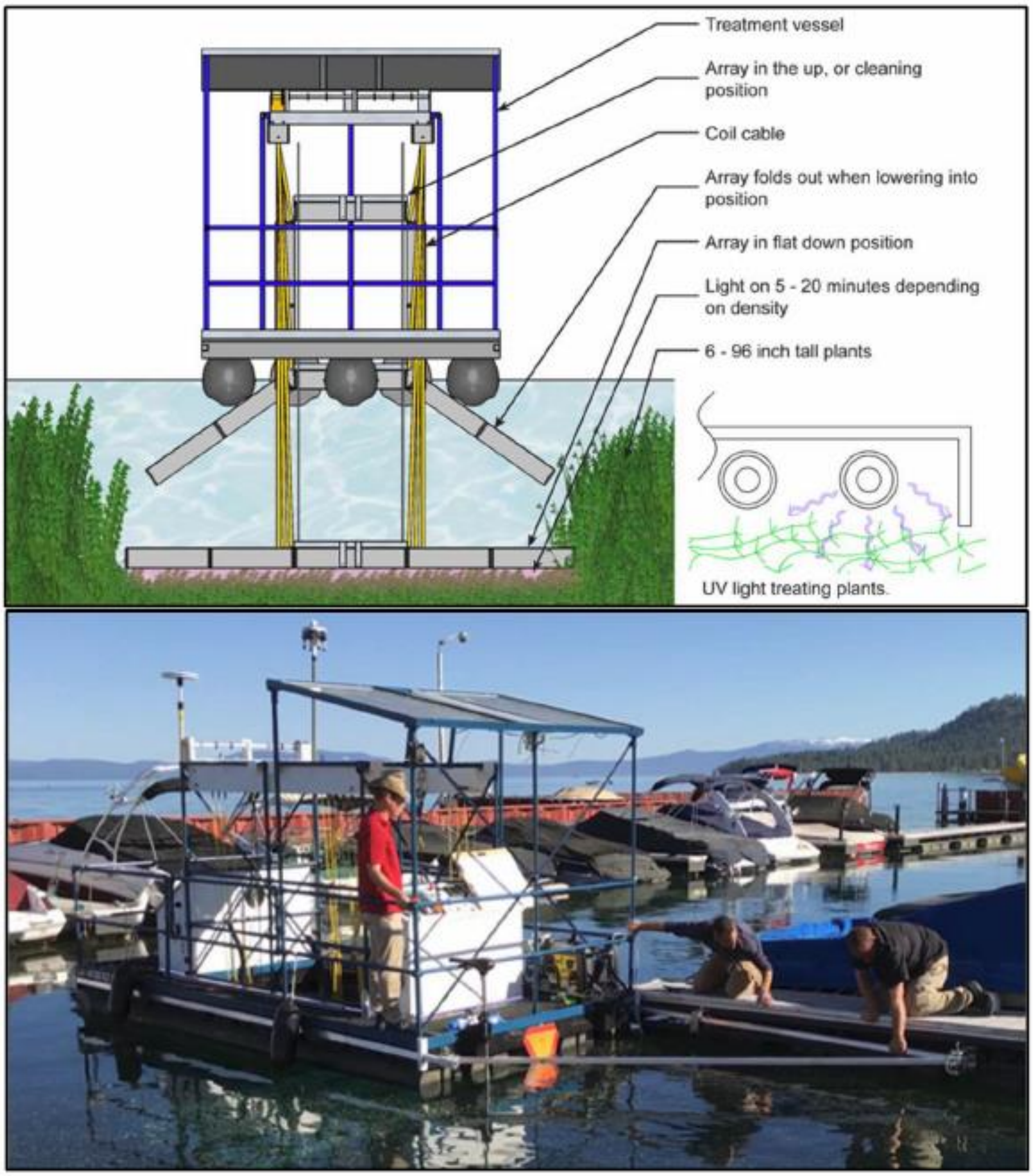

Photo 1. IRI's UV-C light treatment vessel

Source: IRI 2017

The following subsections summarize UV-C light treatment approach and methods, including: field reconnaissance, site plan development, establishment of water quality monitoring points for grab samples, treatment plan development, mobilization, treatment application and visual monitoring.

7.1.1 Field Reconnaissance

IRI technicians conducted field reconnaissance in May 2017. Technicians visited the treatment sites several times, noting obstacles, existing aquatic plant communities, stage of plant development, general treatment site conditions and potential site constraints. Underwater photos were taken and existing conditions such as plant types, height and approximate density of vegetation were documented. Preliminary aerial photos of the treatment sites were taken. Additionally, treatment areas were scanned for access of the treatment vessel, which would allow for take in/take out and/or the area for crane use, if needed. A crane was not necessary because the boat launch was accessible throughout the course of the pilot Project.

7.1.2 Site Plans

Information and observations collected during field reconnaissance were used to prepare the site plans. These plans delineate the treatment area boundaries, identify obstructions such as fences, structures and proposed benthic barrier matted areas and identify access points for the treatment vessel. Global Positioning System (GPS) coordinates were recorded to reference and delineate the treatment area boundaries for repeatability. The LSM and LSB Site Plans were completed and submitted to Tahoe RCD.

7.1.3 Water Quality Monitoring for Treatment Area, Safety and Maintenance

After the site plans were developed and approved, water quality monitoring locations were identified, based on access and overall capture of representative water quality within the treatment sites. The GPS coordinates were recorded for each water quality monitoring point location and submitted with the Treatment Plan. IRI technicians conducted daily water quality sampling at representative monitoring points and recorded information on the daily water quality monitoring form. This information was presented in monthly reports to Tahoe RCD during active UV-C light treatment.

IRI water quality monitoring requirements included daily collection of the following parameters:

- Sample collection times
- GPS coordinates of sample/Monitoring point location
- Temperature, °C
- Dissolved Oxygen
- pH
- Specific Conductivity
- Total Dissolved Solids
- Turbidity

Field monitoring equipment used to measure the aforementioned parameters included an YSI 556 Multi-parameter meter and a LaMotte 2020e unit. In addition, Tahoe RCD staff installed a FTS DTS-12 Turbidity sensor on the treatment vessel for continuous turbidity monitoring during active treatment. Water quality samples were tested as grab samples. Datasheets, calibration and cleaning logs were maintained and submitted with monthly reporting. Weather information was tracked through the National Oceanic and Atmospheric Administration (NOAA) database and website and collected on a daily basis for weather forecast and Lake Tahoe lake levels. This information was also submitted with the monthly reports to Tahoe RCD. Monthly reports and field monitoring forms can be found in **Appendix B**.

Although the UV-C light treatment array is shielded, and UV-C light is housed within a compartment, personal protective equipment (PPE) was worn by IRI technicians when operating the UV-C light array and during troubleshooting and equipment cleaning. The PPE consisted of eye protection (e.g., UV resistant eye wear), ear phones or head set for ease of speaking to other technicians, and gloves when handling lights. Sunscreen, hats, water and coastguard-approved personal flotation devices were also maintained on the treatment vessel at all times.

7.1.4 Treatment Plans

The LSM Treatment Plan presents a grid map of each treatment sites. Each grid was labeled for identification and repeatability, a clearance height recommended based on plant height, as detailed in **Table 2**. Preliminary treatment duration for each treatment grid was identified, based on a combination of observed plant type, height and density. Effective treatment durations are detailed in **Table 3**. The LSM Treatment Plan was developed and submitted to Tahoe RCD in July 2017.

For the LSM treatment site, each boat slip was divided into 10 treatment grids. For example, if one were to walk through Dock Walkway 2 and turn into Dock Walkway 3 each slip will have a walkway. These Piers (arms) are labeled 1 through 19. Pier 1 has treatment grids A6-A10 and B6-B10, Pier 2 has Grids C6-C10 and D6-D10, and so forth, listed in **Table 4**. Every grid consistently had the same steady state UV-C light intensity and treatment duration of approximately fifteen minutes.

Table 2. Recommended Array Height/Clearance

Plant Height Category	Array Height (approximate distance from lake bottom to treatment array)
Low height plants (under 12 inches)	6-12 inches
Medium height plants (12-48 inches)	12-24 inches
Tall height plants (over 48 inches)	12-72 inches

Source: IRI 2018

Table 3. Treatment Durations	
Plant Density Category	**Treatment Duration *(in minutes)***
Low height plants (under 12 inches)	5-10
Medium height plants (1-4 feet)	10-15
Tall height plants (over 4 feet)	15-20

Source: IRI 2018

Treatment vessel repositioning times varied between 5 and 20 minutes, as dictated by site constraints and lake conditions. The Treatment Plan included a total of 174 treatment grids within 19 boat slips and the ingress/egress channel. For those areas observed to have denser plant communities and higher plant canopy heights, IRI technicians treated the taller plants first (i.e., LSM phase 1), and once the taller plants dropped from the water column, a second round (i.e., LSM phase 2) of UV-C light treatment was applied to the sub-canopy plants that were then exposed.

Depending on observed plant height and the presence of any underwater obstructions, the treatment array was lowered into the water column to the recommended clearance depth. Recommended treatment array height and durations were starting points with field adjustments conducted in response to changing lake conditions resulting from boat traffic and weather. In addition, the existing conditions survey of the LSM revealed a substantial amount of muck/sediment that was about 6 to 12 inches in depth. IRI technicians maintained the treatment array at least one (1) foot above this layer to avoid and minimize sediment and lake bed disturbance.

The LSM Piers had GPS locations determined in degrees and decimal minutes (DDM). **Table 4** indicates the treatment grids and GPS locations that are associated with each boat slip/pier and henceforth referred to as Pier. Again, each Pier was delineated into 10 treatment grids. **Figure 6** illustrates the 174 treatment grids delineated within 16 boat slips and the channels of the LSM main throughway. Grids R3 through U7, located on the boat slips nearest the exit of LSM into the open water, were treated with benthic barriers by MTS and are not considered a part of the pilot Project.

Table 4. Crosswalk for Lakeside Marina Treatment Grids Illustrated in Figure 6		
Location	**GPS Coordinates**	**Grids**
Pier 1	38.958530, -119.951876	A6-A10, B6-B10
Pier 2	38.958586, -119.951843	C6-C10, D6-D10
Pier 3	38.958643, -119.951812	E6-E10, F6-F10
Pier 4	38.958697, -119.951778	G6-G10, H6-H10
Pier 5	38.958750, -119.951745	I6-I10, J6-J10
Pier 6	38.958804, -119.951712	K6-K10, L6-L10

Table 4. Crosswalk for Lakeside Marina Treatment Grids Illustrated in Figure 6		
Location	**GPS Coordinates**	**Grids**
Pier 7	38.958860, -119.951678	M6-M10, N5-N10
Pier 8	38.958888, -119.951660	O5-O10
Pier 9	38.958565, -119.951968	A1-A5, B1-B5
Pier 10	38.958620, -119.951932	C1-C5, D1-D5
Pier 11	38.958674, -119.951901	E1-E5, F1-F5
Pier 12	38.958730, -119.951868	G1-G5, H1-H5
Pier 13	38.958783, -119.951837	I1-I5, J1-J5
Pier 14	38.958840, -119.951804	K1-K5, L1-L5
Pier 15	38.958866, -119.951785	M1-M5
Pier 16	38.958940, -119.951748	P1-P7
Pier 17	38.958971, -119.951814	Q3-Q7, R3-R7
Pier 18	38.958986, -119.951853	S3-S7
Pier 19	38.959001, -119.951895	T3-T7, U3-U7
Pt 20a*	38.958485, -119.951932	NONE
Pt 21a*	38.958570, -119.952074	NONE
Pt 22a*	38.958658, -119.952021	NONE
Pt 23a*	38.958880, -119.951882	NONE

*These points are discretionary points outside the project treatment area.

Source: 2017 Progress Report Attachment B - 20171106 Existing Conditions Beach and Taxi Area COMPLETE.pdf

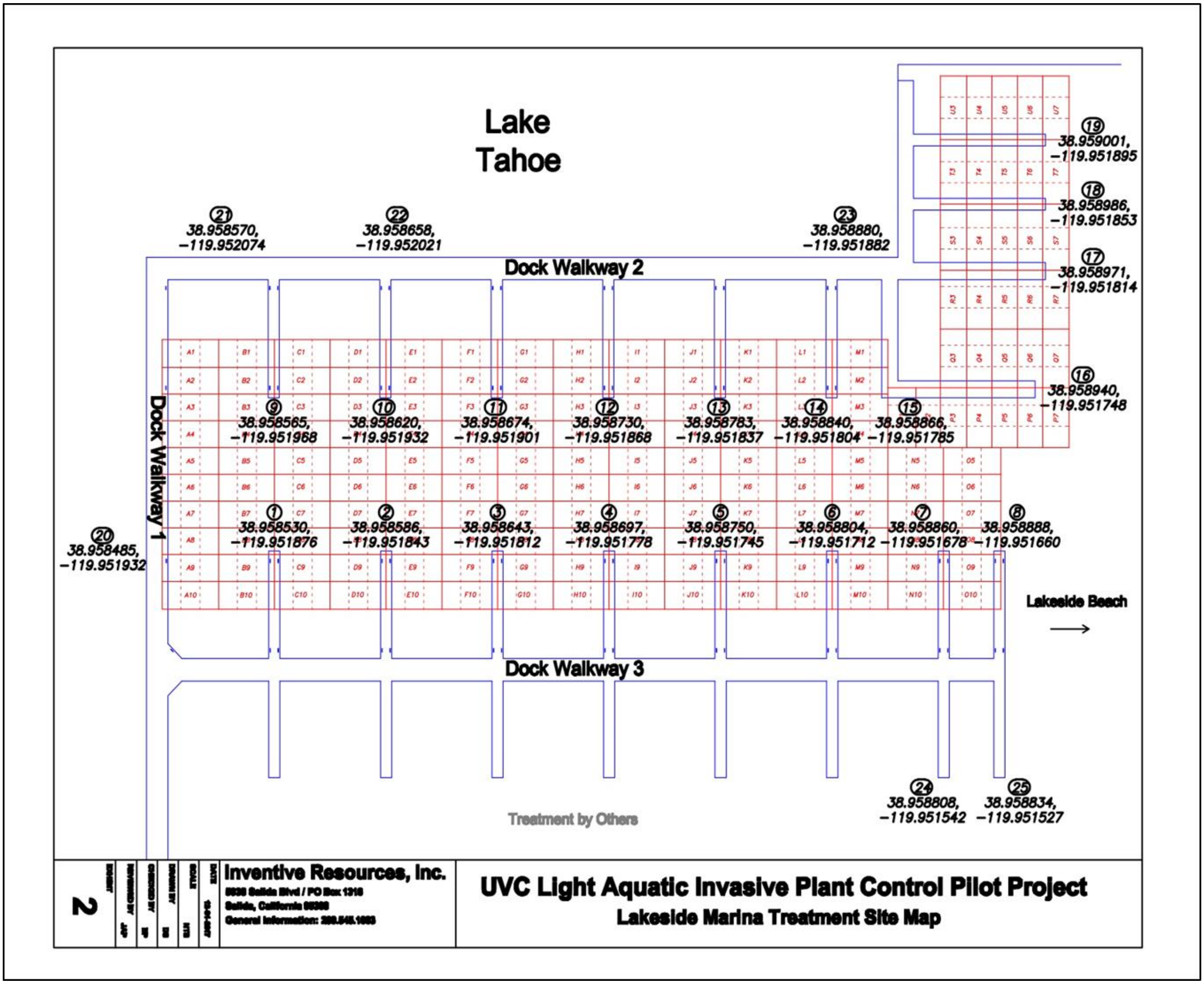

Figure 6. Treatment site map for LSM

The LSB Treatment Plan for the LSB-Taxi and LSB-Swim littoral sites was developed and submitted to Tahoe RCD on November 6, 2017. **Figure 7** depicts the treatment site map developed for LSB-Taxi and **Figure 8** depicts the treatment site map developed for LSB-Swim. For LSB-Taxi and LSB-Swim, the treatment area was divided into 72 treatment grids and 48 treatment grids, respectively. For visual purposes **Figure 7** has the grids labeled with the prefix "T" for Taxi and the grid number 1, 2, 3 and so forth with respect to the end of the walkway; if an one were to walk to the LSB-Taxi area, the farthest tip of dock is labeled T-A1 and the farthest grid away from the dock is T-D1. These grids are labeled 1 through 18 as illustrated in **Figure 7**. **Figure 8** has labeled the LSB-Swim grids with the prefix "B" for the Beach and the grid number 1, 2, 3 and so forth are labeled from the farthest point relative to the beach and rows A, B and so forth relatively numbered from west to east. These grids are labeled 1 through 6 as depicted in **Figure 8**. Every grid had consistently the same steady state UV-C light treatment intensity and duration of approximately 15 minutes.

GPS locations were recorded for the LSB grids for repeatability. **Table 5** and **Table 6** present the treatment point locations, GPS coordinates and grids for the LSB-Taxi and LSB-Swim sites, respectively. Points 1 through 3 are monitoring points for the LSB-Taxi and Points 4 through 10 are monitoring points for LSB-Swim. GPS coordinates are in degrees and decimal minutes (DMM). The tables also indicate which treatment grids are within each sample monitoring point.

Table 5. GPS Coordinates – LSB Taxi

Location	GPS Coordinates	Grids
Point 1	38.959104, -119.951772	None
Point 2	38.959024, -119.951617	None
Point 3	38.959063, -119.951621	T-A1 through T-D18

Source: IRI Existing Condition Report (Appendix B)

Table 6. GPS Coordinates – LSB Swim

Location	GPS Coordinates	Grids
Point 4	38.960424, -119.951284	B-A5, B-B5, B-C5, B-D5
Point 5	38.960436, -119.951243	B-A6, B-B6, B-C6
Point 6	38.960412, -119.951457	B-B3, B-B4, B-C3, B-C4, B-D3, B-D4
Point 7	38.960433, -119.951378	B-B3, B-B4, B-C3, B-C4, B-D3, B-D4
Point 8	38.960456, -119.951476	B-E1, B-F1, B-G1
Point 9	38.960468, -119.951434	B-E2, B-E3, B-F2, B-F3, B-G2, B-G3
Point 10	38.960497, -119.951314	B-E4, B-E5, B-F4, B-F5, B-G4, B-G5
Point 11	38.960509, -119.951276	B-D6, B-E6,B-F6, B-G6
Point 12	38.960500, -119.951495	B-H1, B-H2, B-I1, B-I2
Point 13	38.960520, -119.951412	B-H3, B-H4, B-I3, B-I4
Point 14	38.960550, -119.951295	B-H5, B-H6, B-I5, B-I6

Source: IRI Existing Condition Report (Appendix B)

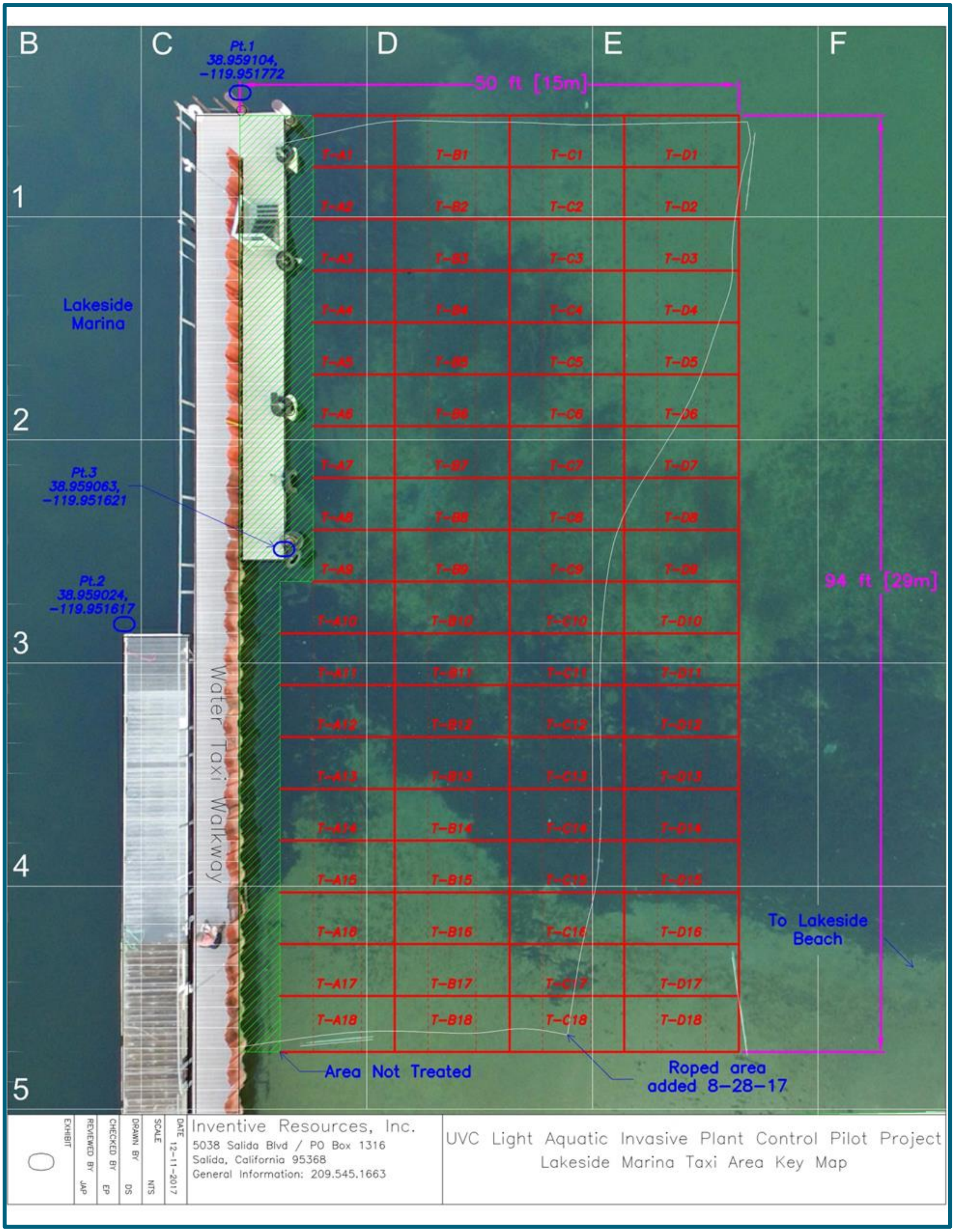

Figure 7. Treatment site map for LSB-Taxi

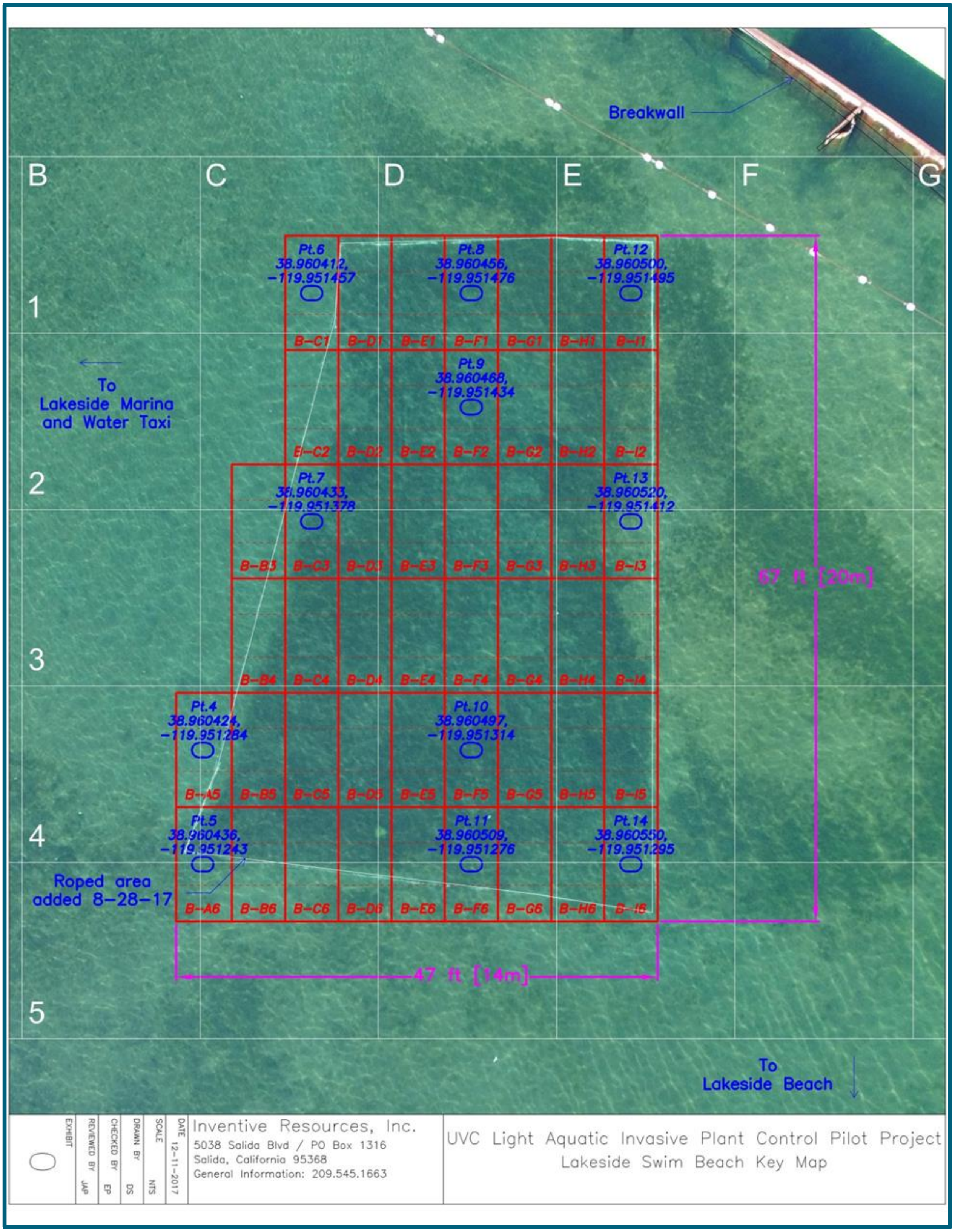

Figure 8. Treatment site map for LSB-Swim

7.1.5 Mobilization

Once necessary approvals and permits from local agencies were issued, the treatment vessel was mobilized to LSM, and a boat inspection and safety check were performed. Mobilization to LSM occurred on June 21 and 22, 2017. Boat inspection was conducted by a Tahoe RCD certified boat inspector for evidence of any water or AIP inside and around all compartments of treatment vessel, including anchor, tanks, ropes and any areas where water is held. A safety check included maneuvering techniques of vessel, calibration of all installed equipment and any water quality instruments that were carried onsite by IRI vessel operators.

Operational testing began on the morning of June 22, 2017 and active treatment at LSM began on June 23, 2017. The UV-C light treatment vessel was assembled and docked at LSM throughout the pilot project. Operations included setting up, photographic/video monitoring in the morning, treatment, working with marina staff as they moved boats around for UV-C light treatment or for customer use, light array cleaning (pollen and sediment build up), and securing site before end of treatment day. Vessel was also used to take photographs in harder to reach grids away from the dock.

7.1.6 UV-C Light Treatment Application

Active treatment was conducted in treatment areas (11,800 square feet) from June 23 through September 11, 2017. **Table 1** details the active treatment implementation timeline. Additional details regarding UV-C light treatment are presented in IRI's monthly reports for June, July, August and September 2017, presented in **Appendix B**.

The treatment vessel was moved to each grid and the light array was lowered to a specific height, no closer than six (6) inches from the lake bed surface to avoid any sediment or lake bed disturbance and fouling of the array lights. UV-C light treatment was approximately 15 minutes unless otherwise noted in monthly reports. IRI operators moved and adjusted treatment array at each grid according to treatment plan and existing field conditions.

Operations included setting up, photographic/video monitoring in the morning, treatment, working with marina staff as they moved boats around for UV-C light treatment or for customer use, light array cleaning (pollen and sediment build up), and securing site before end of treatment day. Vessel was also used to take photographs in harder to reach grids away from the dock. IRI operators kept in close communication with the marina manager and were given at least a 24-hour notice if a parked boat needed to be moved by marina staff. Safety checks, cleaning and maintenance on treatment array and vessel were completed as needed, but typically done at least once per week. Refueling of propane for generators was completed as needed, typically at the end of each treatment day.

Weather forecast was reviewed on a daily basis and if wind gusts were forecasted, operators planned accordingly and allowed extra time for securing treatment vessel with bracing. No treatment occurred during red flag warning or if weather conditions appeared unsafe for treatment. Monthly treatment, calibration, monitoring, cleaning and maintenance reports were submitted to Tahoe RCD. These reports were submitted to Tahoe RCD in June, July, August and September 2017. IRI continued to conduct visual field observations and photo monitoring monthly through September 2018. These monthly reports are attached in **Appendix B**.

7.2 Fish Deterrent Systems

The pilot project used a 4ft x 8ft x 2ft UV-C light treatment array. Treatment occurs immediately beneath this array. The housing was equipped with four underwater cameras to allow observation of what was being treated. When the array lowers, the operator can see if fish are present. If fish are present, the operator can activate one or more of the following deterrents equipped on the treatment vessel:

- Acoustic- Suitable for deflecting migrating fish, resident coarse fish, estuarine and marine fish. The most widely used behavioral system.
- Strobe light- Used in conjunction with other behavioral systems. Suitable for deflecting fish less sensitive to sound, such as eels.
- Bubble curtains- Suitable for guiding fish to a point downstream.

7.3 Macrophyte Surveys and Biomonitoring – Field Methods

Biomonitoring included sampling of periphyton, phytoplankton, zooplankton, chlorophyll-*a*, benthic macro-invertebrates, and submerged aquatic plants. Surveys were administered by Marine Taxonomic Services, Ltd. (MTS) at the LSM and LSB treatment sites and MM and SR control sites. Control sites were selected based on location and comparable environmental conditions relative to the treatment site, specifically for enclosed (e.g., marina) and open (e.g., littoral) water bodies. LSM and LSB treatment sites were surveyed for macrophytes pre-treatment, immediately post-treatment in 2017, approximately one year after the 2017 initial survey date to represent long term post-treatment conditions and then again in August 2018 to represent long term post-treatment conditions further into the growing season. Control sites were sampled pre-treatment and post-treatment, approximately one year after the pre-treatment surveys, representative of the early growing season. No immediate post-treatment samples were taken at the control sites.

Chlorophyll-*a*, periphyton, and plankton samples were processed according to methodologies outlined in the *Analysis of Biological Samples: Technical Summary of Methods provided by Rhithron Associates, Inc.* (Rhithron 2017) and attached in **Appendix B**. BMI samples sent out for taxonomy were processed according to laboratory protocols provided *by Robert Wisseman at Aquatic Biology Associates, Inc.* and attached in **Appendix B**. **Table 7** lists survey sites with corresponding dates of survey and survey methodology.

Table 7. Biomonitoring Survey and Sampling Sites

Location	Date	Treatment or Reference	Method	Transect Number	Length (meters)	Quadrat Count
Lakeside Marina (LSM Treatment)	6/12/17	Pre-Treatment	All	1	50	26
				2	50	26
	9/16/17	Immediate Post-Treatment	Periphyton, Plankton, BMI	--	--	--
	10/8/17	Immediate Post-Treatment	Aquatic Invasive Plant	1	50	26
				2	50	26
	6/20/2018	Long-term Post-Treatment	Aquatic Invasive Plant	1	50	26
				2	50	26
	8/13/18	Long term Post-Treatment	All	1	50	26
				2	50	26
Meeks Marina (MM Control)	6/13/17	Pre-treatment	All	1	50	26
	06/21/18	Long term Post-Treatment		2	50	26
Lakeside Beach (LSB Treatment)	7/15/17	Pre-Treatment	All	1	30	16
				2	30	16
	9/16/17	Immediate Post-Treatment	Periphyton, Plankton, BMI	--	--	--
	10/8/17	Immediate Post-Treatment	Aquatic Invasive Plant	1	30	16
				2	30	16
	06/20/2017 and 6/21/2018	Long term Post-Treatment 1	Aquatic Invasive Plant	1	30	16
				2	30	16
	8/13/18	Long term Post-Treatment 2	All	1	30	16
				2	30	16
Ski Run (SR Control)	7/16/17	Pre-treatment	All	1	50	26
	06/22/18	Long term Post-treatment		2	50	26

Source: MTS field forms and technical summaries (Appendix B and C)

Figures 2, 3, 4 and 5 depict the 2017 and 2018 macrophyte survey transects and biomonitoring sampling locations for the LSM treatment site and paired MM control site and the LSB treatment sites and paired SR control site. Additional details regarding transects and sample locations are provided in **Appendix C**.

7.3.1 Macrophyte Transects

Survey of AIP occurred at five (5) locations: three (3) in treatment sites and two (2) in control sites. LSB (Swim and Taxi) is compared to the control site in the channel area of SR. LSM treatment site is compared to the control site in MM. Using a 100-meter transect tape, an MTS diver on SCUBA swam transects of appropriate size per study or reference area being surveyed. Every two (2) meters along transects the diver reported on plant species presence and percent cover within a 1/16 square meter quadrate.

LSM was surveyed on June 12, 2017 (pre-treatment), October 8, 2017 (immediate post-treatment), June 20, 2018 (long-term post-treatment 1) and August 13, 2018 (long-term post-treatment 2). The two (2) transects established within LSM were 50-meters long and a total of 26 quadrats were measured on each transect. The marina control site, MM, was surveyed on June 13, 2017 (pre-treatment) and June 21, 2018 (long-term post-treatment); two (2) 50-meter long transects were established and a total of 26 quadrats were measured along each transect.

LSB was surveyed on July 15, 2017 (pre-treatment), October 8, 2017 (immediate post-treatment), June 20 and 21, 2018 (long-term post-treatment 1) and August 13, 2018 (long-term post-treatment 2). On each of these dates two (2) 30-meter transects were surveyed and a total of 16 quadrats were measured along each transect. The littoral control site, SR, was surveyed on July 16, 2017 (pre-treatment) and June 22, 2018. Two (2) 50-meter transects were established and a total of 26 quadrats were measured along each transect.

7.3.2 Benthic Macroinvertebrates

BMI samples were collected by an MTS diver on SCUBA. The diver utilized a benthic suction sampler adapted from *Hiscock and Hoare* (1973) to extract benthic and epibenthic organisms from the sediment surface. A 0.5-millimeter (500 micron) mesh sampler bag was secured to the end of the benthic suction sampler to contain all organisms collected. Upon completion of the sampling event the mesh collection bag and contents were taken to shore, jarred, and preserved in 70% ethyl alcohol solution. BMI samples were transported by MTS technicians for sorting. Upon completion of BMI sample sorting the extracted animals were sent to Robert Wisseman at Aquatic Biology Associates, Inc. for taxonomy of species collected.

7.3.3 Periphyton

Periphyton samples were collected by a MTS diver on SCUBA. The diver used a large transfer pipette to suck water and algae from 25 square centimeters of the sediment surface. Material collected in the transfer pipette was transferred into a jar underwater and then preserved with a 2% gluteraraldehyde solution. Periphyton samples were couriered to Rhithron for analysis of soft algae and diatoms. Periphyton samples were analyzed following the method developed by the Academy of Natural Sciences, Philadelphia (ANSP 2002). Diatoms were identified to the most precise possible taxonomic level, generally species, following standard taxonomic references. Soft-bodied algae (non-diatom) were identified to species, where possible, using a Leica DM 2500 compound microscope under 200x and 400x magnification and following standard taxonomic references. Three hundred (300) cells or natural units of algae were identified. Living diatom cells were included in these counts (Including these cells will allow for the calculation of diatom species abundance). Measurements were taken of each diatom and non-diatom algae taxon in each sample and biovolumes were calculated using methods consistent with Hillebrand et al. 1999.

7.3.4 Plankton

Plankton samples were collected using a suction pump. The pump was lowered into the water from a vessel or dock until approximately in the middle of the water column. A calculated volume of water was sucked through the pump allowing for the capture of plankton in the terminal end of the pump. Once the given volume of water had been extracted, the pump was turned off and removed from the water column. The water was then filtered through a 63-micron mesh sieve to collect planktonic organisms. The contents of the sieve were collected in a sample container and preserved. This process was administered two times, once for phytoplankton and once for zooplankton. Phytoplankton was preserved in a 2% gluteraraldehyde solution. Zooplankton was preserved in a 70% ethyl alcohol solution. Preserved samples were shipped to Rhithron for analysis of contents. Measurements were taken of each phytoplankton taxon in each sample and biovolumes were calculated using methods consistent with Hillebrand et al. 1999. Zooplankton were identified to species, where possible, using a Leica DM 2500 compound microscope. A count of 300 specimens per sample was attempted.

7.3.5 Chlorophyll-*a*

For net primary productivity, the presence of chlorophyll-*a* can be viewed as a surrogate to assess productivity. To determine the relative presence of chlorophyll-*a* in each water body, 2,000 mL of water was passed through a glass microfiber filter (0.7 micrometers) under vacuum. The filters were folded, wrapped in aluminum foil, placed in sealed plastic bags, maintained on wet ice, and provided to a subcontractor laboratory (Rhithron) for measurement of chlorophyll-*a* mass. Chlorophyll-*a* samples were analyzed following the USEPA Method 446.0 (Arar 1997).

7.4 Biomonitoring – Laboratory Methods

For each set of samples, a chain of custody document was provided by MTS Project Manager. Upon arrival, samples were unpacked and examined, and checked against the chain of custody. All samples arrived in good condition. An inventory spreadsheet was created which included project code and internal laboratory identification numbers and was uploaded to the Rhithron database prior to sample processing. Laboratory technical summary reports are attached in **Appendix B**.

7.5 Water Quality Monitoring – Field Methods

Green(e) Consulting collected grab samples for pre-treatment water quality sampling (hourly), weekly active treatment water quality sampling, and immediate post-treatment water quality sampling (hourly) at the LSM and LSB treatment areas. The water quality parameters that were measured included: turbidity; dissolved oxygen; specific conductivity; pH; total dissolved solids; and water temperature. Field monitoring equipment used for the third-party QA/QC pre-treatment, active treatment and immediate post-treatment monitoring included the HACH 2100Q, Milwaukee Portable Dissolved Oxygen Meter (Model MW600), and Apera Instruments PC60 Premium Multi-Parameter Tester. The raw data are provided in **Appendix C**.

Pre-treatment water quality monitoring was conducted at LSM on June 11, 2017, grab sampling was conducted weekly during active UCV light treatment, and post-treatment monitoring was conducted on October 17, 2018. Pre-treatment monitoring at LSB was conducted on July 30, 2017, grab sampling was conducted weekly during active UV-C light treatment, and post-treatment monitoring was conducted on October 30, 2018.

IRI made best efforts to conduct monthly post-treatment monitoring site visits, weather permitting. Visual observations and photo monitoring of LSM and LSB treatment sites continued on a monthly basis through September 2018. During monitoring site visits, IRI technicians made visual observations of plant collapse, algae presence, new growth compared to continued growth, spread areas of growth, odor, and any visible changes in the treatment areas, including fish species and general size, water color, water odor, and any floating vegetation. Equipment used for monitoring included a handheld, waterproof video recorder to inspect underwater areas. **Table 1** reports the project timeline and includes the dates of the monthly site visits and **Table 8** in Section 8 below summarizes additional field observations. Photo documentation is provided in the IRI monthly reports submitted to the Tahoe RCD and Conservancy (**Appendix B**).

IRI water quality monitoring requirements at the LSM and LSB treatment sites included daily collection of the following parameters:

- Sample collection times
- GPS coordinates of sample
- Temperature, °C
- Dissolved Oxygen
- pH
- Specific Conductivity
- Total Dissolved Solids
- Turbidity

IRI technicians were responsible for daily water quality monitoring and reporting during periods of active UV-C light treatment. An YSI 556 multimeter was used to measure temperature, dissolved oxygen, pH, specific conductivity and total dissolved solids within the water column in the area of treatment. Grab samples were collected from the water column and turbidity was measured with a LaMotte 2020e turbidimeter.

8 Monitoring Results

Although all plants require some water to live, some can tolerate or even require an aqueous environment throughout their lifetime. Most macrophytes, aquatic plants growing in or near water, occur in freshwater environments. Macrophytes can be placed into three general categories based on overall habit:

- **Emergents:** Plants with some portions partially submerged in water, the other parts growing in the air above the water.
- **Submergents:** Plants with all parts totally submerged.
- **Floating:** Plants floating on the surface of the water, not rooted.

Macrophytes provide cover for fish, substrate for BMI and also produce oxygen and provide food for some fish and other wildlife. Macrophytes respond to a wide variety of environmental conditions, are easily sampled, do not typically require laboratory analysis and are used for calculating simple abundance metrics. The depth, density, diversity and types of macrophytes present in a system can be indicators of waterbody health. Where submerged aquatic macrophytes are abundant, these plants can have a significant influence on habitat structure, fishability, recreational use and nutrient dynamics.

The absence of macrophytes may indicate a problem such as excessive turbidity, herbicides or salinization that interfere with plant growth and development. However, it is important to note Lake Tahoe is an ultra-oligotrophic lake with cold water and low natural nutrient loads such that lack of macrophyte cover is not necessarily an indicator of water quality problems. An overabundance of macrophytes, however, can result from high nutrient levels and may affect ecosystem health, recreational activities and the aesthetic appeal of the system. When such macrophytes are also classified as an AIP, aquatic habitat structure and health and localized water quality, recreational use, and aesthetics can be significantly impacted.

The macrophytes observed during project implementation are depicted in **Photo 2a** through **2h** below. Plants encountered included CPW (*Potamogeton crispus*), EWM (*Myriophyllum spicatum*), Richardson's pondweed (*Potamogeton richardsonii*), Leafy pondweed (*Potamogeton foliosus*), Coontail (*Ceratophyllum demersum*), Elodea (*Elodea* sp.), Sago pondweed (*Stuckenia pectinata*), and filamentous algae.

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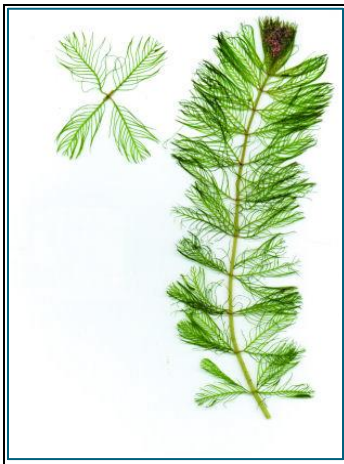
<tr>
<td>
Photo 2a</td>
<td>Eurasian Water-milfoil (Myriophyllum spicatum L.)
Characteristics: long underwater stems, feathery foliage, tolerant to shallow and deep waters, distinguished from native milfoil by threadlike leaflets usually found in pairs of more than 14
Primary Means of Introduction: native to Europe and Asia, present in much of the United States and Canada, spread from lake to lake by boat trailers and aquarium dumping, has been spreading around Lake Tahoe for 15-20 years
Problems: impedes water flow, disrupts navigation, inhibits recreational activities, decreases water quality, reduces plant diversity
Management: physical (hand pulling, harvesting, cutting) and mechanical control methods
Prevention: clean all vegetation off boats and equipment

Established communities are present in Lake Tahoe. Current management techniques controlling populations; eradication has not been achievable using current control methods.</td>
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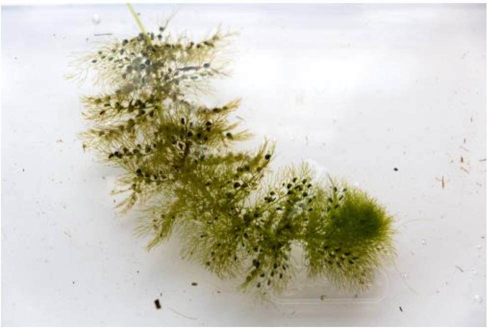
	Photo credit: Robert Johnson, Cornell University. Ruthanna Hawkins, Cayuga Lake Watershed Network
 Photo 2b	**Curly leaf pondweed (*Pontamogeton crispus L.*)** **Characteristics:** submersed aquatic plant with oblong blue-green leaves that have very wavy margin, reproduces by turions (see inset) **Primary Means of Introduction:** native to Eurasia, Africa, and Australia; has begun to expand rapidly in Lake Tahoe over the past three years; primarily has spread in warm, shallow waters (such as marinas) **Problems:** impedes water flow, disrupts navigation, inhibits recreational activities, decreases water quality, reduces plant diversity **Management:** physical (hand pulling, harvesting, cutting) and mechanical control **Prevention:** clean all vegetation off boats and equipment ***Established communities are present in Lake Tahoe. Current management techniques controlling populations; eradication has not been achievable using current control methods.*** **Photo credit:** Three Lakes Council, South Salem, New York Photo credit (inset): Leslie J. Mehrhoff, University of Connecticut
 Photo 2c	**Leafy pondweed (*Potamogeton foliosus*)** **Characteristics:** Linear leaves that are 2-10 cm long and 1-2.5 mm wide, fibrous roots emerging from threadlike rhizomes, flowers have 2-4 whorls on an initially crowded spike (1 cm) **Importance:** seeds and vegetation provide cover and food for aquatic animals **Photo credit:** Clayton Antieau, Washington State Department of Ecology
 Photo 2d	**Coontail (*Ceratophyllum demersum*)** **Characteristics:** floats freely below the surface, no roots, 0.5-4 cm long leaves are forked into 2 flattened segments, leaves often somewhat stiff, leaves arranged in whorls of 5 to 12, tiny submersed green flowers present from June through September **Importance:** provides habitat plant for young fish, small aquatic animals, and aquatic insects **Photo credit:** Clayton Antieau, Washington State Department of Ecology

 Photo 2e	**Canadian waterweed commonly known as Elodea (*Elodea canadensis*)** **Characteristics:** submersed leaves are bright green, translucent, oblong, 6-17 mm long and 1-4 mm broad; small white or pale purple flowers float at the surface **Importance:** provides good habitat for many aquatic invertebrates and cover for young fish and amphibians **Photo credit:** Christian Fischer
 Photo 2f	**Richardson pondweed *(Potamogeton richardsonii)*** **Characteristics:** Richardson's pondweed is similar to clasping-leaved pondweed (Potamogeton perfoliatus), but Richardson's pondweed has more acute leaf blade apices, and when the stipules disintegrate, fibrous strands of the veins persist. **Importance:** Native to Lake Tahoe **Photo credit:** Lars Anderson, PhD, from the League to Save Lake Tahoe's Eyes of the Lake Aquatic Plant ID Guide
 Photo 2g	**Sago pondweed (*Stuckenia pectinata*)** **Characteristics:** Sago pondweed is a very common species of submersed plant that is found in both lakes and ponds. When viewed from the surface of the water, it can resemble long strands of grass growing up from the bottom. The leaves are very thin and about the same size of a needle. The leaves grow in thick layers and originate from a sheath. The plant's flowers and fruit are produced on a slender stalk that may be submersed or floating on the water surface. Propagation occurs through vegetative fragmentation **Importance:** Inhibits other aquatic plants; good source of food for waterfowl but forms thick tangles **Photo credit:** Jack Kelly Clark, Regents of the University of California

 Photo 2h	**Common Bladderwort** ***(Utricularia macrorhiza)*** **Characteristics:** Common bladderwort has finely-divided branching leaves with oval-shaped "Bladders", a strong stem and two-lipped yellow flowers that grow above the water. The bladders are used to capture small aquatic organisms that are then digested inside the traps by enzymes and/or bacteria. **Importance:** Native to Lake Tahoe **Photo credit:** Chris Carney

Sources: Tahoe RCD and League to Save Lake Tahoe

Photo 2. Compilation of macrophyte species surveyed in the treatment and control sites

8.1 Application of the UV-C Plant Control Treatment

Table 8 provides the visual observations that were recorded during active UV-C light treatments and during IRI monitoring visits.

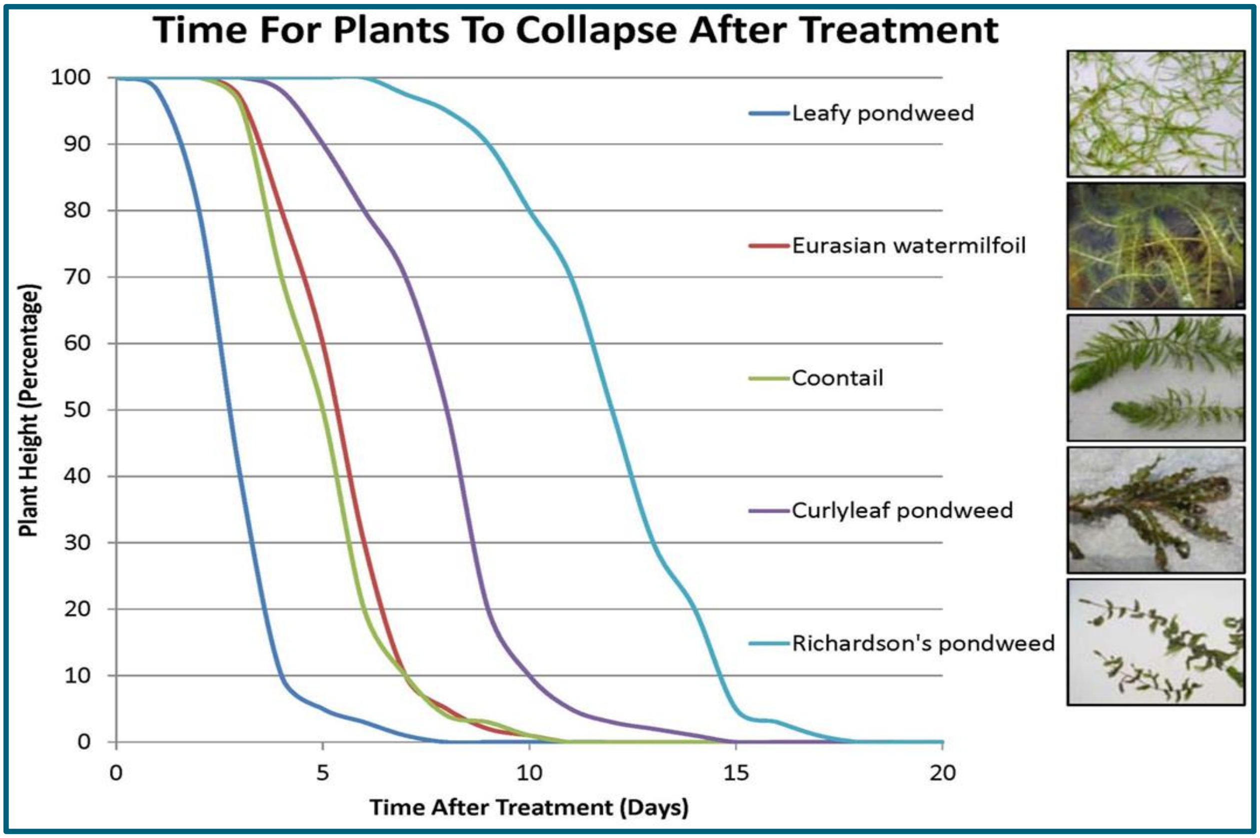
Table 8. IRI Field Observations

Site Visit Dates	Treatment Area	Observations
6/23/2017	LSM	LSM has a lot of vegetation. Some plants are near the water surface.
6/24/2017	LSM	Windy day caused debris to be swept into areas 16-19.
6/25/2017	LSM	Grids 4, 5 and 6 have plants that are about 2 feet from water surface. Heavy boat traffic. Thick layer of pollen in some closed corners of marina.
6/26/2017	LSM	Thick layer of pollen in some closed corners of marina.
6/27/2017	LSM	Windy day.
6/28/2017	LSM	Thick layer of pollen in closed corners of marina.
6/29/2017	LSM	Vegetation visible in several areas of marina that is just below the water surface.
6/30/2017	LSM	Heavy boat traffic. Area of treated and non-treated is becoming more evident.
7/1/2017	LSM	LSM has a lot of vegetation in areas that have not been treated. Some plants are at the water surface. Heavy Boat traffic.
7/3/2017	LSM	LSM has a lot of vegetation in areas that have not been treated. Some plants are at the water surface. Heavy Boat traffic.
7/4/2017	LSM	LSM has a lot of vegetation in areas that have not been treated. Some plants are at the water surface. Heavy Boat traffic and tourists all around Lakeside marina and beach.
7/6/2017	LSM	Rain in the afternoon.
7/7/2017	LSM	Clear day. Plant collapse is visible in area near Slip 1 and 9.
7/8/2017	LSM	Increased wind.
7/9/2017	LSM	Increased wind.
7/12/2017	LSM	Several plants are reaching water surface and turions are visible in many of the plants throughout the marina.
7/13/2017	LSM	Several plants are reaching water surface and turions are visible in many of the plants throughout the marina.

Table 8. IRI Field Observations		
Site Visit Dates	Treatment Area	Observations
7/14/2017	LSM	Turions present.
7/19/2017	LSM	Turions present. Treatment in LSM Phase 1 was completed.
8/1/2017	LSM	Slip 1 through 8 has visible plant collapse in marina.
8/9/2017	LSM	Slip 14-16 have the densest patches of vegetation have visible plant collapse in marina.
8/10/2017	LSM	Treatment of water taxi area and swim beach area Phase 1 has started.
8/28/2017	All sites	Phase 2 of marina treatment started today.
8/29/2017	All sites	Phase 2 of marina treatment.
8/30/2017	All sites	Tender growth observed in marina, in areas where heavy dense patches of plants were, this growth appeared to be from new seeds or young sprouts that quickly grew once they had the ability now that the larger hardier plants have collapsed and more light is available to the small plants.
9/4/2017	All sites	Sand is visible throughout marina.
9/10/2017	All sites	Sand is visible throughout marina.
10/29/2017	All sites	No sign of treated plants. Can see sand, some spots of rolling algae in marina. No plants visible in swim beach area, sand is visible to bottom.
11/22/2017	All sites	Slip 12 in marina full sand visible, no growth, no plants.
1/31/2018	All sites	Rolling algae in some of the areas of the marina. Ice on marina water surface near boats. No plants visible.
3/21/18	All sites	Sand visible throughout swim beach area.
4/29/2018	All sites	No plants visible. Some rolling algae present. Some areas full sand visible.
5/11/2018	All sites	No plants visible. Thin carpet of algae in marina area that moves when disturbed. Some plants starting to grow in diver-assisted suctioned area of swim beach, area of UV-C treatment still no plants visible and sandy bottom is visible. The treated area appears to have less vegetation, if any compared to other areas of the swim beach area. Visible line of treated area and piping still out from MTS. Spotted a few areas in the swim beach area with new sprouts of curly-leaf pondweed.
6/1/2018	All sites	Some small plants in marina are emerging from ground, looks like new plants from turion sprouts - Eurasian watermilfoil. Some areas have curly-leaf pondweed.
6/20/2018	All sites	Thin carpet of algae in marina with some sporadic vegetation starting to emerge in some areas. Large fish observed in marina. Plants do not have mature turions yet, but turions are green and visible.
7/7/2018	All sites	Water was murky throughout marina, possibly from heavy boater use over the holidays. Some curly-leaf pondweed visible. Mixture of plants growing on the bottom surface of the marina in a few areas. Some rolling algae.
7/12/2018	All sites	Some plants emerging through thin carpet of algae in marina.
7/26/2018	All sites	No plants visible in slip/pier 1, thin clusters of algae visible in marina. Diver assisted suction in non UV-C treated areas near swim beach area. Some plants visible in swim beach treated area.
7/30/2018	All sites	Thin layer of algae around pier/slip 15. No plants visible.

Source: IRI 2017 and 2018 monitoring reports (Appendix B)

Preliminary laboratory testing was performed on coontail, EWM and CPW in 2015 and additional laboratory testing has been ongoing. The observed field results for the Project are



consistent with laboratory testing results. **Figure 9** presents a compilation of data and observations collected in the field during the Project. Plant height shown on the Y-axis is plotted over time, as shown in Days plotted across the X-axis. The resultant graph illustrates the number of days that macrophytes (a mixture of leafy pondweed, coontail, Richardson's pondweed, EWM, and CPW) treated with UV-C light in LSM and LSB treatment areas took to lose turgor pressure and collapse to the lake bottom. The photo sequencing provided with **Figure 9** below illustrates this process of macrophytes dropping from the water column, as originally demonstrated in the laboratory setting with leafy pondweed.

Figure 9a. Time for plant collapse following UV-C light treatment application at LSM and LSB treatment sites

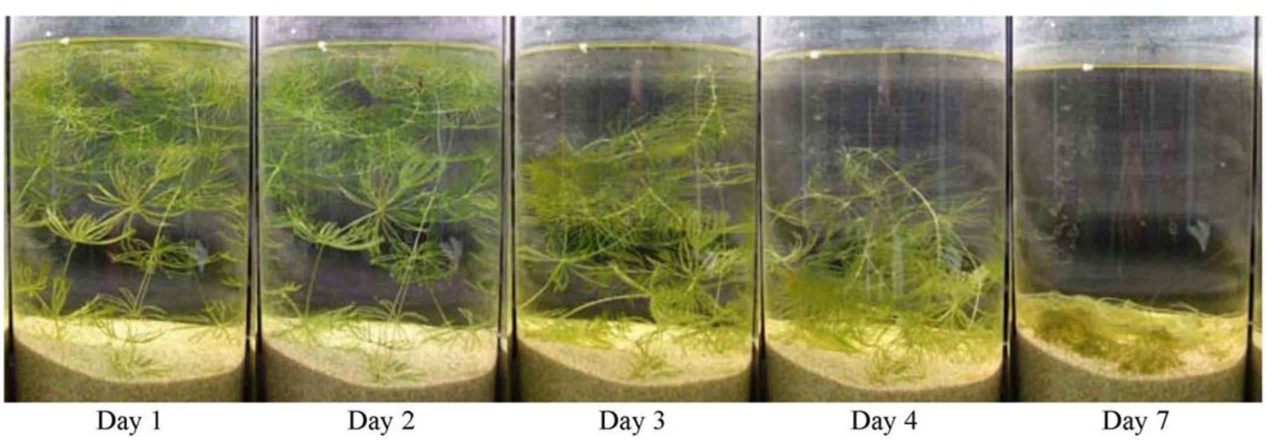


Figure 9b. Field results and lab results for plant collapse time generally aligned

Richardson's pondweed has a much thicker, denser leaf structure compared to all other species noted. In the field, this plant took the longest to collapse as noted in **Figure 9**. Richardson's pondweed was detected in only one treatment site location; therefore, limited data was collected to accurately plot Richardson's pondweed collapse time.

The time lapse sequence below, identified as **Photo 3** and **Photo 4** for reference, illustrate the response to field testing in LSM marina site over the 16-day period following UV-C light treatment. **Photo 5** illustrates the response to field testing at LSB-Swim littoral site over an eight (8) week period.

Photo 3. Photo documentation over a 16-day period following UV-C light treatment in the LSM, June 23, 2017 through July 14, 2017

Photo 4. Photo documentation over a 16-day period following UV-C light treatment in the LSM, June 30, 2017 through July 19, 2017

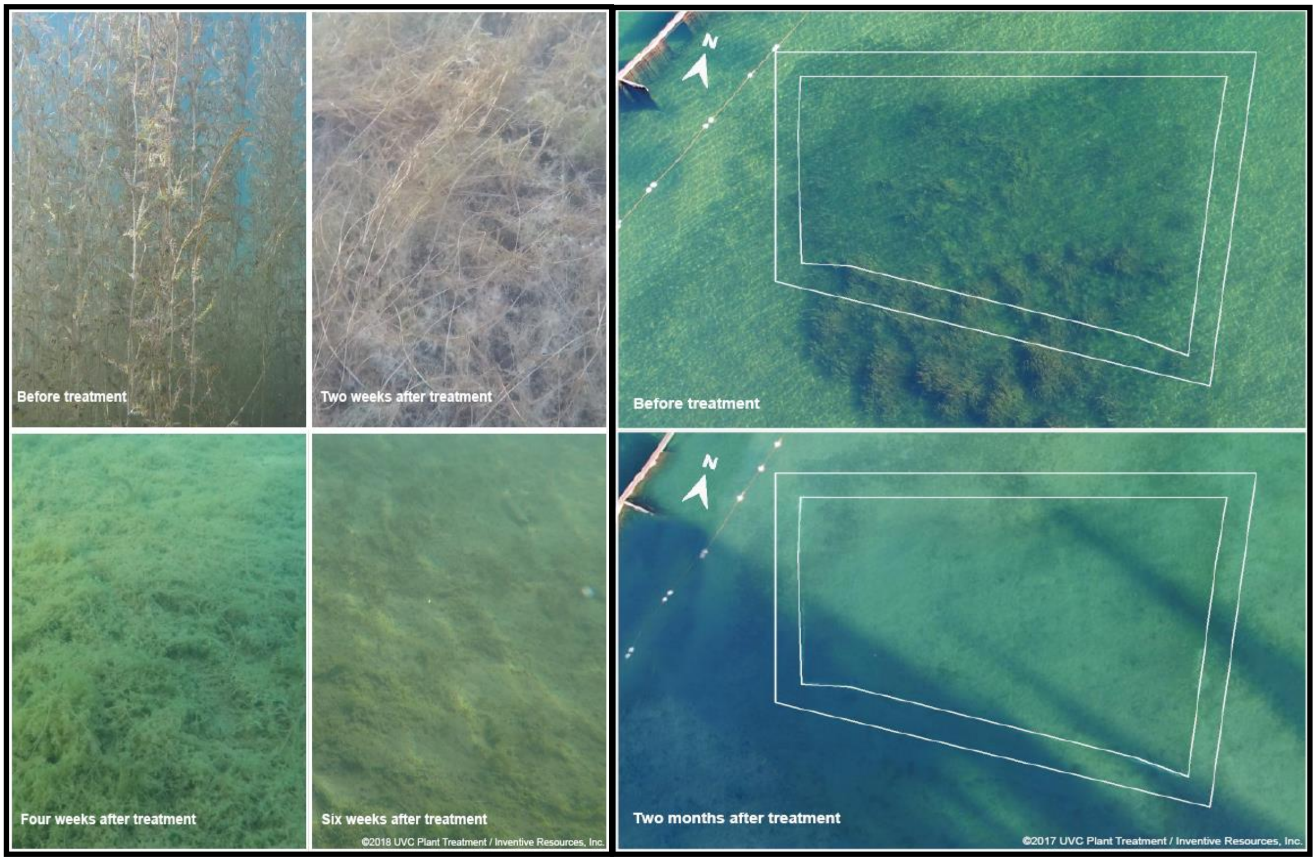


Photo 5. Photo documentation over a 2-month period following UV-C light treatment in the LSB-Swim

In LSM, Piers 1, 7, 8 and 9, for example, showed plants decrease in height dramatically between Day 5 and Day 7. While compared to the laboratory setting, full plant collapse (0% height) was observed within the Day 4 and 7. By reviewing the time-lapse underwater photographs, it was observed that the first macrophyte to collapse was leafy pondweed. This earlier collapse may be attributable to the thin leaf structure of this species. As discussed above, denser plants such as Richardson's pondweed took longer to collapse. **Appendix B** contains the IRI monthly monitoring reports.

8.2 Macrophyte Surveys (Percent Cover, Height, and Frequency of Occurrence)

Table 9 indicates the sampling regime for LSM and LSB treatment areas, along with the corresponding MM and SR control sites. Species were recorded, and plant height and percent cover measured. When no plants were present within transects, sample points were recorded as bare ground.

Table 9. Macrophyte Survey Location Names, Labels, and Dates					
	Marina Sites		**Littoral Sites**		
	LSM (Treatment)	**MM (Control)**	**LSB-Swim (Treatment)**	**LSB-Taxi (Treatment)**	**SR (Control)**
Pre-treatment	06/12/2017	06/13/2017	07/15/2017	07/15/2017	07/16/2017
Immediate Post-treatment	10/08/2017	--	10/08/2017	10/08/2017	--
Long-term Post-treatment 1	06/20/2018	06/21/2018	06/21/2018	06/20/2018	06/22/2018
Long-term Post-treatment 2	08/13/2018	--	08/13/2018	08/13/2018	--

Source: Appendix B, Report Files

Table 10 presents Mean Plant Cover and Mean Plant Height results by location, date and category. For purposes of the following macrophyte analyses for percent cover, plant height and frequency of occurrence, the following categories or groupings are utilized for reporting:

- **Native** – Leafy pondweed, Coontail, Richardson pondweed, Sago pondweed, Elodea, Bladderwort, Chara sp., Naiad sp., and aquatic moss
- **Invasiv**e – Eurasian watermilfoil (EWM), Curly-leaf pondweed (CPW)
- **Algae** – Filamentous algae
- **Bare** – No aquatic plant, algae or moss cover

For percent cover, the results that total 99% or 101% reflect the rounding of raw data.

Table 10. Mean Plant Cover and Mean Plant Height (by Location, Date, Plant Category)										
	Mean Plant Cover (%)					Mean Plant Height (cm)				
	Category	Pre-treatment	Immediate Post-Treatment	Long-term Post Treatment 1	Long-term Post-treatment 2	Category	Pre-treatment	Immediate Post-Treatment	Long-term Post Treatment 1	Long-term Post-treatment 2
LSB-Swim	Algae	0	0	0	0	Algae	0	0	0	0
	Bare	28	38	3	43	Bare	0	0	0	0
	Invasive	26	24	10	9	Invasive	73	15	13	34
	Native	46	37	60	48	Native	24	41	21	20
LSB-Taxi	Algae	0	10	0	0	Algae	0	14	0	0
	Bare	52	62	73	75	Bare	0	0	0	0
	Invasive	16	6	1	9	Invasive	24	13	8	18
	Native	32	23	26	16	Native	21	10	8	15
SR (Control)	Algae	0	--	0	--	Algae	0	--	0	--
	Bare	6	--	51	--	Bare	0	--	0	--
	Invasive	30	--	4	--	Invasive	88	--	11	--
	Native	64	--	44	--	Native	97	--	10	--
LSM	Algae	26	98	30	38	Algae	54	49	22	23
	Bare	0	1	0	7	Bare	0	0	0	0
	Invasive	23	1	5	1	Invasive	132	64	37	15
	Native	51	0	64	54	Native	99	7	34	40
MM-(Control)	Algae	0	--	1	--	Algae	0	--	0	--
	Bare	80	--	42	--	Bare	0	--	0	--
	Invasive	6	--	20	--	Invasive	16	--	37	--
	Native	15	--	37	--	Native	18	--	26	--

Source: Appendix C, Raw Data Files

8.2.1 Marina Sites

8.2.1.1 Percent Plant Cover

Percent plant cover was measured as canopy cover to estimate the area of influence of the plant or algae. For any area, the total canopy cover can exceed 100% because plants can overlap. Cover is thought to be more ecologically significant than density or frequency because it is an estimate of how much a plant dominates an ecosystem. Cover is expressed as percent (%) of area. Therefore, the meaning of cover is the same for natives, invasives and algae. Relative contribution of these different life-forms in the community can be easily understood.

The advantages of collecting cover data include:

- Used to measure a variety of life forms.
- Related to ecosystem processes and biomass.
- Does not require determining number of individuals within a species and is usually estimated by species.
- Used to easily measure plants at the ground surface.

The disadvantages of collecting cover data include:

- Most measures, with the exception of basal cover vary greatly depending on climatic conditions.
- Most measures with the exception of basal cover are affected by utilization of animals.
- Not always easy to estimate.
- Variation between observers because Cover is subjective, variation can occur between observers, and determination of the accuracy of the estimate is difficult.

Figure 10 depicts the marina sites' mean (or average) percent cover as a stacked 100% bar graph for comparison of pre-treatment cover composition to post-treatment cover composition. Focusing on Native and Invasive categories, UV-C light treatments at LSM resulted in mortality of plant species in both categories, as measured by immediate post-treatment. Immediate post-treatment results captured an increase in algae from 26% pre-treatment to 98%. Long-term post-treatment 1 results indicate that Natives re-established (64%), along with some Invasives (6%), while Algae decreased to 30%. Later in the growing season, Long-term Post-treatment 2 results indicate that percent cover of Natives persists but decreased by 10%. Meanwhile, Invasives appear to be outcompeted by Natives, with percent cover decreasing from 6% to 0% for Invasives.

Considering the MM control site, little to no Algae cover was measured pre-treatment or post-treatment. In the absence of UV-C light treatment, percent cover by both Natives and Invasives at MM increased between 2017 and 2018 surveys.

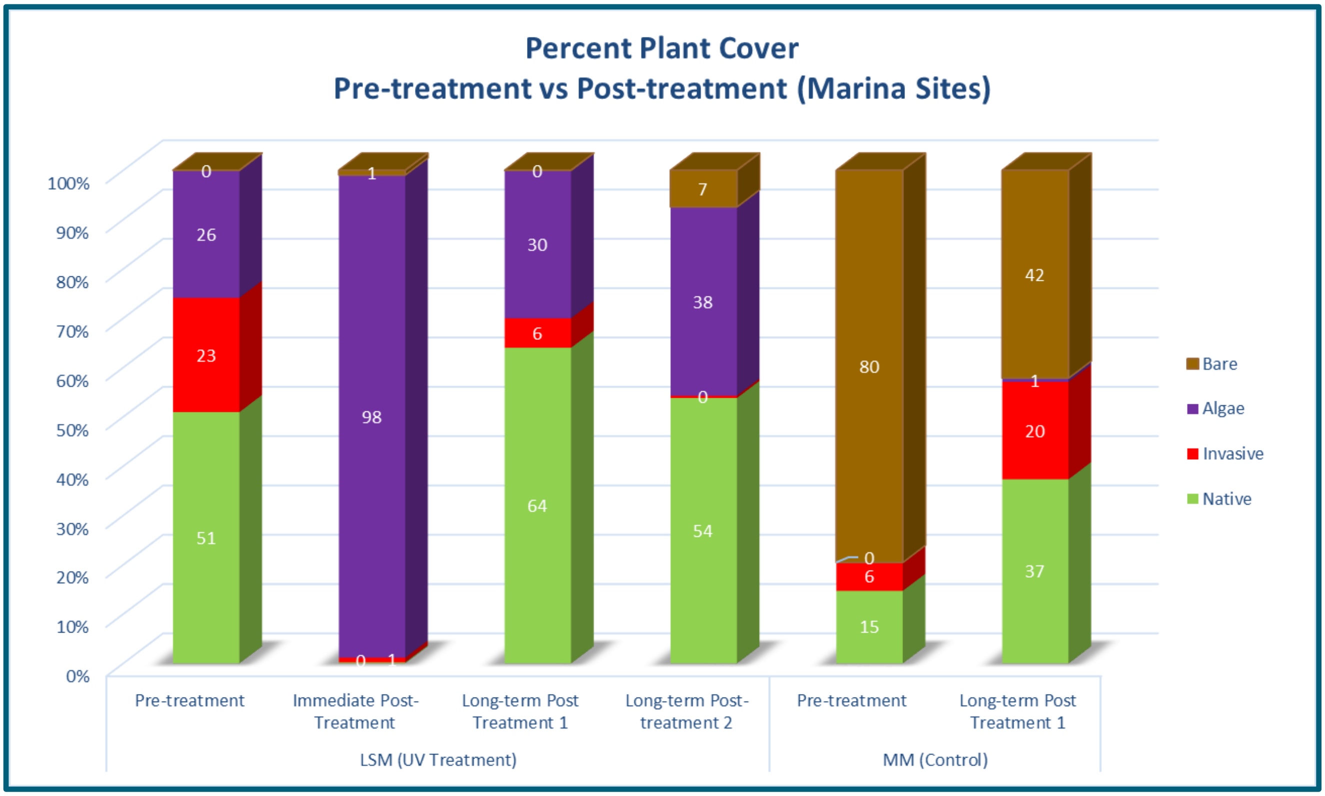


Figure 10. Stacked composite bar graph presented percent plant cover measured at marina sites for comparison of pre-treatment to post-treatment conditions

Figure 11 presents the same percent cover results for the marina sites by Plant Category for comparison of pre-treatment to post-treatment measurements.

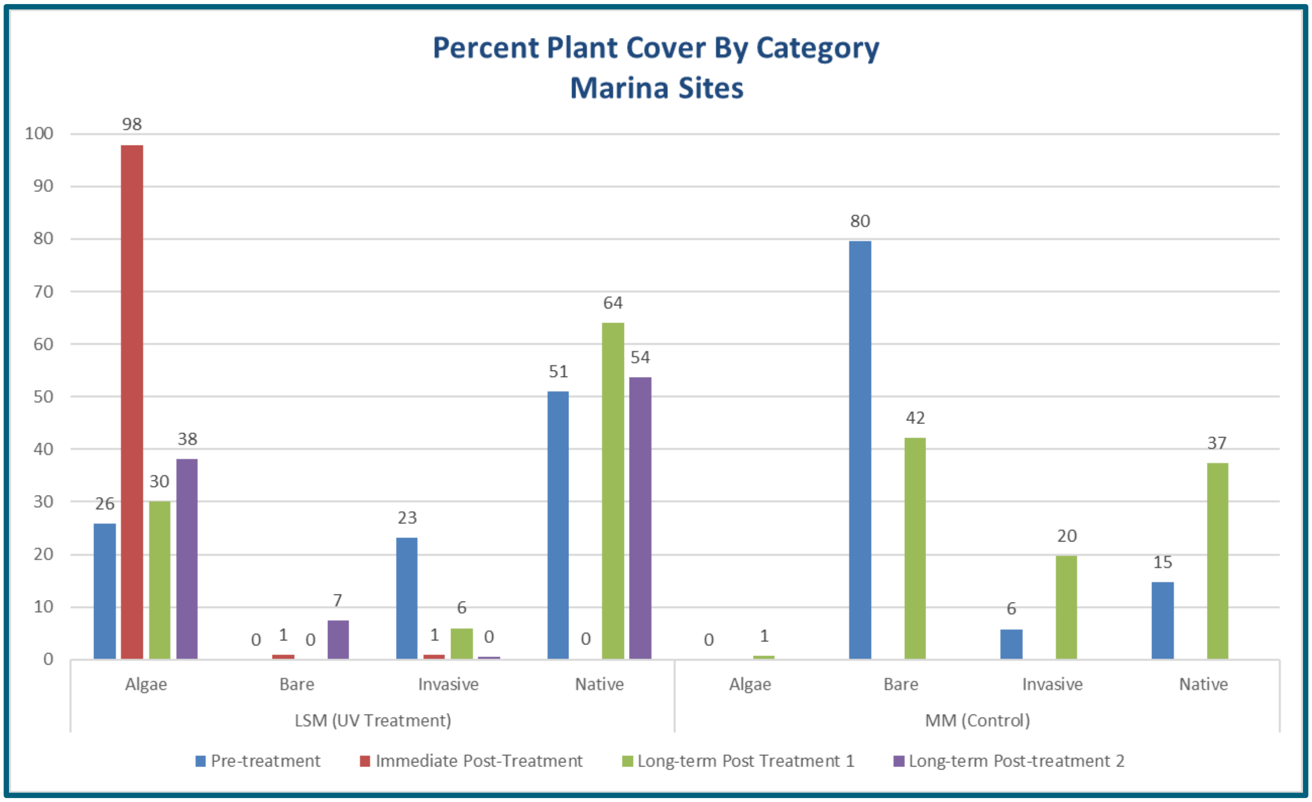


Figure 11. Mean percent cover measured at marina sites, as presented by Category

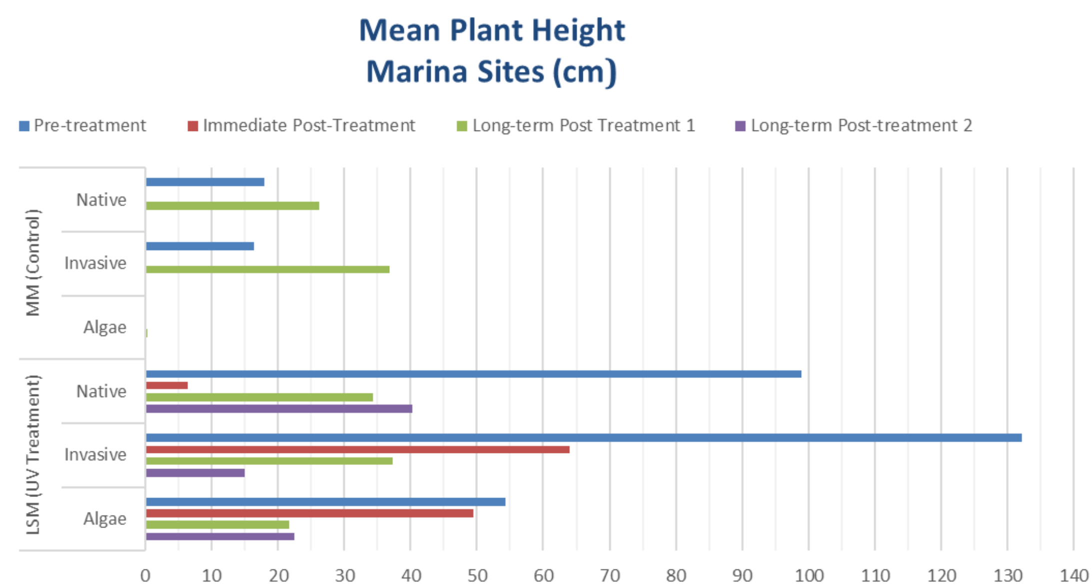
8.2.1.2 Plant Height

Plant height is the shortest distance between the upper boundary of the main photosynthetic tissues (excluding inflorescences) on a plant and the ground level, expressed in centimeters (cm). Plant height is the maximum stature a typical mature individual of a species attains in a given habitat. Plant height is associated with growth form, position of the species in the vertical light gradient of the vegetation, competitive vigor, reproductive size, whole-plant fecundity, potential lifespan, and whether a species is able to establish and attain reproductive size between two disturbance events. In the case of this Project, the disturbance event is defined as UV-C light treatment (Pérez-Harguindeguy et al. 2013).

Mean plant height measurements for the marina sites are graphed in **Figure 12**. Although the percent cover of Algae increased according to post-treatment measurements, the mean height (or in the case of Algae the depth of percent cover) was reduced by around 50%, from 54 cm pre-treatment to 23 cm long-term post-treatment.

Mean height of Invasives was also reduced following UV-C light treatment at LSM, and important to note is that the mean of 64 cm reported for immediate post-treatment in 2017 is representative of only 1 percent plant cover measured for Invasives (Refer to **Figure 10** and **Figure 13**, respectively). Mean plant height for 2018 long-term post-treatment results are 37 cm (June 2018) and 15 cm (August 2018) and are based on the frequency of occurrence of

Invasives of 13% and 3%, respectively. Mean plant height for Natives decreased as expected following UV-C light treatment. The 2018 post-treatment mean plant height results suggest that Natives may be outcompeting Invasives one year following UV-C light treatments. Long term post-treatment measurements conducted in August 2018 report mean plant height for Natives at 40 cm and Invasives at 15 cm, which appears to reflect the height of new plant growth and not the persistence of the previously established populations.



	LSM (UV Treatment)			MM (Control)		
	Algae	Invasive	Native	Algae	Invasive	Native
Pre-treatment	54	132	99	0	16	18
Immediate Post-Treatment	49	64	7			
Long-term Post Treatment 1	22	37	34	0	37	26
Long-term Post-treatment 2	23	15	40			

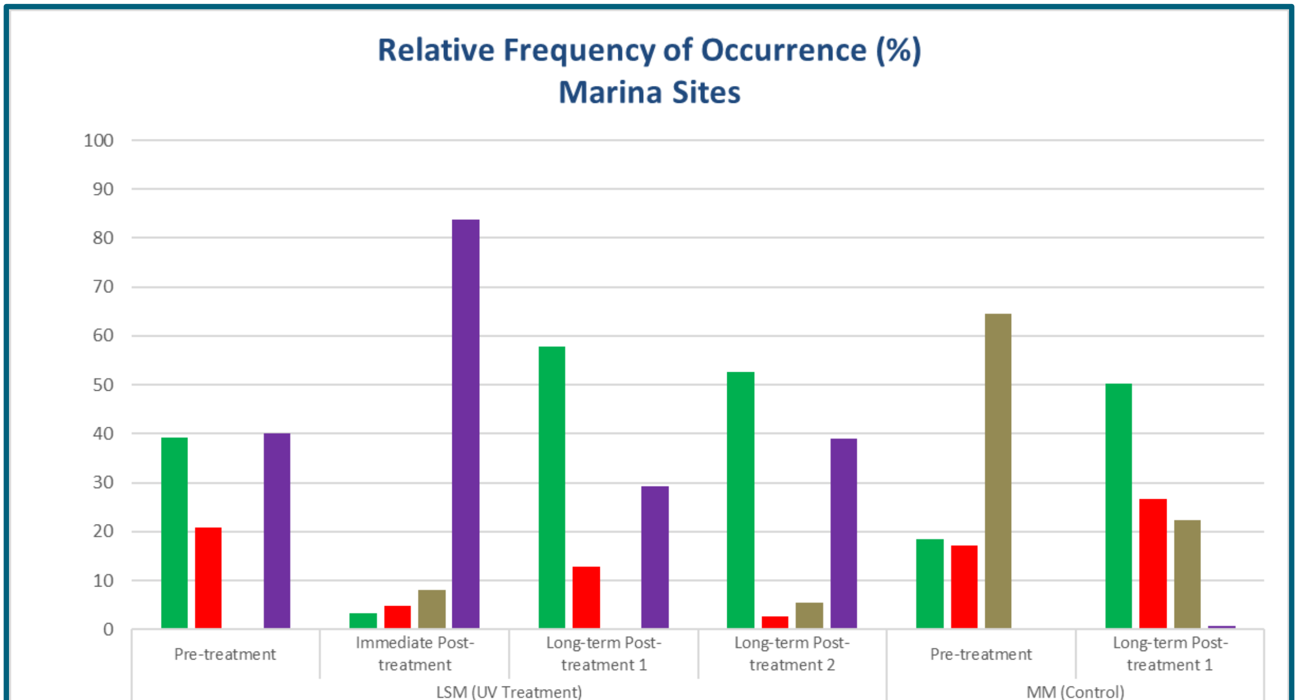
Figure 12. Mean plant height in centimeters measured at marina sites, as presented by Category

8.2.1.3 Relative Frequency of Occurrence

Relative frequency of occurrence is calculated based on the number of occurrences of a species relative to total occurrence of all species. Frequency is expressed as a percentage. Results were again grouped by individual species in the appropriate Plant Category. The percent frequency of each Plant Category was calculated by dividing the number of sampling points at which it occurred by the total number of sampling points. The greater this value, the more frequent the plant type occurs in the treatment or control area.

Figure 13 presents the relative frequency of occurrence of Natives, Invasives, Algae and Bare categories at LSM treatment site and MM control site. At LSM, the frequency of occurrence of Natives increased from 39%, as measured pre-treatment, to 58% and 53%, as measured in June and August 2018 (long term post-treatment). The frequency of occurrence of Natives at the MM control site also increased from 18% in 2017 to 50% in 2018.

At LSM the frequency of occurrence of Invasives decreased from 21%, as measured pre-treatment, to 13% and 3%, as measured in June and August 2018 (long-term post-treatment). In contrast, the frequency of occurrence of Invasives at the MM control site increased from 17% in 2017 to 27% in 2018.



	Pre-treatment	Immediate Post-treatment	Long-term Post-treatment 1	Long-term Post-treatment 2	Pre-treatment	Long-term Post-treatment 1
	LSM (UV Treatment)				MM (Control)	
Native	39	3	58	53	18	50
Invasive	21	5	13	3	17	27
Bare	0	8	0	5	64	22
Algae	40	84	29	39	0	1

Figure 13. Relative frequency of occurrence by Category for marina sites

8.2.2 Littoral Sites

8.2.2.1 Percent Plant Cover

Figure 14 depicts the littoral sites' mean (or average) percent cover as a stacked 100% bar graph for comparison of pre-treatment cover composition to post-treatment cover composition. Focusing on Native and Invasive categories, UV-C light treatments at LSB-Swim and LSB-Taxi resulted in mortality of the established plant species in both categories, as measured immediate Post-treatment, but the regeneration of plants from turions observed in the treatment areas occurred fairly rapidly in the open water environment. Percent plant cover for Invasives at LSB-Swim decreased by only 2%, as measured immediate post-treatment.

The mean Invasive plant height, however, decreased from 73 cm pre-treatment and 15 cm immediate post-treatment, which indicates that the plant cover that persisted reflects new grow of Invasives and not that of Invasives that avoided mortality from UV-C light treatment. Considering percent plant cover reported for June and August 2018 long-term post-treatment, the percent cover of the regenerating Invasives decreased to 10% and 9%, respectively, at LSB-Swim.

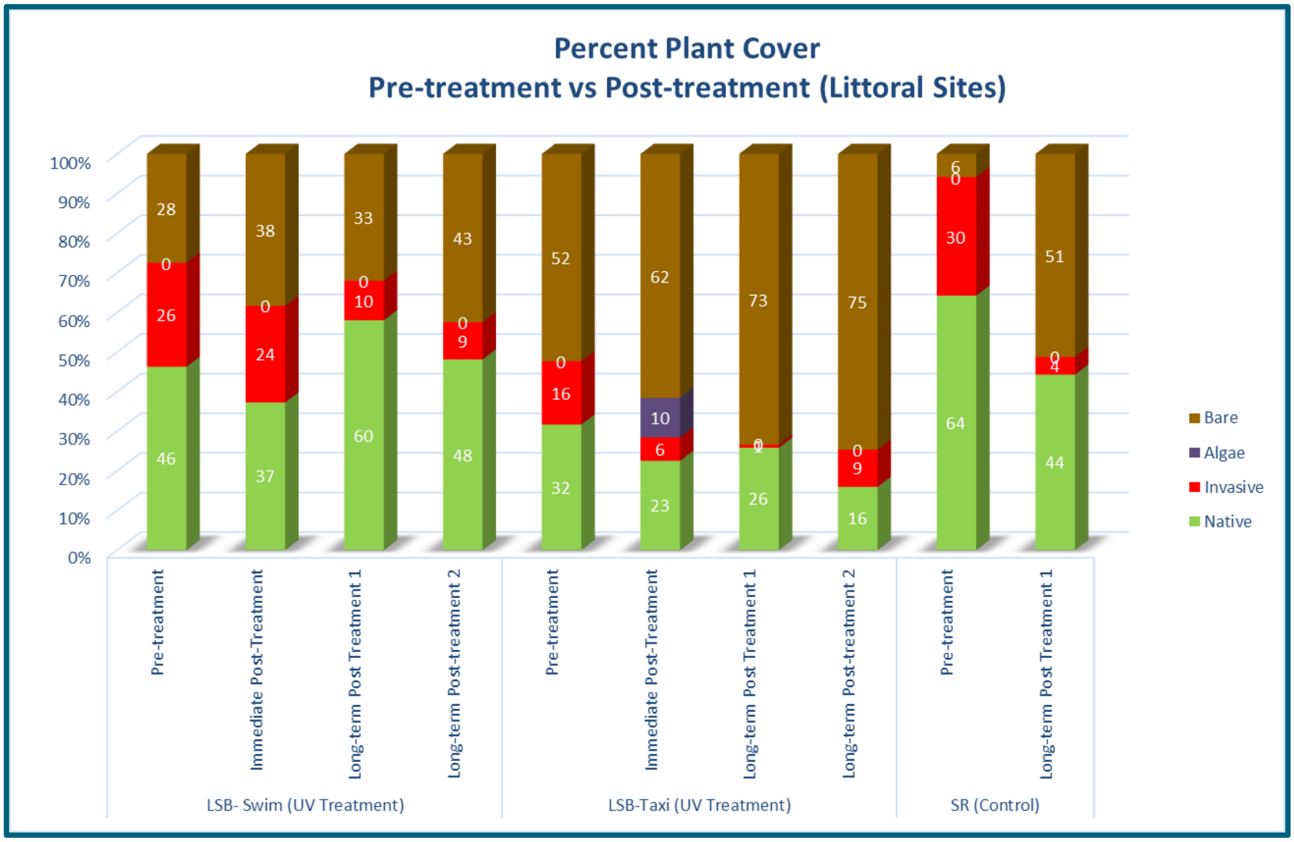


Figure 14. Stacked composition bar graph for percent cover measured at littoral sites, as presented pre-treatment compared to post-treatment

Percent plant cover measured for Natives also decreased, from 46% pre-treatment to 37% immediate post-treatment; conversely, mean plant height measured for Natives increased from 24 cm pre-treatment to 41 cm immediate post-treatment at LSB-Swim. Native species that reestablished following UV-C light treatment appear to have spread in terms percent cover measured in June 2018, peaking at 60% cover at LSB-Swim with an average height of 21 cm and then decreasing to 48% cover with an average height of 20 cm.

UV-C light treatments appear to have been more effective at the LSB-Taxi site with Invasive percent plant cover decreasing from 16% pre-treatment to 6% immediate post-treatment and a continued decline reflected in 2018 long-term post-treatment results of 0% and 9%, as reported for June 2018 and August 2018, respectively. Percent cover for Natives also decreased at LSB-Taxi as a result of UV-C light treatment. Percent cover decreased from 32% pre-treatment to 23% immediate post-treatment. 2018 long-term post-treatment results show a slight rebound in Native percent cover as measure in June 2018 (26%). August 2018 long-term post-treatment results then report Native percent cover reduced to 16% at LSB-Taxi. Conversely, plant height of newly established Natives doubled from 8 cm to 15 cm. Some Algae was measured at LSB-Taxi immediate post-treatment (10%), but Algae did not persist into 2018.

Considering the SR control site, in the absence of UV-C light treatment, percent cover by both Natives and Invasives onsite decreased between July 2017 and July 2018. The SR control site is located in an area of high boat traffic so plant populations could be impacted by scouring and effectively mowing by propellers. **Figure 15** presents the same percent cover results for the littoral sites by Category for comparison of pre-treatment to post-treatment measurements and appears to show a similar trend for LSB-Taxi and the SR control site. Treatment response at LSB-Swim is similar but muted and is possible due to this treatment site being more protected from boat traffic.

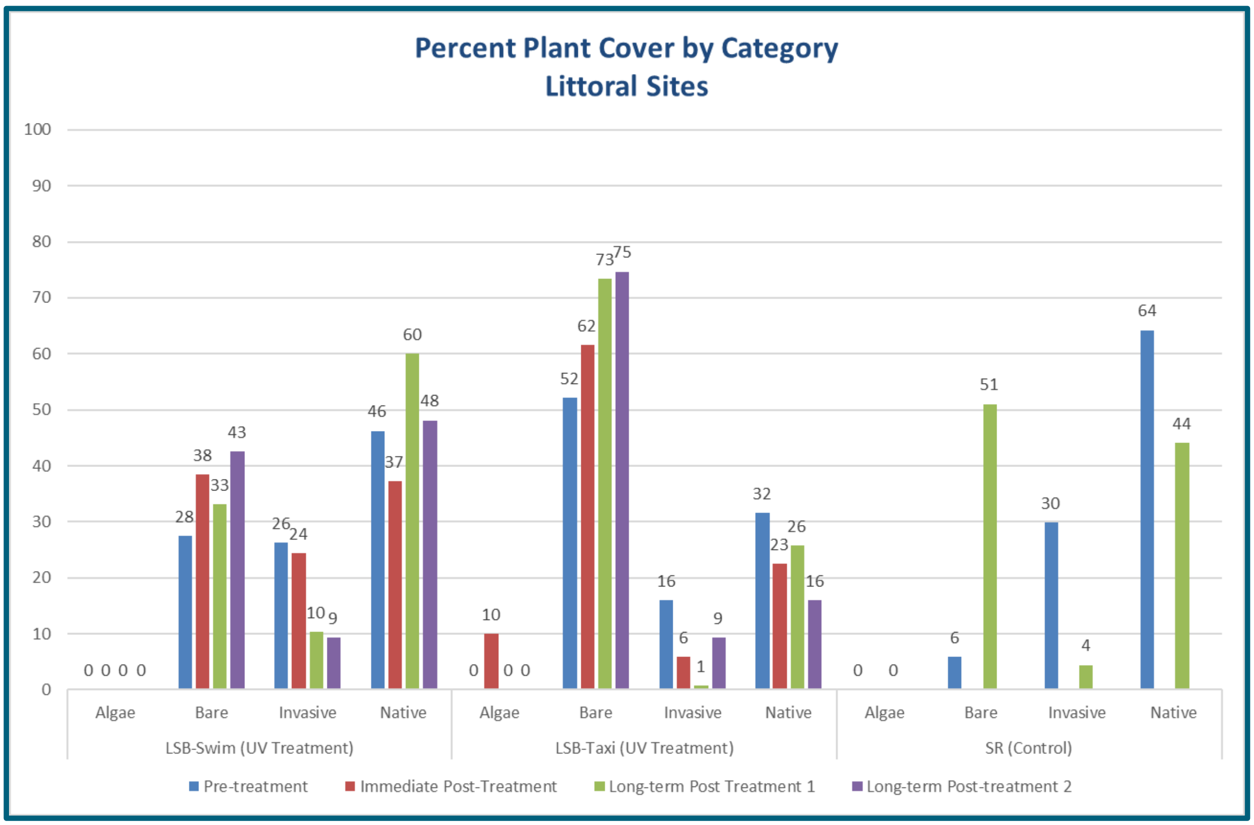


Figure 15. Mean percent cover measured at littoral sites, as presented by Category

8.2.2.2 Plant Height

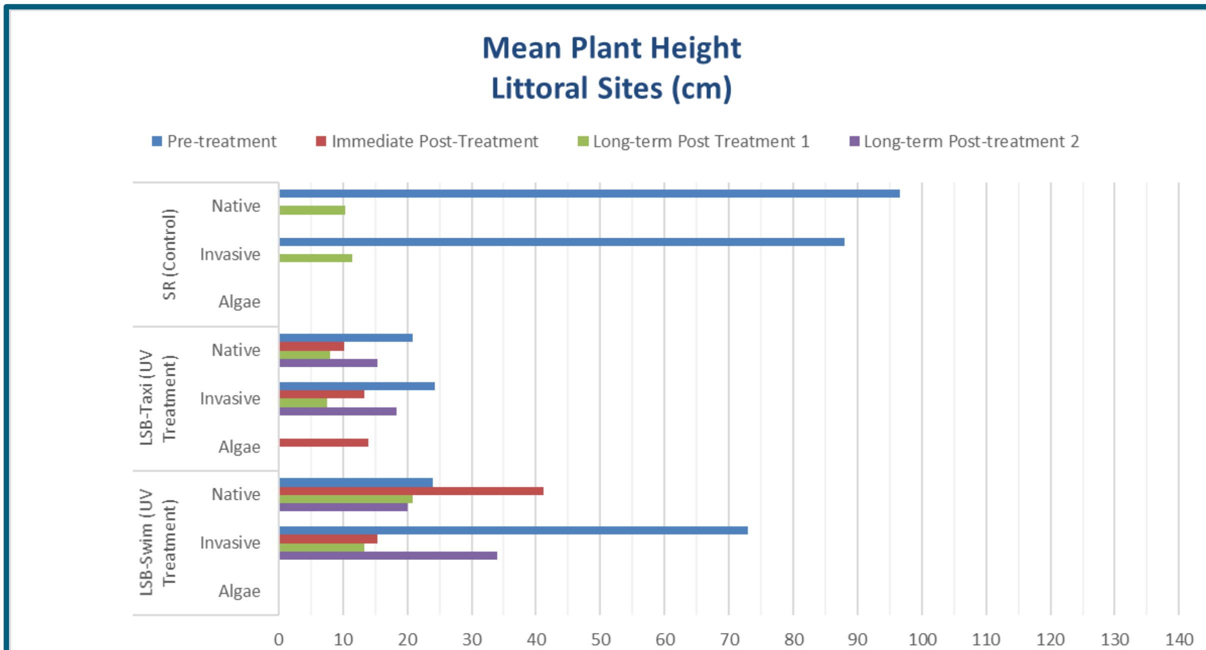
Mean plant height measurements for the littoral sites are graphed in **Figure 16.** Measured results differ between the littoral sites. At LSB-Swim mean Invasive plant height was reduced from 73 cm pre-treatment to 15 cm post-treatment, indicating some re-establishment of Invasives following UV-C light treatment. Mean Invasive plant height then measured 13 cm in June 2018 during the early growing season and increased to 34 cm as measured in August 2018. However, while Invasive plant height increased at LSB-Swim over the 2018 growing season, Invasive percent cover continued to decrease to 9%.

While percent cover decreased following UV-C light treatments, mean plant height for Native species at LSB-Swim reportedly increased from 24 cm to 41 cm, indicating that some Native plants may have persisted following treatments and in the absence of competition with Invasives sustained a growth spurt. The 2018 long-term post-treatment results indicate that these Natives may not have survived the winter season and were replaced by newly established Native plants. Long-term post-treatment measurements for mean Native plant height were 21 cm (June) and 20 cm (August).

Measured results at LSB-Taxi more closely reflect expected results. UV-C light treatments reduced mean Invasive plant height from 24 cm pre-treatment to 13 cm immediate post-treatment. Mean plant height continued to decrease as measured in June 2018 (8 cm) but then increased to an average of 18 cm as measured in August 2018. Mean Native plant height also reflected this trend, decreasing from 21 cm to 10 cm immediately following UV-C light treatment, decreasing to 8 cm as measured in June 2018, but then increasing to 15 cm as measured in August 2018.

In the absence of UV-C light treatments, the results reported for the SR control site do not align with results expected from the control site. In 2018, the established populations of Natives and Invasives appear to have been replaced by new plant growth. Noting that water column depths at SR do differ from water column depths at LSB, past monitoring observations by Tahoe RCD staff report that macrophyte populations do not typically persist through the winter months at the SR control site. So, this measured regeneration is likely attributable to environmental variables since lake levels in 2017 and 2018 provided for adequate water column depth to avoid impacts to macrophytes from boat propeller and rotor scour. Significant macrophyte growth at SR typically commences in late May to early June. Long term post-treatment surveys were not conducted as part of the pilot Project, and therefore, late growing season (i.e., August 2018) results were not available for comparison to LSB.

As depicted in **Figure 16**, Invasive and Native mean plant height decreased from 88 cm and 97 cm as measured in June 2017 to 11 cm and 10 cm, respectively, as measured in June 2018.



	LSB-Swim (UV Treatment)			LSB-Taxi (UV Treatment)			SR (Control)		
	Algae	Invasive	Native	Algae	Invasive	Native	Algae	Invasive	Native
Pre-treatment	0	73	24	0	24	21	0	88	97
Immediate Post-Treatment	0	15	41	14	13	10			
Long-term Post Treatment 1	0	13	21	0	8	8	0	11	10
Long-term Post-treatment 2	0	34	20	0	18	15			

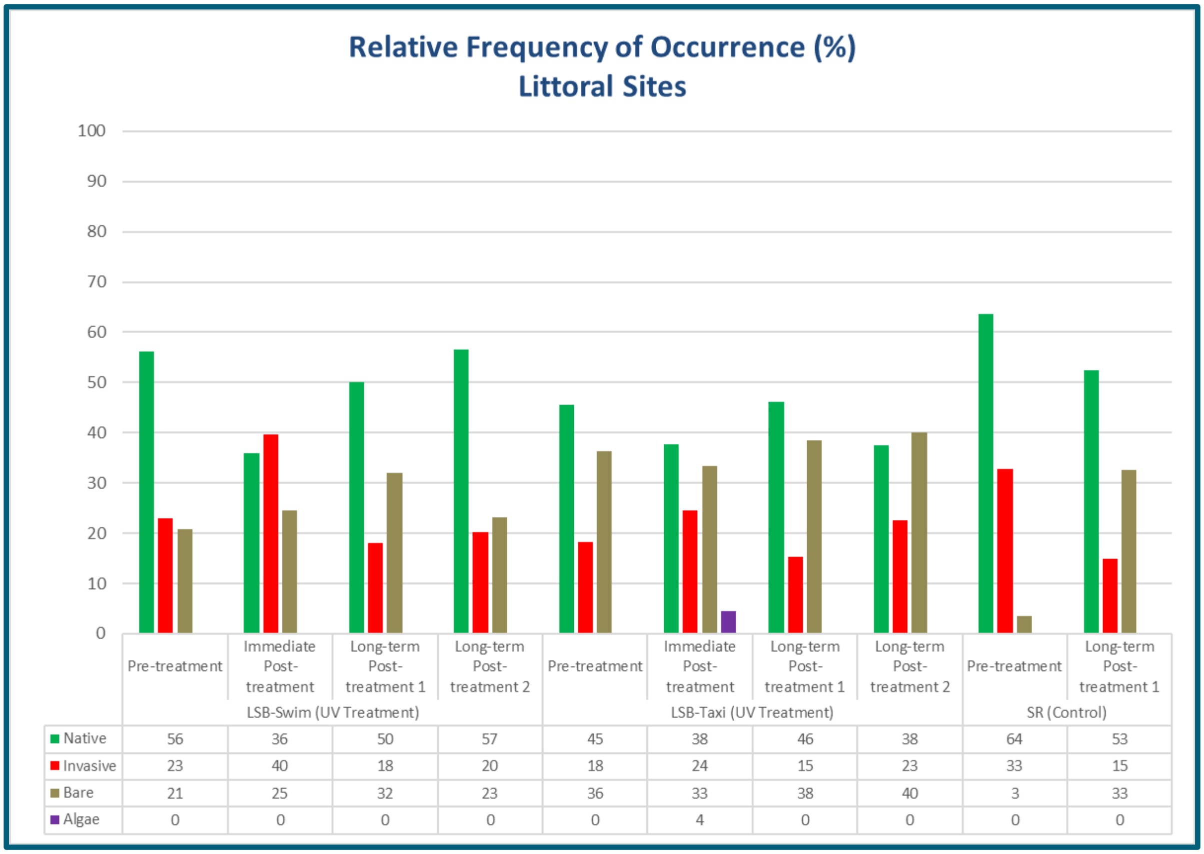
Figure 16. Mean plant height in centimeters measured at littoral sites, by Category

8.2.2.3 Relative Frequency of Occurrence

Figure 17 presents the relative frequency of occurrence of Natives, Invasives, Algae and Bare categories at LSB treatment sites and SR control site. At LSB-Swim, the frequency of occurrence of Natives decreased following UV-C light treatment from 56% pre-treatment to 36% immediate post-treatment and then returned to pre-treatment levels by August 2018 (57%). Comparatively, frequency of occurrence of Invasives increased following UV-C light treatment, increasing from 23% to 40%, but then decreased to below pre-treatment levels (18%) as reported for June 2018 long-term post-treatment surveys. August 2018 survey results report frequency of occurrence of Invasives remaining below pre-treatment levels at 20% at LSB-Swim.

At the LSB-Taxi, the frequency of occurrence of Invasives follows a trend similar to results reported at LSB-Swim with Invasives increasing slightly from 18% pre-treatment to 24% immediate post-treatment and then decreasing to 15% occurrence in June 2018 approximately one year following UV-C light treatments. August 2018 long-term post-treatment results report an increase in occurrence of Invasives over the 2018 growing season to 23%, which is similar to 2017 immediate post-treatment occurrences. Frequency of occurrence of Natives at LSB-Taxi also followed this response pattern.

Interestingly, in the absence of UV-C light treatments, the frequency of occurrence of Natives at the SR control site decreased from 64% in 2017 to 53% in 2018, and the occurrence of Invasives decreased from 33% in 2017 to 15% in 2018. These results at our littoral control site exemplify the variability to aquatic plants from year to year and how dynamics and environmental influences can alter a population.



	LSB-Swim (UV Treatment) Pre-treatment	LSB-Swim (UV Treatment) Immediate Post-treatment	LSB-Swim (UV Treatment) Long-term Post-treatment 1	LSB-Swim (UV Treatment) Long-term Post-treatment 2	LSB-Taxi (UV Treatment) Pre-treatment	LSB-Taxi (UV Treatment) Immediate Post-treatment	LSB-Taxi (UV Treatment) Long-term Post-treatment 1	LSB-Taxi (UV Treatment) Long-term Post-treatment 2	SR (Control) Pre-treatment	SR (Control) Long-term Post-treatment 1
Native	56	36	50	57	45	38	46	38	64	53
Invasive	23	40	18	20	18	24	15	23	33	15
Bare	21	25	32	23	36	33	38	40	3	33
Algae	0	0	0	0	0	4	0	0	0	0

Figure 17. Relative frequency of occurrence by Category for littoral sites

8.3 Benthic Macroinvertebrates

BMI are elements of water quality monitoring with taxonomic identification of a BMI community reflecting conditions and changes in water quality. For this Project, 2017 pre-treatment conditions are compared to 2018 post-treatment conditions, with 2017 intermediate post-treatment conditions also considered for the LSM and LSB treatment sites.

General observations can be stated regarding the relative treatment area conditions. The BMI summary metrics are presented primarily to assess if the application of UV-C light plant control treatment resulted in a change from pre-treatment conditions to post-treatment conditions. Also, important to note is that the BMI results reflect single sample sets or a snapshot in time and not a robust sampling of the population over time. Consideration of all

BMI metrics is important. Individual metrics are not as meaningful considered separately. To translate complex individual BMI data into an overall measure of littoral ecosystem health, some level of conceptual modeling and potentially the development of an index is assumed to be necessary to account for noise from environmental factors (https://www.waterboards.ca.gov/water_issues/programs/swamp/swamp_iq/bioassessment.html). These efforts are outside the scope and purpose of this monitoring report.

The results below are a direct comparison of pre and post sample results for the individual treatment sites. Pre and post treatment results can then be compared to the respective control site results to assess if UV-C light treatment may have resulted in a long-term change in BMI community metrics.

Table 11 details the locations, labels and dates corresponding to pre-treatment, immediate post-treatment and long-term post-treatment biomonitoring sampling. Refer to **Figure 3** and **Figure 5**, which illustrate the sample point locations at the treatment sites and the control sites.

Table 11. Biomonitoring Sampling Location Names, Labels, and Dates

	Marina Sites		Littoral Sites	
	LSM (Treatment)	**MM (Control)**	**LSB (Treatment)**	**SR (Control)**
Pre-treatment	06/12/2017	06/13/2017	07/15/2017	07/16/2017
Immediate Post-treatment	09/16/2017	--	09/16/2017	--
Long-term Post-treatment	06/20/2018	06/21/2018	06/21/2018	06/22/2018

Table 12 summarizes the observed trends of the individual BMI results for LSM and LSB that are presented in **Table 13**. Post-treatment columns for LSM and LSB present the relative trend as compared to pre-treatment conditions.

Table 12. Benthic Macroinvertebrate (BMI) Reporting Metrics

Metric	Description	Water Quality Indicator: Response to Impairment	Post-treatment Results: LSM	Post-treatment Results: LSB
Richness Measures				
Taxa Richness	Number of individual taxa collected from each sample	Decrease	Increase	Decrease
Total (Cumulative) Richness	Total number of individual taxa collected from each site	Decrease	Increase	Decrease
Total Abundance	Total abundance in sample converted to a full sample and 1 square meter basis	Variable	Increase	Increase

Table 12. Benthic Macroinvertebrate (BMI) Reporting Metrics				
Metric	**Description**	**Water Quality Indicator: Response to Impairment**	**Post-treatment Results: LSM**	**Post-treatment Results: LSB**
EPT Tax Richness	Number of taxa in the taxa in the insect orders *Ephemeroptera* (mayflies), *Plecoptera* (stoneflies), *Trichoptera* (caddisflies) collected from each sample	Decrease	Increase	Decrease
EPT Abundance	Total number of taxa in the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddisflies) collected at each site	Decrease	Increase	Decrease
Hilsenhoff Biotic Index	Estimates the overall tolerance of the community in a sampled area, weighted by the relative abundance of each taxonomic group with 0 being most sensitive and 10 being most tolerant	Increase	Decrease	Decrease
Dominance and Diversity Measures				
% Dominant Taxa	Percent composition of the single most abundant taxa	Increase	Decrease	Increase
% Subdominant Taxa	Percent composition of the second most abundant taxa	Increase	Decrease	Similar
Shannon-Weaver Diversity Index (loge)	General measure of sample diversity that incorporates richness and evenness (Shannon Weaver 1963)	Decrease	Increase	Decrease
Tolerance/Intolerance Measures				
Total Tolerant Taxa Richness	Sum of the moderately and highly tolerant taxa; taxa found frequently in habitats with warm water temperature and low dissolved oxygen	Increase	Increase	Decrease
Total Tolerant abundance	Total tolerant abundance in a sample converted to a full sample and 1 square meter basis	Increase	Increase	Decrease
% Tolerant by abundance	Percent of organisms highly tolerant to impairment	Increase	Decrease	Decrease
Total Intolerant taxa richness	Sum of moderately intolerant and highly intolerant taxa. Cool and cold water biota found in habitats with high dissolved oxygen	Decrease	No Taxa Reported	No Taxa Reported
Total Intolerant abundance	Total intolerant abundance in sample converted to a full sample and 1 square meter basis	Decrease	No Taxa Reported	No Taxa Reported
% Intolerant by abundance	Percent of organisms highly intolerant to impairment	Decrease	No Taxa Reported	No Taxa Reported

Table 12. Benthic Macroinvertebrate (BMI) Reporting Metrics				
Metric	Description	Water Quality Indicator: Response to Impairment	Post-treatment Results: LSM	Post-treatment Results: LSB
Composition Measures				
Shannon Weaver Diversity	Measure of diversity that takes into account the number of species present, as well as the relative abundance of each species (as species richness and evenness increase so does diversity)	Decrease	Increase	Decrease
Shannon Evenness Index	Accounts for both abundance and evenness, equitability assumes a value between 0 and 1, with 1 being complete evenness (evenness refers to how close in numbers each species is in an environment)	Decrease	Increase	Decrease

Source: J. Harrington 2000 and Appendix C, Raw Data

Table 13. Benthic Macroinvertebrate (BMI) Results Summary										
Location	LSM (Treatment)	LSM (Treatment)	LSM (Treatment)	MM (Control)	MM (Control)	LSB (Treatment)	LSB (Treatment)	LSB (Treatment)	SR (Control)	SR (Control)
Sample Date/Type	Pre-treatment	Immediate Post-treatment	Long term Post-treatment	Pre-treatment	Long term Post-treatment	Pre-treatment	Immediate Post-treatment	Long term Post-treatment	Pre-treatment	Long term Post-treatment
NUMBER OF REPLICATES AVERAGED	7	7	7	7	7	7	7	7	7	7
SUMMARY METRICS										
Total taxa richness	21	31	45	42	47	38	44	29	29	39
Total abundance	3506.29	6407.22	15755.43	7193.14	5498.06	5632	8539.43	6459.43	7078.86	13791.2
EPT taxa richness	0	3	9	7	5	4	5	1	3	5
EPT abundance	0	16	173.71	18.29	46.63	38.86	546.29	16	25.14	314.19
Hilsenhoff Biotic Index (WY DEQ version)	6.3	5.4	5.6	6.5	6.6	6.9	5.8	5.4	6.7	6.1
DOMINANCE AND DIVERSITY										
% Dominant taxa	66.17	78.81	53.78	44.01	32.96	28.9	37.34	54.49	38.94	30.5
% Subdominant taxa	10.76	7.65	8.46	11.85	12.31	15.54	17.67	15.04	17.21	15.29
% Top 3 taxa	84.62	88.42	69.37	63.11	53.24	56.49	60.47	80.93	67.78	58.89
% Top 5 taxa	93.35	91	79.57	72.42	65.29	75.37	70.69	88.68	80.11	74.56
% Top 10 taxa	98.44	94.85	91.75	88.81	85.06	90.95	86.22	95.44	92.73	89.4
Shannon-Weaver Diversity (loge)	1.3	1.06	1.91	2.19	2.52	2.35	2.34	1.65	2.08	2.35
Shannon-Weaver Diversity (log2)	1.88	1.53	2.76	3.16	3.64	3.39	3.38	2.38	2.99	3.39
Shannon Evenness Index	0.43	0.31	0.5	0.59	0.66	0.65	0.62	0.49	0.62	0.64
TOLERANT AND INTOLERANT TAXA										
Total tolerant taxa richness	13	15	25	23	26	19	22	17	15	21
Total tolerant abundance	854.86	945.74	2820.57	2672	2458.51	2157.71	3433.14	1517.71	2089.14	7253.17
% Total tolerant by abundance	24.38	14.76	17.9	37.15	44.72	38.31	40.2	23.5	29.51	52.59
Highly tolerant taxa richness	4	7	9	7	8	10	7	7	8	9
Highly tolerant abundance	294.86	250.24	1254.86	694.86	586.06	1229.71	1188.57	349.71	1456	2802.29
% Highly tolerant by abundance	8.409	3.906	7.965	9.66	10.66	21.83	13.92	5.414	20.57	20.32

Table 13. Benthic Macroinvertebrate (BMI) Results Summary										
Location	LSM (Treatment)	LSM (Treatment)	LSM (Treatment)	MM (Control)	MM (Control)	LSB (Treatment)	LSB (Treatment)	LSB (Treatment)	SR (Control)	SR (Control)
Sample Date/Type	Pre-treatment	Immediate Post-treatment	Long term Post-treatment	Pre-treatment	Long term Post-treatment	Pre-treatment	Immediate Post-treatment	Long term Post-treatment	Pre-treatment	Long term Post-treatment
Moderately tolerant taxa richness	9	8	16	16	18	9	15	10	7	12
Moderately tolerant abundance	560	695.5	1565.71	1977.14	1872.46	928	2244.57	1168	633.14	4450.88
% Moderately tolerant by abundance	15.97	10.85	9.938	27.49	34.06	16.48	26.28	18.08	8.944	32.27
Total intolerant taxa richness	0	0	0	2	1	0	0	0	0	0
Total intolerant abundance	0	0	0	4.57	4.57	0	0	0	0	0
% Total intolerant by abundance	0	0	0	0.06355	0.08315	0	0	0	0	0
Highly intolerant taxa richness	0	0	0	0	0	0	0	0	0	0
Highly intolerant abundance	0	0	0	0	0	0	0	0	0	0
% Highly intolerant by abundance	0	0	0	0	0	0	0	0	0	0
Moderately intolerant taxa richness	0	0	0	2	1	0	0	0	0	0
Moderately intolerant abundance	0	0	0	4.57	4.57	0	0	0	0	0
% Moderately intolerant by abundance	0	0	0	0.06355	0.08315	0	0	0	0	0

Source: Appendix C, Raw Data

8.3.1 Marina Sites

Figure 18 presents a compilation of BMI results, graphs 18a through 18e, which were reported for the marina sites for a general comparison of pre-treatment conditions to post-treatment conditions. At LSM total taxa richness and EPT taxa richness increased immediate post-treatment and continued to increase long-term post-treatment, one (1) year following UV-C light treatment. Total taxa richness and EPT abundance (i.e., the total number of taxa in the insect orders Ephemeroptera [mayflies], Plecoptera [stoneflies], and Trichoptera [caddisflies], which are typically the least tolerant taxa) at the MM control site followed the same trend for LSM. Conversely, total abundance and EPT taxa richness decreased at MM as compared to LSM.

The Hilsenhoff Biotic Index (HBI) estimates the overall tolerance of the community in a sampled area, weighted by the relative abundance of each taxonomic group. Insect taxa are assigned tolerance values based on the ability of the particular insect to live under a variety of stressful conditions, such as low oxygen content in the water. Organisms are assigned a tolerance value from 0 to 10 that indicates a group's known sensitivity to organic pollutants; 0 being most sensitive, 10 being most tolerant (http://cfb.unh.edu/StreamKey/html/biotic_indicators/indices/Hilsenhoff.html). Following UV-C light treatment the HBI decreased for LSM, indicating a shift towards a slightly less tolerant BMI community composition. Comparatively, the MM control site had little change in HBI between 2017 and 2018. Low HBI values reflect a higher abundance of sensitive groups, thus a lower level of pollution.

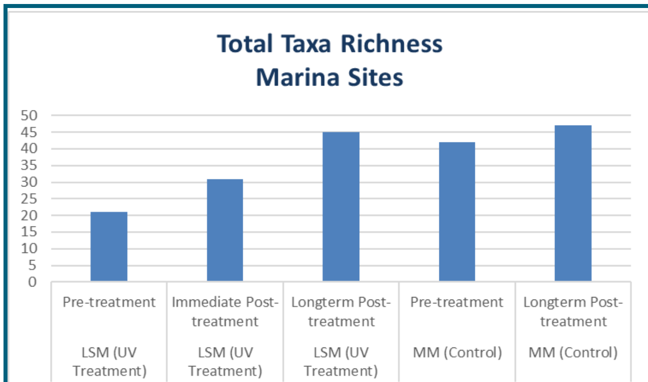


Figure 18a. BMI Total Taxa Richness, marinas

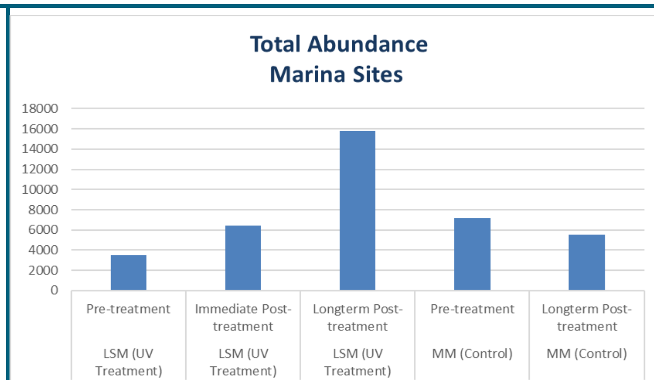


Figure 18b. BMI Total Abundance, marinas

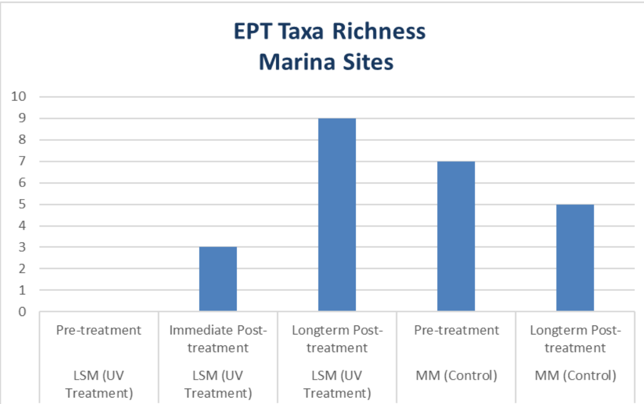


Figure 18c. EPT Taxa Richness, marinas

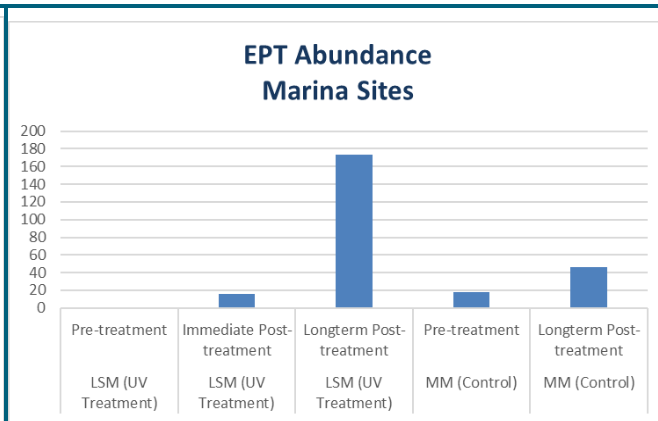


Figure 18d. EPT Abundance, marinas

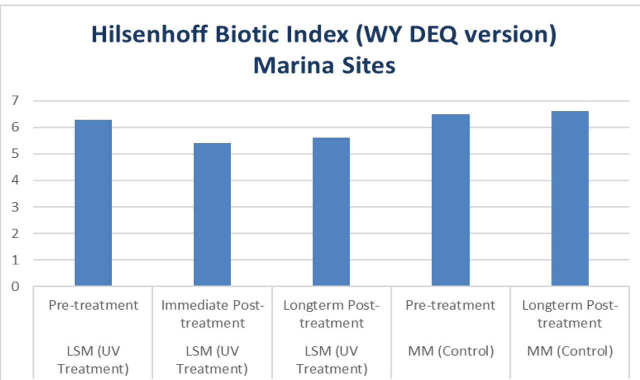


Figure 18e. Hinsenhoff Biotic Index, marinas

Figure 18. BMI summary results for marina sites

8.3.2 Littoral Sites

Figure 19 presents a compilation of BMI results, as titled for 19a through 19e, that were reported for littoral sites for a general comparison of pre-treatment conditions to post-treatment conditions. At LSB total taxa richness, total abundance, total EPT richness and EPT abundance increased immediately following UV-C light treatment, but one (1) year later these metrics measured below pre-treatment level. This possible trend for the open water littoral sites is not the same as potential trends graphed for LSM, an enclosed water system. The HBI response at the LSB littoral sites indicates a less tolerant BMI community immediately following UV-C light treatment with long term post-treatment results also reporting a less tolerant BMI community composition. Comparatively, for the SR control site total taxa richness, total abundance, EPT richness and EPT abundance all increased between the 2017 and 2018 growing seasons. HBI decreased slightly between 2017 and 2018 indicating a shift towards less tolerant BMI community composition.

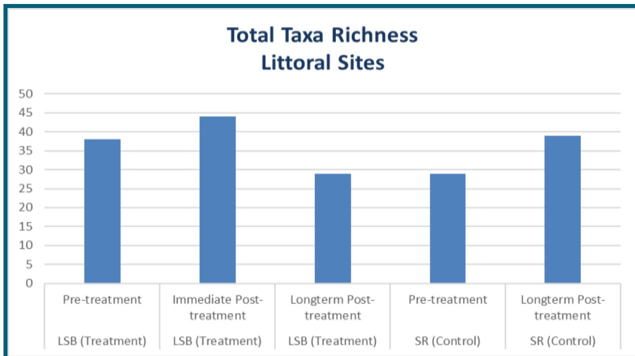


Figure 19a. BMI Total Abundance, littoral

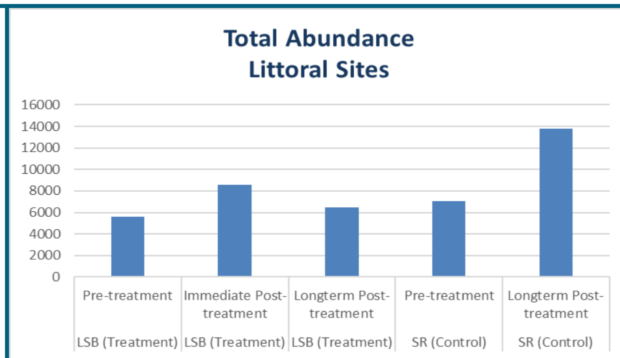


Figure 19b. BMI Total Taxa Richness, littoral

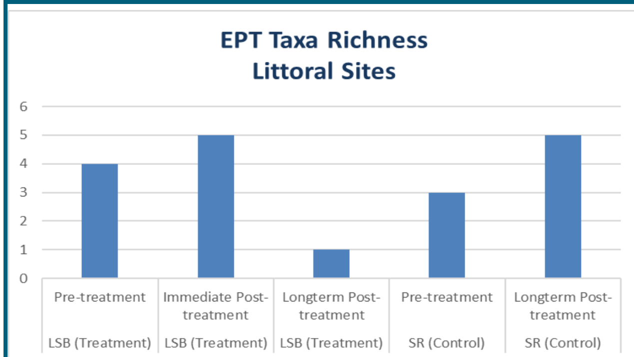


Figure 19c . EPT Taxa Richness, littoral

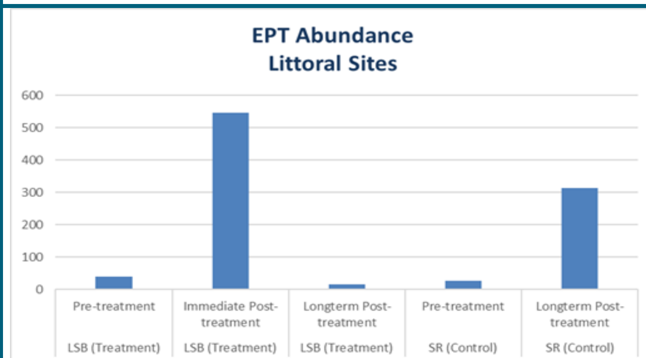


Figure 19d. EPT Abundance, littoral

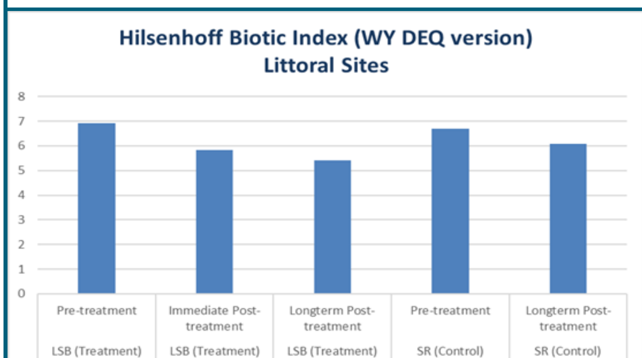


Figure 19e. Hilsenhoff Biotic Index, littoral

Figure 19. BMI summary results for littoral sites

8.4 Chlorophyll-a

The presence of chlorophyll-*a,* the photosynthetic green pigment found in algae, can serve as a surrogate to assess net primary productivity. Excessive chlorophyll-a (e.g., >6 *micro*gram chl-*a*/cm^2) in cold water indicates excessive nutrient inputs (CRAM 2012). Chlorophyll-*a* results for the Project were reported as a concentration of milligrams/Liter (mg/L) and are converted to *micro*gram/Liter for a general comparison of concentration results to the California Rapid

Assessment Methodology (CRAM) weight per area threshold. Concentrations are as reported and do not reflect corrections for phaeophytin. Important to note is that the chlorophyll results reflect single sample sets or a snapshot in time and not a robust sampling of the population over time.

8.4.1 Marina Sites

Figure 20 graphs Chlorophyll-*a* concentrations measured at the marina sites. At LSM immediate post-treatment concentrations were lower than pre-treatment concentrations, 0.134 *micro*grams/L compared to 0.4 *micro*grams/L, respectively. Concentrations appear to rebound a year later with long term post-treatment concentrations reported at 0.2 *micro*grams/L. Interestingly, concentrations at the MM control site were lower in 2018 than in 2017. Important to note is that in 2017 the Lake Tahoe Basin Management Unit and the Washoe Tribe of Nevada and California removed the dock structures from MM, which may have altered the production of chl-*a* in the control site.

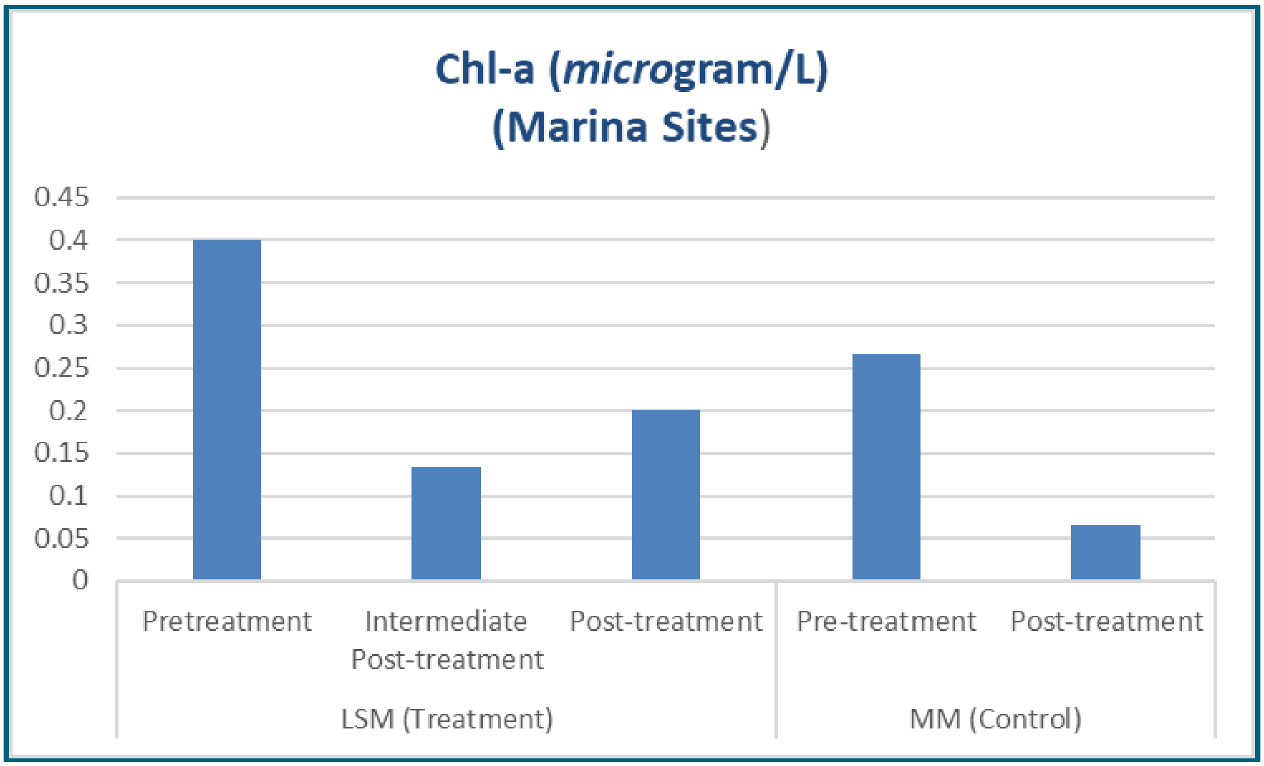


Figure 20. Chlorophyll-*a* concentrations measured at marina sites

8.4.2 Littoral Sites

Chlorophyll-a concentrations measured at littoral sites are depicted in **Figure 21**. At LSM immediate post-treatment concentrations were lower than pre-treatment concentrations, 0.4 *micrograms*/L compared to 0.26 *micro*grams/L, respectively. Concentrations continued to decrease one (1) year later with long term post-treatment concentrations reported at 0.14

*micro*grams/L. Conversely, chlorophyll concentrations increased at SR control between 2017 and 2018.

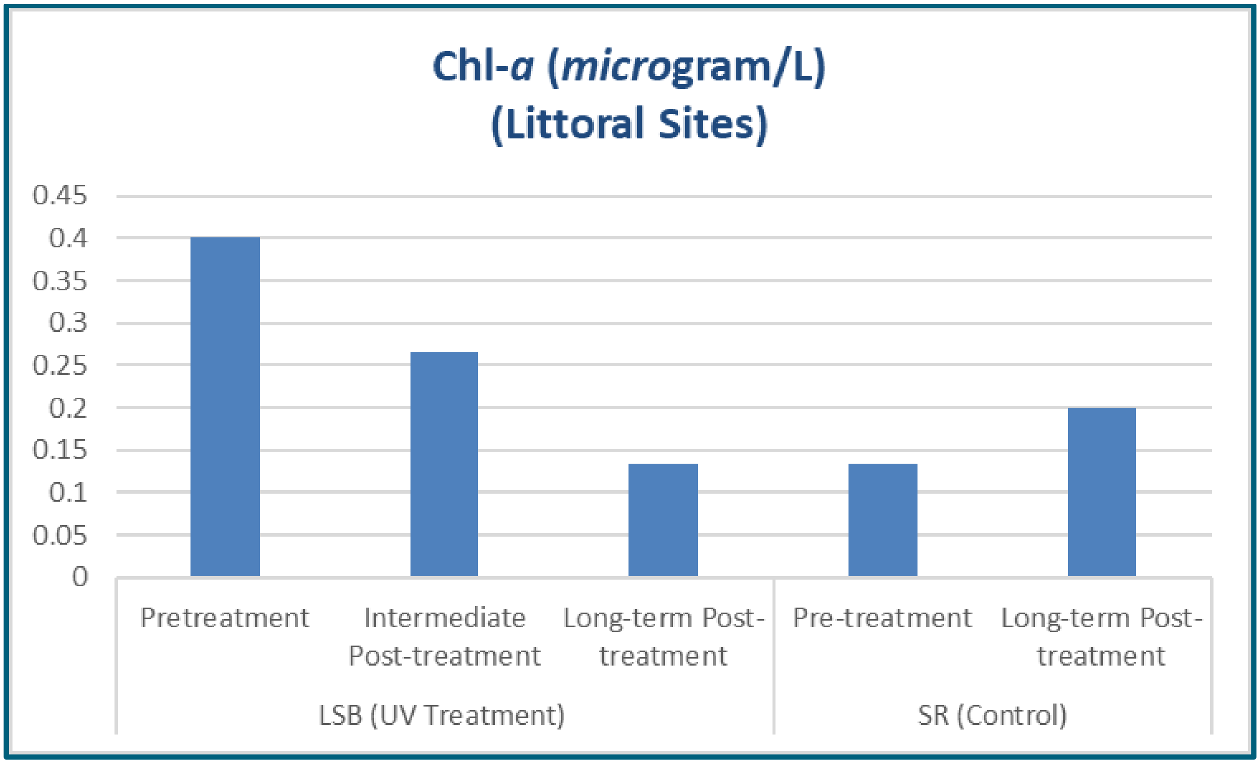


Figure 21. Chlorophyll-*a* concentrations measured at littoral sites

8.5 Periphyton

A periphyton is a type of microbial aggregate usually comprised of algae, bacteria and other micro-and meso-organisms (Wu et al. 2011) that spreads between the overlying water column and sediments and the lake bed, specifically on the surface of sediments, rocks, plants, and suspended particles in aquatic ecosystems. Periphyton are primary producers and are an important foundation of many aquatic food webs. These organisms stabilize substrata and serve as habitat for many other organisms. Periphyton are easily grazed upon by small invertebrates, fish and other aquatic animals and is important in aquatic systems because it provides community structure and primary productivity that supports a range of aquatic organisms (Stevenson, J. and Bahls, L. 2018). Because benthic algal assemblages are attached to substrate, their characteristics are affected by physical, chemical, and biological disturbances that occur during the time in which the assemblage developed. Consideration of such disturbances was outside the scope of the pilot Project, but determination of appropriate baseline is recommended for future studies.

Diatoms and many other algae can be identified to species by experienced algologists and can serve as useful ecological indicators because they are found in abundance in most aquatic ecosystems. The great number of species can provide sensitive indicators of environmental change and habitat conditions. Diatom species adapt differently to a wide range of ecological conditions. Excessive biomass of periphyton in cold water can be indicative of excessive nutrient inputs (Collins et. al. 2006).

Important to note is that periphyton results reflect single sample sets or a snapshot in time and not a robust sampling of the population over time.

8.5.1 Marina Sites

Figure 22 presents a compilation of periphyton results, as described below for 22a through 22f, for the marina sites. Non-diatom taxa richness and mean total biovolume markedly increased following UV-C light treatment, while non-diatom densities reportedly decreased. Diatom metrics were variable, but as compared to pre-treatment, diatom taxa richness, total biovolume and density generally decreased at LSM. Diatom and non-diatom measurements at the MM control site were variable and disclose no apparent trends.

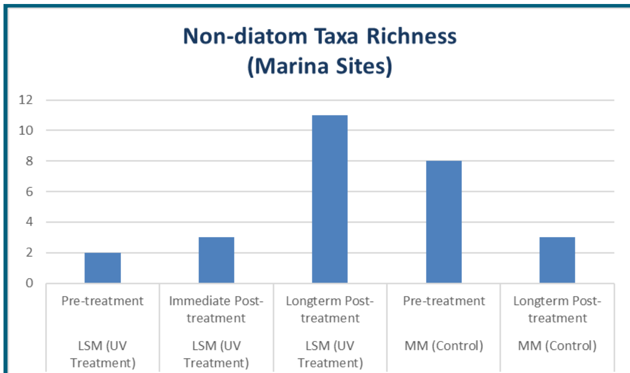


Figure 22a. Non-diatom Taxon Richness, marinas

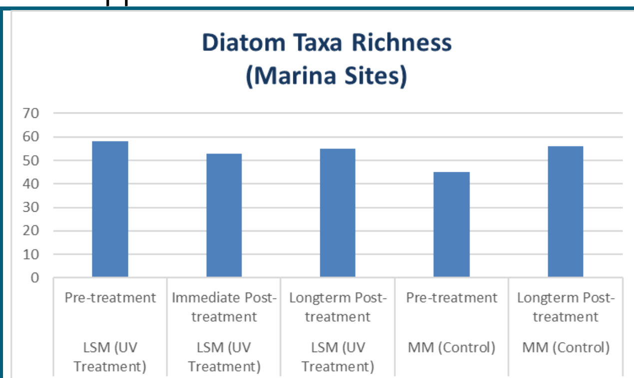


Figure 22b. Diatom Taxon Richness, marinas

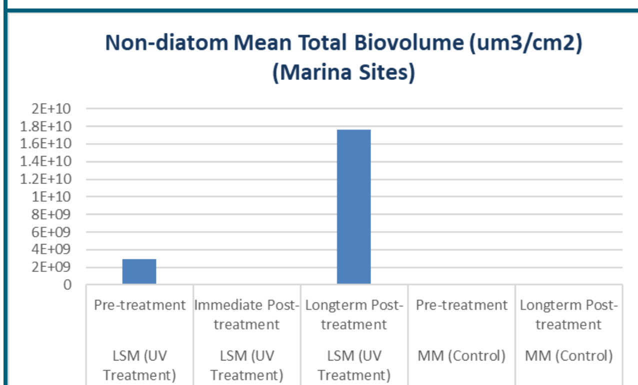


Figure 22c. Non-diatom Mean Total Biomass, marinas

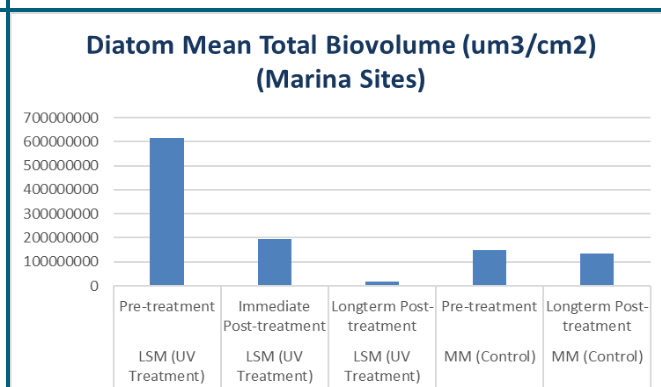


Figure 22d. Diatom Mean Total Biovolume, marinas

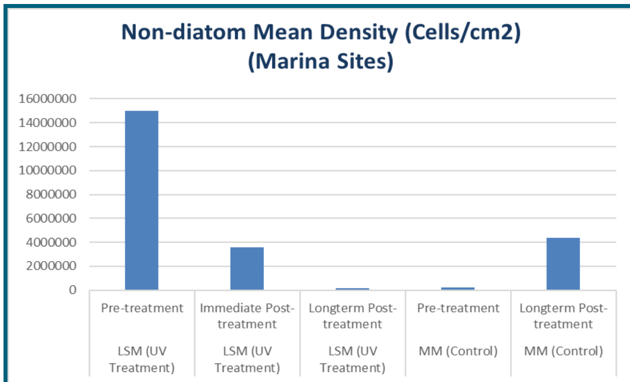


Figure 22e. Non-diatom Mean Density, marinas

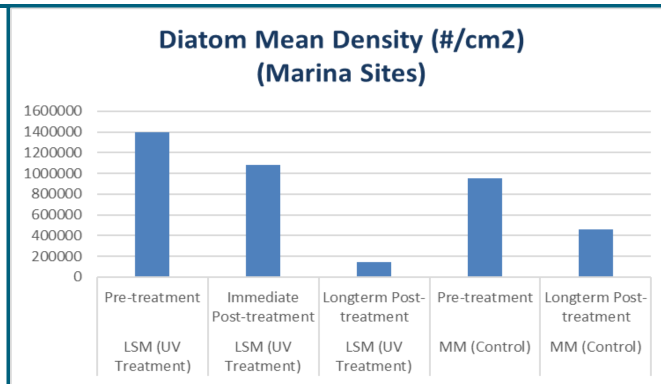


Figure 22f. Diatom Mean Density, marinas

Figure 22. Periphyton (non-diatom and diatom) taxon richness, mean total biomass and mean density results measured at marina sites

8.5.2 Littoral Sites

Figure 23 presents a compilation of periphyton results, as titled below for 23a through 23f, for the littoral sites. Diatom and non-diatom taxa richness, total biovolume and densities reported for LSB. All metrics decreased following UV-C light treatment and continued to decrease one (1) year later, long term post-treatment. Diatom and non-diatom metrics reported for SR control site were variable and disclose no apparent trends.

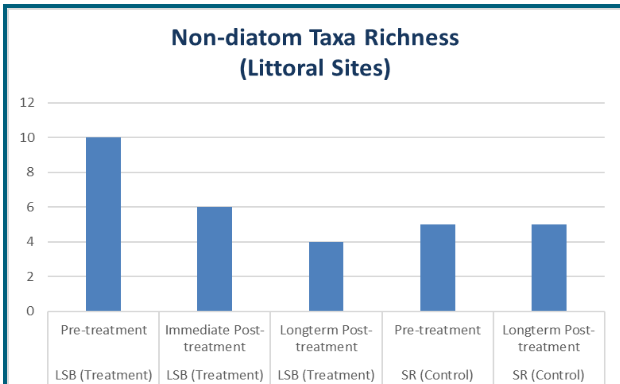


Figure 23a. Non-diatom Taxon Richness, littoral

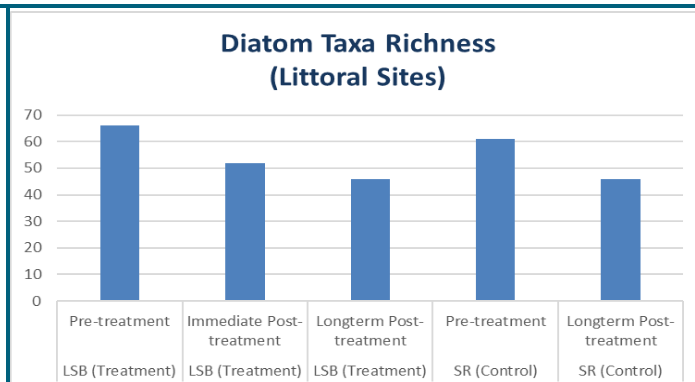


Figure 23b. Diatom Taxon Richness, littoral

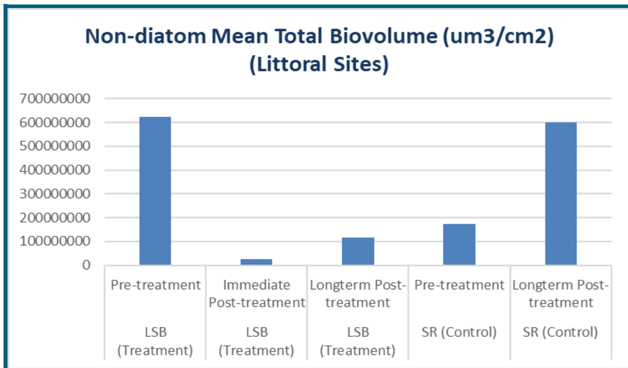


Figure 23c. Non-diatom Mean Total Biovolume, littoral

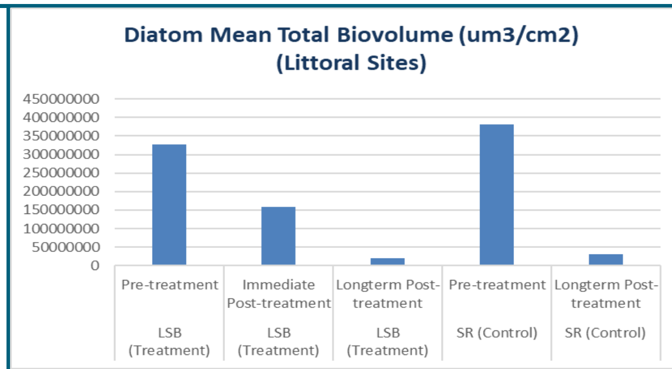


Figure 23d. Diatom Mean Total Biovolume, littoral

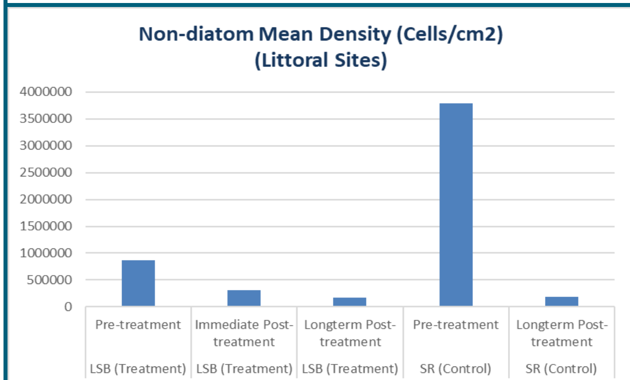


Figure 23e. Non-diatom Mean Density, littoral

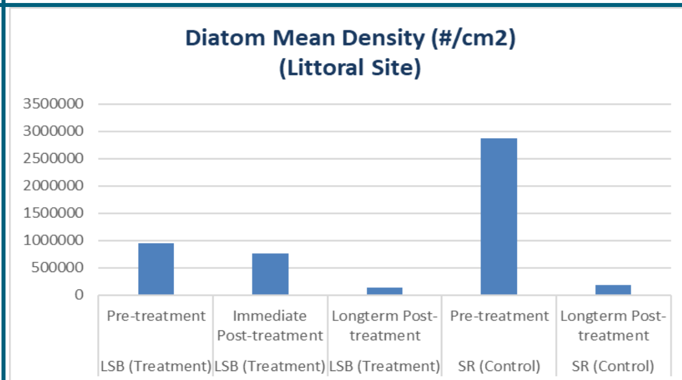


Figure 23f. Diatom Mean Density, littoral

Figure 23. Periphyton (non-diatom and diatom) taxon richness, mean total biomass and mean density results measured at littoral sites

8.6 Zooplankton

There are two types of planktons: phytoplankton and zooplankton. Zooplankton are animal plankton and include small protozoans or metazoans (e.g. crustaceans and other animals) that feed on other planktons, detritus and even nektonic organisms. The counting of zooplankton is necessary to know about the fauna of an aquatic habitat, as zooplankton are primarily found in surface waters where food resources (phytoplankton or other zooplankton) are abundant. Given their unique position in the food chain, zooplankton are indicators of water quality. Species density and composition can respond rapidly to environmental changes such as nutrient enrichment, toxic conditions brought by algal blooms, introduction of invasive fish and other influences (Wells et. al. 2015). Important to note is that the zooplankton results reflect single sample sets or a snapshot in time and not a robust sampling of the population over time.

8.6.1 Marina Sites

Figure 24 and **Figure 25** presents zooplankton taxa richness and mean density (reported as count per milliliter) for the marina sites. At LSM, taxon richness, or the number of different taxa measured, increased slightly following UV-C light treatment, while mean density reported as the count of zooplankton per milliliter decreased by an order of magnitude. Conversely, zooplankton taxon richness and mean density at MM control site increased.

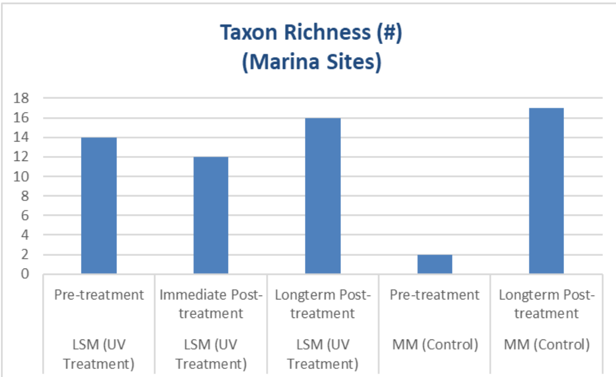


Figure 24. Zooplankton Taxon Richness, marinas

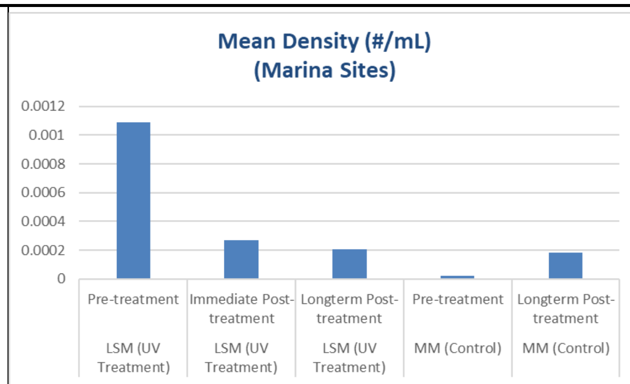


Figure 25. Zooplankton Mean Density, marinas

8.6.2 Littoral Sites

Figure 26 and **Figure 27** presents zooplankton taxa richness and mean density (reported as count per milliliter) for the littoral sites. As compared to pre-treatment results, zooplankton taxa richness doubled and mean density increased following UV-C light treatment at LSB. Zooplankton results for SR control site reflect those results reported for the littoral treatment sites.

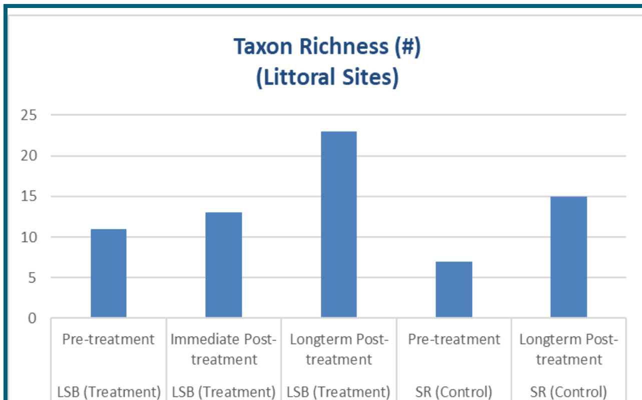


Figure 26. Zooplankton Taxon Richness, littoral

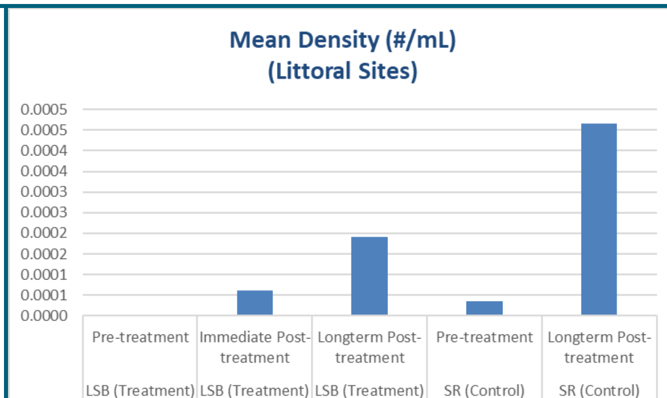


Figure 27. Zooplankton Mean Density, littoral

8.7 Phytoplankton

There are two types of planktons: phytoplankton and zooplankton. Phytoplankton are plant plankton and include autotrophic, prokaryotic or eukaryotic algae that live near the water surface where there is sufficient light to support photosynthesis. The counting of planktons is necessary to know about the flora of a particular area. Phytoplankton live near the surface of the water body because they need sunlight. Phytoplankton use water and CO_2 to grow, however they also need other vitamins and minerals, like iron, to survive. Phytoplankton, unlike periphyton, are comprised of algae in the open water column. Samples can provide an insight to waterbody health based on species assemblages. Important to note is that phytoplankton results reflect single sample sets or a snapshot in time and not a robust sampling of the population over time.

8.7.1 Marina Sites

Figure 28 presents the compilation of phytoplankton results, as titled for 28a though 28d, for the marina sites. Taxon richness shows little decrease from pre-treatment to post-treatment, and are comparable to that of the control site. Mean total biovolume was variable when comparing pre-treatment to post- treatment at LSM and then to the MM control site.

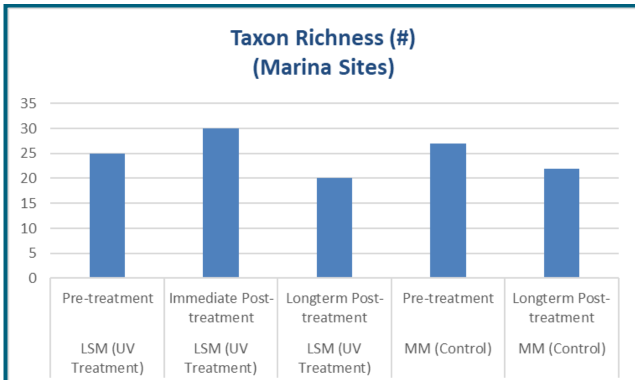


Figure 28a. Phytoplankton Taxon Richness, marinas

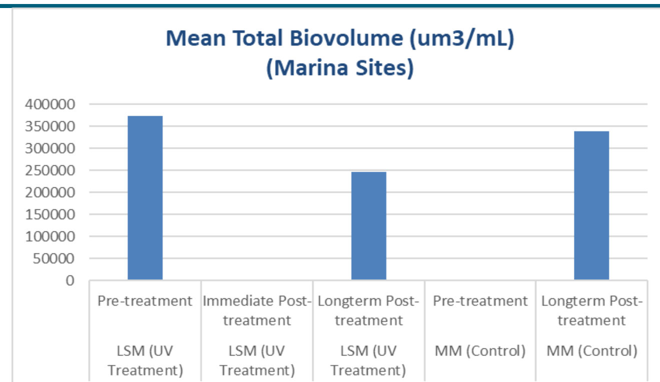


Figure 28b. Phytoplanton Mean Total Biovolume, marinas

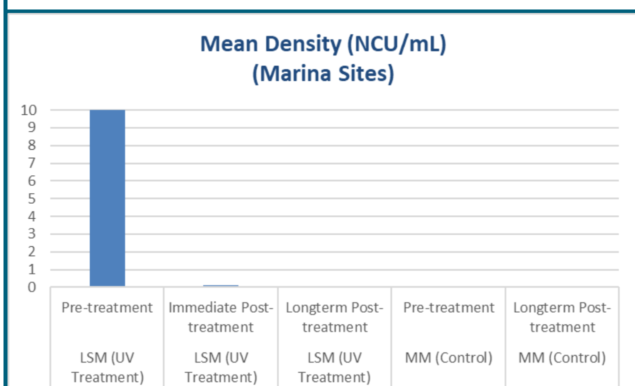


Figure 28c. Phytoplankton Mean Density (NCU/mL), marinas

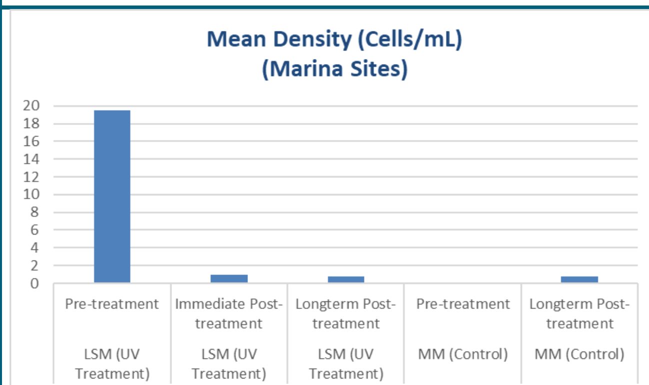


Figure 28d. Phytoplankton Mean Density (Cells/mL), marinas

Figure 28. Phytoplankton results for taxa richness, mean total biovolume and mean density, marina sites

8.7.2 Littoral Sites

Figure 29 presents the compilation of phytoplankton results, as titled for 29a though 29d, for the littoral sites. Taxon richness and mean density appear to have decreased at LSB following UV-C light treatment, but when compared to the SR control site, uncontrolled physical, chemical or biological inputs may have had influence. No concluding trends are reported for the data set.

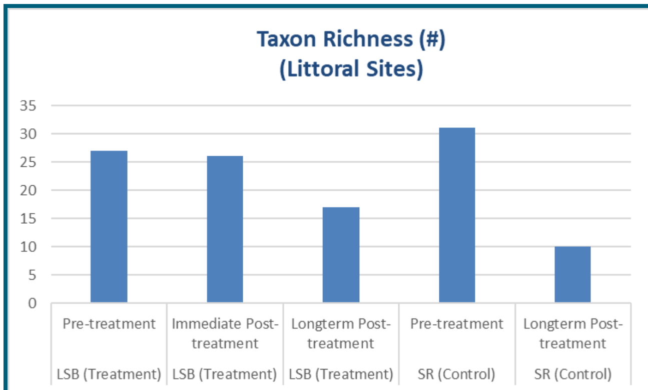


Figure 29a. Phytoplankton Taxon Richness, littoral

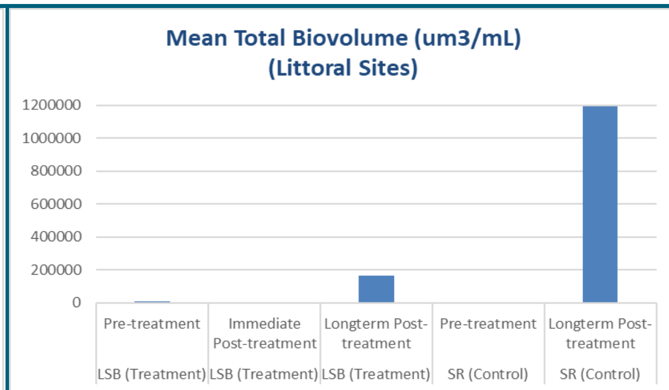


Figure 29b. Phytoplankton Mean Total Biovolume, littoral

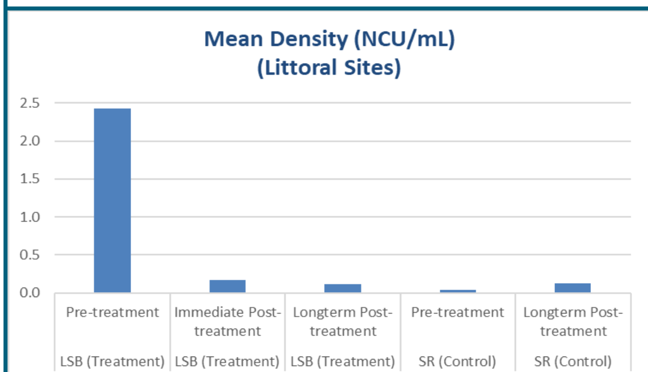


Figure 29c. Phytoplankton Mean Density (NCU/mL), littoral

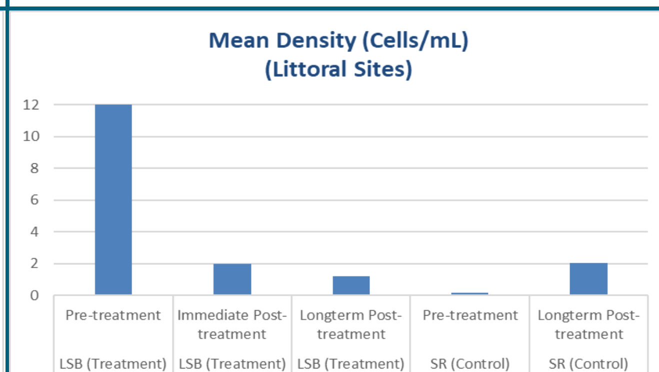


Figure 29d. Phytoplankton Mean Density (Cells/mL), littoral

Figure 29. Phytoplankton results for taxa richness, mean total biovolume and mean density, littoral sites

8.8 Water Quality

Water quality parameters were measured to gauge compliance with Lahontan Regional Water Quality Control Board and Tahoe Regional Planning Agency numeric water quality objectives. Pre-treatment water quality sampling at the LSM and LSB treatment sites established baseline conditions. Water quality monitoring occurred daily during active UV-C light treatment with parameters measured approximately each hour. Post-treatment water quality sampling at LSM and LSB occurred in October 2017 upon completion of active UV-C light treatment in September 2017. Constant visual observations were conducted to assure narrative water quality objectives were met throughout active UV light treatment applications. Post-treatment, visual observations and photo documentation continued monthly, at a minimum, through 2018.

Water quality results report no instances of violation of narrative or numeric water quality objectives. **Table 14** presents the Lake Tahoe water quality limitations set in the Water Quality Control for the Lake Tahoe Basin (Basin Plan) and the TRPA 2012 Regional Plan Update (RPU) Chapter 60. The Porter-Cologne Water Quality Control Act defines "water quality objectives" as the allowable "limits or levels of water quality constituents or characteristics which are established for the reasonable protection of beneficial uses of water or the prevention of nuisance within a specific area. Water quality objectives apply to "waters of the State" and "waters of the United State." Wherever federal, state, or local air and water quality standards apply for the region, the strictest standards shall be attained, maintained, or exceeded pursuant to Article V(d) of the Tahoe Regional Planning Agency Bi-State Compact.

Table 14. Water Quality Objectives for the Lake Tahoe Hydrologic Unit

Parameter	Lahontan Water Board Water Quality Narratives
Dissolved Oxygen	The dissolved oxygen concentration, as percent saturation, shall not be depressed by more than 10 percent, nor shall the minimum dissolved oxygen concentration be less than 80 percent of saturation; % saturation above 80% and DO >7 mg/L except if saturation exceeds 80% DO at lake bottom (105m) > 6mg/L
pH	In fresh waters with designated beneficial uses of COLD, changes in normal ambient pH levels shall not exceed 0.5 pH units. For all other waters, the pH shall not be depressed below 6.5 nor raised above 8.5
Water Temperature	The natural receiving water temperature of all waters shall not be altered unless it can be demonstrated to the satisfaction of the Regional Board that such an alteration in temperature does not adversely affect the water for beneficial uses
Total Dissolved Solids	60 mg/L Annual Average and 65 mg/L 90th percentile
Turbidity	Waters shall be free of changes in turbidity that cause nuisance or adversely affect the water for beneficial uses. Increases in turbidity shall not exceed natural levels by more than 10 percent
Conductivity	In Lake Tahoe, the mean annual electrical conductivity shall not exceed 95 umhos/cm at 25 degrees C at any location in the Lake
Plankton Counts	For Lake Tahoe, the mean seasonal concentration of plankton organisms shall not be greater than 100 per ml and the maximum concentration shall not be greater than 500 cells per ml at any point in the Lake
Chlorophyll-*a*	0.6 µg chl-a/L; 0.9 µg chl-a/L; 1.5 µg chl-a/L, as corrected for phaeophytin degradation pigment

Source: Lahontan Basin Plan Chapter 5

8.8.1 Marina Sites

Pre-treatment water quality parameters were sampled hourly at the LSM treatment area on June 11, 2017 and immediate post-treatment water quality parameters were sampled on October 17, 2017. Additionally, Green(e) Consulting conducted third party QA/QC monitoring once a week during periods of active treatment. Active treatment occurred in the LSM treatment area (11,800 square feet or 0.27 acres) on select days, as reported in **Table 1**, from June 21 through September 5, 2017. Additional details regarding active treatment in the LSM treatment area are presented in IRI's monthly reports for August and September 2017, which are contained in **Appendix B**, along with the raw data files for daily monitoring that were submitted with monthly status reports by IRI, along with QA/QC field data forms and raw data submitted by Green(e) Consulting. **Table 15** summarizes pre-treatment, monthly, and immediate post-treatment water quality monitoring results for temperature, dissolved oxygen, pH, specific conductivity, total dissolved solids and turbidity at LSM and LSB.

8.8.2 Littoral Sites

Pre-treatment water quality parameters were sampled hourly at the LSB treatment area on July 30, 2017 and immediate post-treatment water quality parameters were sampled on October 29, 2017. Additionally, third party QA/QC monitoring occurred once a week during periods of active treatment.

Table 15. Pre-treatment, Monthly, and Post-Treatment Water Quality Results

			Water Temperature °C	Dissolved Oxygen (mg/L)	pH (0-14)	Specific Conductivity *(µS/cm)*	*Total Dissolved Solids* (g/L)*	*Total Dissolved Solids* (ppm)*	*Turbidity NTU*	Weather Conditions, Temp °C	Lake Level Elevation Feet
PRE-TREATMENT	**LSM**	*Mean***	20.70	10.37	7.94	*105.25*	*0.077*	*76.99*	*1.76*	N/A	6228.94
	LSB	*Mean***	23.89	10.52	7.95	*74.91*	*0.052*	*52.02*	*0.88*	N/A	6228.91
JUNE	**LSM**	*MIN*	18.11	6.18	7.34	*78.00*	0.040	*40.00*	0.16	9.44	6228.86
		MAX	21.60	8.96	8.00	*90.00*	0.065	*65.00*	1.98	28.88	6228.93
		*Mean****	19.77	7.91	7.55	*84.00*	0.057	*56.58*	0.57	20.72	6228.90
JULY	**LSM**	*MIN*	20.66	9.29	7.33	*88.00*	*0.057*	*57.00*	0.10	10.56	6228.97
		MAX	22.30	12.98	7.77	*104.00*	*0.068*	*68.00*	1.25	28.89	6229.01
		*Mean****	21.45	10.76	7.54	*97.44*	*0.063*	*63.35*	0.43	23.30	6229.00
	Discretionary Points	*MIN*	20.06	9.98	7.51	*83.00*	*0.054*	*54.00*	0.11	11.11	6228.97
		MAX	22.60	13.04	7.98	*101.00*	*0.066*	*66.00*	0.95	28.89	6229.01
		*Mean****	21.36	11.53	7.75	*92.95*	*0.060*	*60.32*	0.45	21.92	6229.00
AUGUST	**LSB- Swim**	*MIN*	20.45	6.86	7.60	*89.00*	*0.057*	*57.00*	0.06	24.00	6228.70
		MAX	22.62	11.03	8.28	*92.00*	*0.062*	*62.00*	0.69	26.11	6228.88
		*Mean****	21.17	8.44	8.01	*90.68*	*0.059*	*58.95*	0.36	24.26	6228.80
	LSB- Taxi	*MIN*	20.67	6.79	7.39	*91.00*	*0.059*	*59.00*	0.15	23.00	6228.70
		MAX	22.43	9.73	7.97	*94.00*	*0.061*	*61.00*	1.47	28.00	6228.80
		*Mean****	21.48	7.99	7.84	*92.19*	*0.060*	*60.15*	0.53	25.92	6228.73
	LSM	*MIN*	20.59	5.62	6.84	*68.00*	*0.060*	*60.00*	0.14	23.00	6228.60
		MAX	22.11	10.49	7.91	*109.00*	*0.071*	*71.00*	0.97	30.00	6228.80
		*Mean****	21.40	8.49	7.56	*98.27*	*0.065*	*65.47*	0.51	26.49	6228.65
	Discretionary Points	*MIN*	21.72	8.81	7.58	*94.00*	*0.061*	*61.00*	0.19	23.00	6228.8
		MAX	21.80	9.12	7.78	*97.00*	*0.063*	*63.00*	0.19	23.00	6228.8
		*Mean****	21.76	8.94	7.65	*96.25*	*0.063*	*62.50*	0.19	23.00	6228.8
SEPTEMBER	**LSB- Swim**	*MIN*	19.11	7.39	7.60	*97.00*	*0.063*	*63.00*	0.28	20.00	6228.50
		MAX	19.89	8.59	7.80	*101.00*	*0.065*	*65.00*	0.87	25.00	6228.50
		*Mean****	19.51	8.33	7.66	*98.55*	*0.064*	*63.64*	0.54	21.36	6228.50
	LSB- Taxi	*MIN*	19.79	8.09	7.62	*96.00*	*0.064*	*64.00*	0.29	20.00	6228.50
		MAX	21.72	9.22	7.81	*100.00*	*0.069*	*69.00*	0.72	29.44	6228.50
		*Mean****	20.30	8.50	7.70	*97.83*	*0.066*	*65.67*	0.52	22.96	6228.50
	LSM	*MIN*	19.87	7.50	7.45	*97.00*	*0.064*	*64.00*	0.30	24.40	6228.50
		MAX	21.62	9.09	7.81	*105.00*	*0.069*	*69.00*	1.12	29.44	6228.60
		*Mean****	20.71	8.39	7.60	*100.57*	*0.068*	*67.53*	0.54	27.49	6228.52
IMMEDIATE POST-TREATMENT	**LSM**	*Mean***	14.00	10.25	8.1	*92*	*0.067*	*66.5*	*0.46*	N/A	6227.94
	LSB	*Mean***	13.20	10.2	8.27	*91.7*	*0.069*	*68.6*	*0.56*	N/A	6224.93

Source: 2017 Progress Report Attachment B, IRI and Green(e) Consulting raw data files

Notes:
* The YSI meter collected Specific Conductivity in mS/cm and was needed to be reported to TRCD in µS/cm. Total Dissolved Solids were collected in g/L in the field and are were required to be reported to TRCD in ppt/ppm
** Average based on daily dataset
***Average based on monthly dataset, not the average between low and high data values

Active treatment occurred in the LSB treatment area (7,800 square feet or 0.18 acres) on select days, as reported in **Table 1,** from August 8 through September 11, 2017. Additional details regarding active treatment in the LSB treatment sites were presented in IRI's monthly reports for August and September 2017, which are contained in **Appendix B. Table 15** summarizes the pre-treatment, monthly and immediate post-treatment water quality monitoring results for temperature, dissolved oxygen, pH, specific conductivity, total dissolved solids and turbidity at the LSB treatment area.

8.8.3 Water Quality Monitoring Results for the Cumulative Data Set (LSM and LSB)

Figure 30 presents the compilation of water quality monitoring results measured at the LSM and LSB treatment sites, as titled for 30a though 30f, for the combined cumulative data set. The Box and Whisker plots graphically display the median, quartiles and extremes to show the distribution of the data for water temperature, dissolved oxygen, pH, specific conductivity, total dissolved solids and turbidity, as measured in 2017 for pre-treatment, during active treatment (monthly data sets presented), and immediate post-treatment. Water quality monitoring was not conducted for long term post-treatment in 2018.

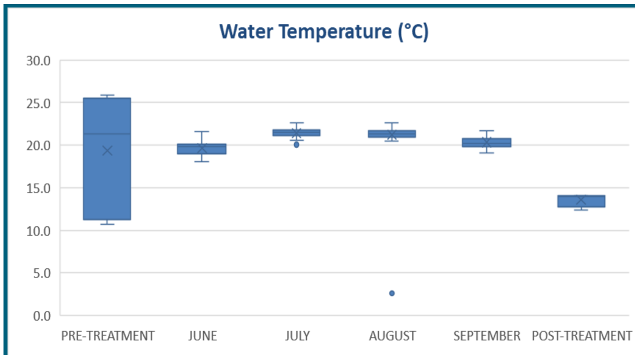


Figure 30a. Water Temperature

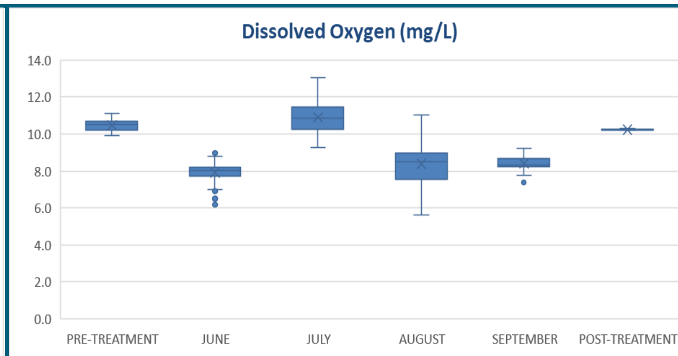


Figure 30b. Dissolved Oxygen

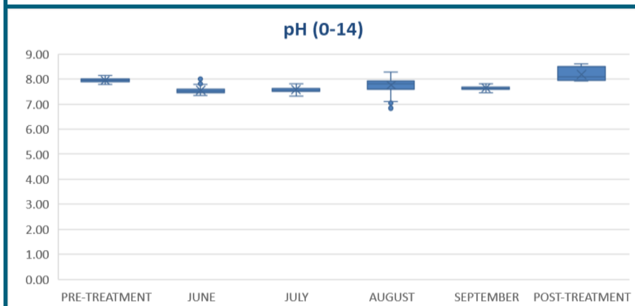


Figure 30c. pH

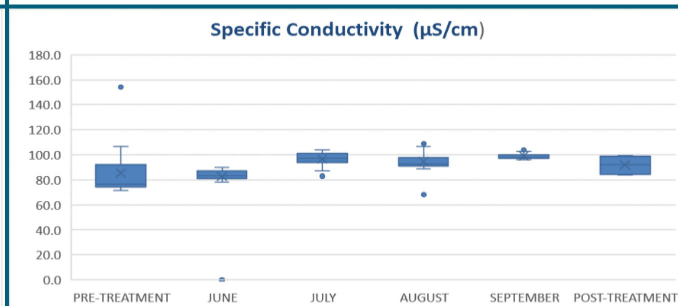


Figure 30d. Specific Conductivity

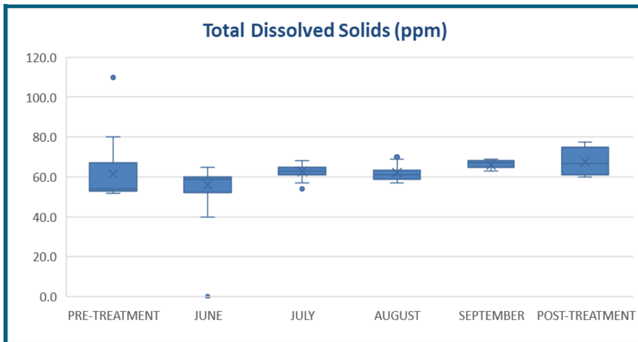


Figure 30e. Total Dissolved Solids

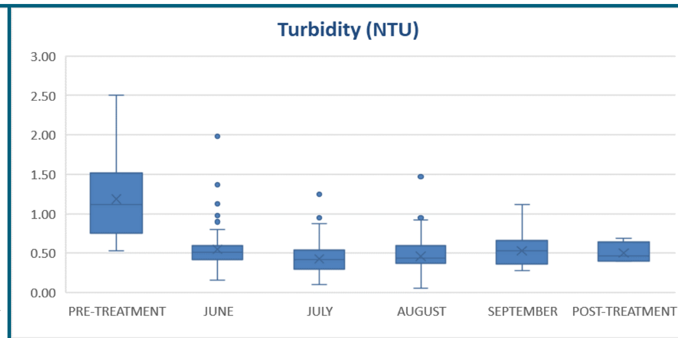


Figure 30f. Turbidity

Figure 30. Box and Whisker plots for water temperature, dissolved oxygen, pH, specific conductivity, total dissolved solids and turbidity, representative of the cumulative data set for treatment sites

9 Responses to Monitoring Questions and Findings

The following section provides a discussion of findings by the Advisory Team for the Project questions that were originally outlined in the Monitoring Plan (**Attachment A**):

- **Does UV-C light kill aquatic invasive plant species?**

In laboratory-controlled testing, UV-C light treatment killed most AIP tested. Plants did not reproduce or regrow, when exposure times of 5 to 15 minutes were used. Some regrowth was observed on plants that dropped or degraded following treatment with lower exposure times. Regrowth was observed to be slow and quickly turned yellow after a second round of treatment. UV-C light treatment damages the DNA structure of the plant and the life cycle of the plant is disrupted. The field pilot testing at LSM and LSB treatment areas showed similar results. Plants dropped or degraded after proper treatment applications (i.e., application intensity and durations varied according to observed field conditions and in response to variable lake and weather conditions), and treated plants disintegrated, as observed in the lab tests.

UV-C light was successful at treating the leaves and stems but does not penetrate the lake bed or sediment profile, and therefore, roots can be shielded from UV-C light. New plant growth that was observed appears to have originated from CPW turions, untreated plants or rigorous root structures. Mature CPW turions may exist on the lake bed and can accumulate in the sediment profile. As long as the crown of the plant was treated effectively, minimal new growth occurred from the stock of the plant.

Exposure to UV-C light is controlled and focused. UV-C light disinfects, sterilizes or kills virtually all plants that receive a lethal dose. However, only the small volume of water under the UV-C light array is exposed to the UV-C light. The UV-C light treatment method treats the entire plant from the leaves to the crown. The light array is lowered over the plants until it approaches the lake bed or sediment. This pushes the taller flimsy plants downward and confines them under the shielded chamber. From past benthic barrier and diver-assisted hand removal work, Tahoe RCD and their contractors have observed that fish, crayfish and other mobile species immediately evacuate the area of disturbance. Similar observations were made by field technicians during treatment with mobile species evacuating the area. When field conditions dictate, a strobe light or other fish deterrent method can be mounted on the UV-C light array to deter mobile species from entering the treatment area.

Based on the pilot Project results, the UV-C light treatment method can be used to control AIP and ultimately reduce total plant cover, height and density. UV-C light treatment is an effective tool to control AIP, with a site-specific prescription treatment plan that considers multiple factors. Further testing, observation and analysis is recommended to measure longer term results (e.g., a second growing season) and to further define strategies to use in connection with other approved AIP control tools like benthic barriers and diver-assisted suction removal and hand removal.

Immediate post-treatment results in 2017 indicated the potential for regeneration from mature turions. Testing of UV-C light on multiple stages of curlyleaf pondweed, including mature turions is underway by University of Nevada and IRI and laboratory results are expected in 2020. The successful application of UV-C light to control regrowth occurring from mature turions would address the unquantified potential for long term macrophyte regeneration from the lake bed seed bank.

- **How far does UV-C light penetrate sediment on the lake bed?**

Prior laboratory testing concluded that UV-C light has very little penetrating power through sediment with almost all light blocked at a depth of 1.5mm of test media. The field assumption is that the UV-C rays will be stopped at the surface of the lakebed sediments with virtually no penetration occurring. The UV-C light array was designed to minimize any treatment outside of the shielded light chamber, which is set approximately six (6) inches above the lake bed or lake sediment surface. The treatment chamber has five walls (i.e., four side walls and a top wall) that do not allow UV-C light to go outside the immediate treatment area, minimizing the environmental impacts. The minimized numbers of BMI that may be exposed to lethal dose of radiant energy are expected to repopulate from the surrounding area. Refer to **Appendix B** for additional discussion of UV-C light concentration versus sediment depth.

- **How do BMI respond to UV-C light treatment methods?**

The size and duration of the pilot Project, which treated a very small area of Lake Tahoe (< 2 acres of the 122,624 acres in Lake Tahoe's aquatic environment), resulted in temporary, short-term effects to the benthic community at LSM and LSB treatment sites. Approximately 0.86 acres of the roughly 2-acre project area is within a highly disturbed marina environment. This disturbed environment is dominated by non-native and invasive species, including AIP, Asian clams, and warm water fish.

Table 12 presents BMI response to impairment for a variety of richness, dominance, diversity and tolerance measures comparing pre-treatment to long term post-treatment. Important to note is that the biomonitoring results reflect single sample sets or a snapshot in time and not a robust sampling of the population over time. **Table 13** adds immediate post-treatment results for consideration.

UV-C light impacts may occur to species above the sediment-water interface with limited to no impact to flora and fauna that live below the surface since UV-C light is rapidly attenuated (decreases penetration) when organic material is present. By removing the invasive, non-native species, field observations reported that organic matter on the lake bed or substrate increases in patches but is visibly intermittent and temporary, as materials did not persist with the flossing of matter between the marina site and the open lake. Organic matter associated with the decomposition of AIP in the LSB treatment area, dissipated over the course of just a few days, assumedly being carried with the littoral drift.

Increase in organic matter, even for temporary periods, is assumed to facilitate the recovery of BMI and recolonization by providing food sources. Immediate post-treatment results as compared to pre-treatment results, support this assumption with total taxa richness, total abundance, EPT taxa richness and EPT abundance increasing at LSM and LSB just a few weeks following UV-C light treatment. Previous efforts to target invasive clam invertebrates or AIP with alternate treatment and control methods (e.g. suction and benthic barriers) in the open lake neighboring LSM also suggest recovery of the BMI community after treatment (Wittmann et. al 2011).

Findings from the Tahoe Keys Aquatic Plant Management Research Project Final Report (2012), reported BMI densities artificially higher in the Tahoe Keys marina (with no endemic taxa detected) compared to the Lake proper. The authors concluded that the lack of significant difference in invertebrate responses observed between control and treatment plots indicated that BMI were able to persist under synthetic barriers or could rapidly recolonize treatment plots. Removing AIP has an impact on BMI, which in the Tahoe Keys study, did not appear to preferentially colonize areas containing plants. In fact, BMI densities in treatment plots, which contained no plants 7- and 50-days post-removal, were often higher than in adjacent control plots containing plants. The distribution and density of BMI in the Tahoe Keys treatment and control sites were likely driven by taxon-specific substrate preferences rather than by treatment effects. Additionally, the density differences between plots seemed to be related to differences in dominant plant type. Densities of midges and scuds, and the overall invertebrate assemblage in samples that contained EWM were significantly greater than densities of these taxa in samples containing native coontail or no plants at all. This information suggests that the assemblage of benthic communities is altered in habitats containing AIP such as EWM. Additionally, Ka Lai Ngai et al. (2010) reported that native fish have a higher tolerance for UV transparency. Therefore, by removing AIP, habitat preference shifts from non-native warm water fish to native fish.

Significant or major impact to BMI communities as a result of UV-C light applications were not measured in LSM and LSB, as the benthic community recolonized as expected (Wittmann et al. 2011) and organic matter rapidly decomposed and dissipated through lake flushes and littoral currents. With the successful removal of AIP, the aquatic environments (e.g., marina and littoral sites) did not exhibit concerning trends to ecological health or significant or sustained impairment as seen in long-term post-treatment monitoring results.

- **How does UV-C light affect water temperature?**

The effect of UV-C light on ambient water temperatures was tested in the laboratory and after four (4) hours of the UV-C light application, the last recorded measurements illustrated that the thermometer 1 inch away from the light array had risen 1.5°F with the other sensors at 12 and 24 inches both increasing by 0.5°F. Consider the UV-C apparatus adding 2,000 watts of UV-C light energy per hour to the water. One (1) watt is equivalent to 3.412142 BTU/hour. Water temperature monitoring occurred throughout active UV-C light treatment and no significant temperature differences were recorded. UV-C light applications did not result in measurable temperature changes in the water column. Refer to **Appendix B** for additional information about laboratory testing results.

Based on pre-treatment, active treatment, immediate post-treatment, and QA/QC water quality sampling results, the water quality parameters that were monitored are not altered by the UV-C light treatment method nor significantly degraded during the decomposition of plant materials. Based on the preliminary review of the climatic data collected throughout the pre-treatment, active treatment and immediate post-treatment periods, localized water temperature was not affected by UV-C treatment. When considering ambient weather conditions, as the air temperature increased between June and August, the water temperature also slightly increased. As air temperature fluctuated and decreased from August to October, water temperature eventually decreased as well. No spikes in localized water temperature were recorded in the vicinity of the UV-C light array. The 2017 field results support the conclusions from laboratory testing that water temperature is not significantly altered by UV-C light. Water temperatures were consistent with seasonal warming and cooling trends. The highest temperatures measured in the project vicinity were recorded just outside the treatment area along the marina wall.

- **What are the effects of the UV-C light treatment method to dissolved oxygen levels in the treatment area**?

Pre-treatment, active treatment and immediate post-treatment Dissolved Oxygen levels consistently measured between 8.5 and 10.5 mg/L. This range is within normal lake concentrations with fluctuations tied to water temperatures. Monitoring results reported no significant difference between pre-treatment, active treatment, and immediate post-treatment levels. Long-term post-treatment water quality monitoring was not conducted.

- **How do plankton (phytoplankton or zooplankton) or periphyton respond to the UV-C light treatment method?**

Periphyton biomass data collected for Lake Tahoe's nearshore has exhibited an increasing trend over the last 10 to 12 years (https://nevada.usgs.gov/TahoeNearshore/index.html). United State Geological Survey (USGS 2016) conducted high frequency sampling along five transects on the west shore of Lake Tahoe over a 10-month period in 2015 to 2016 with an objective of better understanding the mechanisms that contributed to this change. Analyses (including hydrodynamic modeling) are ongoing and exploring relationships between explanatory variables and seasonal change in periphyton biomass. Researchers with Tahoe Environmental Research Center (TERC) monitor periphyton growth around Lake Tahoe five times per year and report the heaviest growth during spring months (https://tahoe.ucdavis.edu/periphyton-0), which can reflect local nutrient loading and be affected by long-term environmental changes.

Modeling of physical, chemical and biological inputs to understand the driving forces of periphyton and plankton growth is often necessary, but was beyond the scope of this pilot Project (https://tahoe.ucdavis.edu/periphyton-biomass-modeling). Results from this Project indicate that UV-C light may have a short-term effect on plankton and periphyton populations, but long-term post-treatment results did not indicate that populations were eliminated. The UV-C treatment system effectively treats AIP within approximately 6-inches of the lake bed or substrate. The UV-C light array is lowered through the water column to concentrate UV-C light applications at the crown of the plant. A perimeter shield allows only plants within the chamber to receive a lethal dose of radiant energy. Assuming a depth of around 10 feet, approximately 5% of the water column is exposed to the lethal rays. Periphyton and plankton in the other 95% of the water column above the chamber persist to replenish the 5% treated water volume, as the UV-C light array chamber moves through the treated area. Overall, pilot Project results do not appear to indicate trends for long-term degradation.

- **What are the regrowth rates for AIP treated with UV-C light?**

Four important variables contribute toward AIP regrowth rates: existing turions; root mass; smaller plants protected from larger canopy shadowing; and plant mortality. During pre-treatment site visits in June 2017, some CPW already had mature turions developing. After active treatment, IRI technicians commenced daily visual monitoring of the treatment areas and observed and documented signs of mortality and deterioration of AIP treated with UV-C light. Most AIP treated with UV-C light exhibited signs of deterioration within 7 to 10 days following UV-C light treatment. Smaller plants under the tall and well-developed AIP canopies appear to have been shielded during Phase 1 of UV-C light treatment and then grew once exposed to more sunlight and resources. During Phase 2 of treatment, the smaller plants were treated with UV-C light and in most cases, treatment occurred before mature turions developed. Complete eradication of AIP may not be achieved during the first few rounds of treatments, but a decrease in AIP percent cover and mean plant height, and thus plant density, over time is likely achievable when AIP populations are treated before turions develop and plants are shorter (less mature). The ideal scenario is to treat AIP with UV-C light early in the growing season (e.g., typically May and June) and conduct several phases of treatment in order to control any new AIP that may sprout from existing mature turions or roots.

Long-term post-treatment results allowed for further analysis of AIP regrowth rates. Long-term post-treatment surveys indicate that some Natives reestablished by June 2018. Some invasive plants also reestablished with mean plant height measured at 132 cm pre-treatment and 15 cm measured post-treatment by August 2018. This represents an 88% reduction in average plant height. Long-term post-treatment results from August 2018 measured Natives out competing Invasive in percent cover, mean plant height (cm) and frequency of occurrence.

10 Economic Assessment of Treatment Methods

This section, composed by Advisory Team member Dr. Ravi Jain, Dean Emeritus of the School of Engineering and Computer Science at University of the Pacific, presents an economic assessment of UV-C light treatment as compared to other AIP control method applications. The assessment is presented according to the following sub-sections:

- Project background
- Project objectives
- Cost comparison among UV-C light, benthic barriers, and diver-assisted suction removal for aquatic plant treatment. *(Chemical treatment methods were excluded)*
- Post treatment results -water quality and environmental assessment
- Technology selection and implementation

The Advisory Team highlights the Projects focus to work closely with the various project participants to seek cost effective and sustainable solutions to the AIP control program, an important and crucial issue for Lake Tahoe.

10.1 Project Background

Aquatic Invasive Plants (AIP) specifically Eurasian watermilfoil (*Myriophyllum spicatum*) are important environmental, economic, and aesthetic problems at Lake Tahoe, an important national treasure. Several methods such as benthic barriers and diver assisted suction removal are commonly used to control AIP. This combination of methods is used in marina settings and open water, however, there are some limitations related to cost, effectiveness in open water and the lake bed morphology.

The AIP issue primarily affects marinas and near shore environments. TRPA estimated on their website that the environmental impact of AIP is approximately $22 million dollars per year. From 2007 to 2009, funding secured and allocated for spending on AIP prevention, control/eradication, research, monitoring, amounted to around $5.2 million dollars. AIPs will become a pervasive problem; environmental and economic impacts are likely to increase markedly if reliable and sustainable invasive species control technologies are not implemented.

10.2 Project Objectives

This Project assessed the effectiveness of various technologies, short and long-term environmental impacts and their economic feasibility. Also of interest are suggestions for effective and sustainable treatment methods for AIP. Below is an analysis of cost comparison among these technologies or methods implementation and suggested selection guidelines.

10.3 Cost Comparison

Labor for each treatment method currently used in Lake Tahoe was reviewed. For general operations and maintenance, most equipment has multiple years of service life, however, labor to run such equipment plays a significant role each time you deploy the treatment method selected. There are numerous factors that are not included in these estimates including, weather conditions, heavy boat traffic interruptions, water obstructions, mobilization issues, special access, seasonal changes, plant height/density, and marina vs. open water. These estimates also do not include project and contract management costs for lead agency or equipment costs. **Table 16** illustrates labor cost for each of the treatment method options reviewed. These costs are present costs and may change in the future as technology or methods improve.

Table 16. Labor Cost per Treatment Method

Method	Labor Cost	Treatment Area
Diver Assisted Suction[1]	$50,000	1 acre
Benthic Barrier Mats[1]	$40,000	1 acre
UV-C Treatment System[2] 160 ft^2	$28,000	1 acre
UV-C Treatment System[2] 320 ft^2	$14,000	1 acre
UV-C Treatment System[2] 640 ft^2	$7,000	1 acre

Source: Ravi Jain, Appendix B

[1]Costs based from Tahoe Conservation Resources District projects, Nicole Cartwright

[2]Costs based on Inventive Resources Inc. cost estimates, John J. Paoluccio. The costs for bigger treatment systems are lower; however, capital cost of the system is higher.

Cost comparison among UV-C, benthic barrier mats, and diver assisted suction for aquatic plant treatment was completed. Chemical treatment methods were excluded because they are currently not allowed in Lake Tahoe. Cost comparison information presented here is derived from various reports and other documents provided by the project participants.

10.3.1 Diver Assisted Suction Removal

Diver assisted suction removal is essentially a dive team using a suction pump and hose to extract AIP in the area. AIP is collected in a basket or bag with little to no substrate and then hauled off site for disposal. Typically, a 4-person dive team is used and an approximate cost per day is about $3,500. It can take approximately two weeks for a dive team to cover a one-acre site. This method is effective when the target area is small and or the ground surface is uneven and broken which makes other methods such as benthic barriers inapplicable. This method can vary greatly depending on plant density and height. Some limitations include: divers can only be deployed during daylight with minimal or managed boat traffic; safe water currents; localized turbidity during suction and ground surface disturbance is minimal; and weather conditions are desirable. Additionally, diver and marina coordination is essential and thus may limit diver scheduling. Cost does not include labor for permitting, hauling away AIP and dump fees. Diver assisted suction approximate labor cost is $50,000 per acre for a light to moderate infestation. Suction equipment is currently owned by the Lake Tahoe Aquatic Invasive Species Program.

10.3.2 Benthic Barriers

A benthic or benthic barrier is a piece of synthetic material that rests on the benthos layer of a lake (or water body) to keep sunlight from penetrating the lake bottom, preventing plants from undergoing photosynthesis. For illustrative purposes, it takes approximately 150 (10 feet x 40 feet) barriers to cover a one-acre site. The barrier needs to be weighted and anchored down by up to ½ inch rebar or sandbags.

Most benthic barriers on the market are labor intensive to install and require more than one person for installation and adjustments. In addition, gases of decomposing plant material underneath will form gas bubbles and, thus, occasionally the mats will need to be adjusted for release of gases. Careful and periodic inspection of barrier mats is needed to ensure that gas bubbles are timely released. If gas is not released from barrier mats, they can become detached and cause an obstruction or danger for boaters. An impact from using benthic barriers is the creation of some localized disturbance of the lake bottom surface during installation. It seems that when this method is done correctly it is relatively cost effective and can reduce plants over time. The benthic barrier approximate labor cost is $40,000 per acre. Barriers cost approximately $40,000 per acre and can be reused for up to 5 to 10 years. The cost provided in the table is for the installation and periodic inspection labor of barrier mats. The purchase of five acres of barriers would cost approximately $200,000.

10.3.3 UV-C Light Treatment Vessel (160 ft^2)

This treatment method applies Ultraviolet light in the C range to an infested area in an enclosed treatment chamber. Treated AIP will drop or desiccate approximately two (2) weeks after treatment.

The vessel stations itself over the infested area and lowers the 160 ft^2 (or larger size) treatment chamber down to the crown of the plant. UV-C lights are turned on and treated for a specific duration depending on the type of plants. Limitations include: heavy wind or gusts; boat traffic and strong wave currents. Assuming eight days of labor per acre, labor cost is estimated at $28,000 per acre. The treatment vessel has an estimated value of $200,000. UV-C bulbs have a rated life of 5,000 hours for an expected use of approximately 10 years. This unit typically requires two operators for open water treatment. Fuel costs are included in the labor costs.

10.3.4 UV-C Light Treatment Vessel (320 ft²)

Same treatment as above, but a larger 320 ft² UV-C treatment array is attached to the vessel which ultimately lowers labor cost to $14,000 per acre. The treatment vessel has an estimated value of $334,000. The same list of limitations exists as in the smaller version, assuming four (4) days of labor per acre. UV-C bulbs have a rated life of 5,000 hours for an expected use of approximately 10 years. Fuel costs are included in the labor costs. This unit typically requires two operators.

10.3.5 UV-C Light Treatment Vessel (640 ft²)

Same treatment as above, but a larger 640 ft² UV-C treatment array is attached to the vessel which ultimately lowers labor cost to $7,000 per acre. The treatment vessel has an estimated value of $558,000. The same list of limitations exists as in the smaller version. UV-C bulbs have a rated life of 5,000 hours for an expected use of approximately 10 years. Fuel costs are included in the labor costs. This unit typically requires two to three operators and would take two days of labor per acre of treatment.

Figure 31 below illustrates labor cost for each of the treatment method options reviewed when client owns the treatment vessel. UV-C treatment method is the least expensive method in terms of labor.

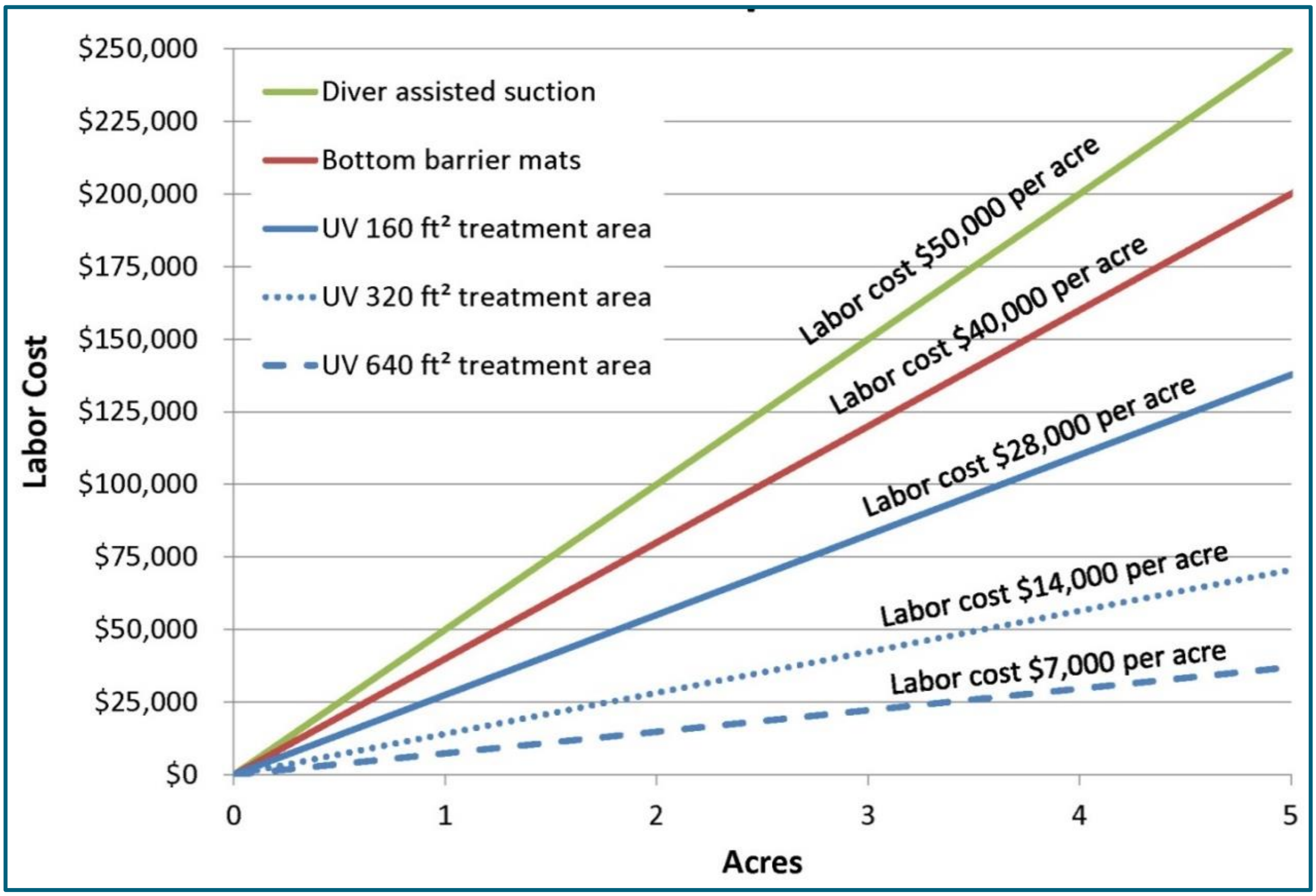


Figure 31. Labor cost comparisons

For comparison purposes, contracting services out, then the overall contract treatment cost, using UV-C technology, is estimated using the UV-C 320 ft^2 vessel, based on treating 10 acres per year over five years, to be approximately $24,000 per acre per year. Annual costs significantly drop when using the larger UV-C 640 ft^2 unit when treating 40 acres per year.

10.4 Post Treatment Results

After reviewing data and visiting the project site, there have been significant improvements to LSM and LSB treatment areas. **Table 17** illustrates that no adverse reaction to water quality were noted. All water parameters are essentially within historical values. Please note that Lake Tahoe water levels were at historic lows for several years until 2017 and water temperatures have been warmer earlier in the year.

Table 17. Water Quality Averages

Month	Water Temp, C[bc]	Dissolved Oxygen, DO	pH	Total Dissolved Solids, (g/L)	Turbidity[e], NTU
June[a]	19.77	7.91	7.55	0.057	0.57
June (Historical)	10.0-18.0	8.0-10.0	7.3-8.8	0.057-0.100	<1NTU
July[a]	21.45	10.76	7.54	0.063	0.43
July[d] (Historical)	15.0-22.0	8.0-10.0	7.3-8.8	0.057-0.100	<1NTU
August[a]	21.40	8.49	7.56	0.065	0.51
August[d] (Historical)	18.0-22.0	8.0-10.0	7.3-8.8	0.057-0.100	<1NTU
September[a]	20.71	8.39	7.6	0.068	0.54
September[d] (Historical)	15.0-21.0	8.0-10.0	7.3-8.8	0.057-0.100	<1NTU

[a] Averages were based on LSM daily monitoring and observation log
[b] Historical water temperature averages based on USGS water quality gaging stations and National Oceanic and Atmospheric Administration (NOAA) in the Lake Tahoe Basin and Consumer Confidence Reports from Lake Tahoe.
[c] Stream flow and Water-Quality Data for Selected Watersheds in the Lake Tahoe Basin, California and Nevada through Sept 1998., U.S. Geological Survey and U.S. Department of the Interior.
[d] All historical data was collected from USGS water quality gaging stations, CCRs around South Lake Tahoe and published reports.
[e] Historical Turbidity is TRPA Turbidity Threshold.

The UV-C light treatment array reduces the environmental impact by only treating what is under the treatment chamber. The treatment array and treatment method appear easy to use and can in the future be modified to be operated "in house." This system represents a visionary approach, with appropriate upgrades in the future, the system can essentially be operated robotically with minimal human intervention. Thus, further reducing the labor cost markedly and improving the effectiveness of the treatment process.

10.5 Technology Selection and Implementation

Depending on the site, one technology or method may be more appropriate than the other. In general, it is suggested that the following items be considered in making the decision:

- Relative Advantage
- Compatibility
- Complexity
- Trial-ability
- Observability

10.5.1 Relative advantage

Relative advantage is, to an extent, a degree of superiority and attractiveness to use a specific treatment method. A competitive advantage is a common value of a treatment method. In this case it would be cost and sustainability.

10.5.2 Cost

A cost comparison of different technologies for a given site should be conducted. A technology that provides a marked cost advantage should be considered. However, cost should not be the main factor and sustainability as described below should be considered as well. UV-C light treatment is the least costly reviewed.

10.5.3 Sustainability

A treatment method or technology that does the least damage to the lake bed morphology and does not disturb it in any way should be preferred. The treatment method/technology that addresses the problem for this and future time-domains, as requirements and AIP conditions change, may be preferable. A technology that provides more flexibility should be desirable. At times, a combination of technologies may be most effective. Overall, Lake Tahoe needs consistent, long term results with a cost-effective approach to AIP management.

10.5.4 Compatibility

Considering which technology is most compatible includes considering lake resource user needs and which technology is consistent with positive past-experience. One may consider a technology that is least intrusive to be most compatible. In this case, a rough ground surface terrain would require diver assisted suction rather than barriers.

10.5.5 Complexity

Technology that is well understood and accepted in the scientific community and has a demonstrated track record of its implementation on the site should be another criterion.

10.5.6 Trialability

Technology applications should be flexible so that methods can be tried on a limited basis and adjustments can be made if the AIP problem is more or less severe depending upon the lake conditions. Consider, for a given site, whether UV-C light treatment can be used two or more times per year depending upon project needs or used on a trial basis to ascertain its effectiveness. Thus, the UV-C light treatment system may provide better flexibility than others.

10.5.7 Observability

Consider the degree to which the results from the use of the technology are readily visible and can be easily monitored and communicated to the sponsor. This requirement could be a part of the contract with the technology implementer.

11 Observations, Recommendations and Next Steps

Assessing different AIP plant control technologies, including UV-C light treatment, will continue to be important in lake-wide implementation. The 2017 Progress Report (Section-Interim Observations and Recommendations) reports the observations made by IRI technicians, Green(e) Consulting, and MTS field staff throughout Project implementation in 2017 and long-term monitoring in 2018.

Observations

- Results are evident (plants collapsing) within two weeks of UV-C light treatment.
- Post-treatment, new plant growth was observed in some grids with very dense infestations. This regrowth appeared to be from turions, viable roots or young sprouts that quickly grew once they received sunlight after the larger canopy plants were gone.
- Algae fouls the UV-C light treatment array and requires cleaning.
- Mature CPW turions were visible along the lake bed throughout project implementation.
- Mature CPW turions were present in the lake-bed and were observed sprouting later in the growing season.
- Plants growing near the water taxi area were significantly smaller/shorter than plants growing in the marina, making it difficult for the current light array to treat close to the plant crown. Modification can be made for future treatments in order to lower the light array a few more inches.
- Post-treatment, a sample of turions varying in maturity was collected: tender green turions and mature brown turions. These turions were grown in the laboratory after they were exposed to treatment in the lake. Within a few weeks the brown turions sprouted and grew what appeared to be normally. Subsequently, the plants sprouting from the brown turions in the lab were treated with UV-C light while young and they died as expected. In contrast, the tender green turions did not sprout or grow. Preliminary conclusion: brown/mature turions have already developed a harder, tougher layer that the UV-C light cannot penetrate and green turions have not fully developed their outer layer. Therefore, the UV-C light can penetrate the young, green

turion, stopping all further development, but this was not effective on mature, brown turions.

- The LSM and LSB treatment areas showed promising results initially and, in most areas, only a thin layer of biomass residual remained, and sandy surfaces were visible from the water surface. Plants approximately 8 feet in height that were treated in a heavily infested area dropped and deteriorated within 10 days. Immediately before Phase 2 of treatment commenced in LSM and LSB, a significant reduction in plant height and density was observed and photo documented. After Phase 2 of treatment was completed in the LSM, progress photos were taken. During Phase 2 of treatment at LSM, IRI technicians could see the lake bottom, which allowed for the UV-C light array to treat within 6 inches of the sediment surface.

- Thick areas of EWM, especially around Pt 15 and Pt 16 (Grids P1-P7) in LSM, showed complete destruction of plant mass, resulting in visibility throughout the water column down to sand.

- Technicians noticed slight increases in turbidity as boat traffic increased in the marina throughout the day.

- LSB-Taxi and LSB-Swim had less fine sediment, compared to the marina, where dense clusters of plants and floating algae was observed.

Recommendations

- Multiple treatments are recommended until all existing turions and new growth are treated.

- Applying UV-C light treatment as early in the growing season as possible (i.e., May) can reduce treatment duration and frequency.

- Treatment is recommended to start early in the plant growing season (i.e. May/June) with an additional treatment in late summer or early fall.

- If the treatment site contains dense tall plants, a second round of treatment or longer exposure times are needed following the initial treatment. This is due to the morphology of mature plants that can obscure the crowns of the understory plants. For example, when plants dropped at LSM after the first treatment, a second treatment was applied directly to the crowns of the understory plants. It is recommended to conduct the second understory treatment approximately three (3) weeks after the initial treatment. This should successfully treat the plants that were shadowed during initial treatment and any turions or roots that are newly sprouting.

- It is recommended that turions be immediately treated upon sprouting to minimize a new turion cycle.

- To determine if native plants continue to outcompete invasive plants throughout a second winter and growing season following UV-C light treatment, continuation of long-term post-treatment monitoring of macrophyte populations at LSM and LSB is recommended.

- Based on the pilot Project results, the UV-C light treatment method can be used to control AIP and ultimately reduce total plant cover, height and density. UV-C light treatment is an effective tool to control AIP, with a site-specific prescription treatment plan that considers multiple factors. Further testing, observation and analysis is recommended to measure longer term results (e.g., a second growing season) and to further define strategies to use in connection with other approved AIP control tools like benthic barriers and diver-assisted suction removal and hand removal.

- UV-C light implementation was the least expensive treatment method when compared to diver-assisted suction removal and bottom barriers.

- It is recommended that UV-C light prescription treatments should consider the following: project area, treatment frequency, project duration, size of light array, plant species present, desired outcomes, and cost.

- UV-C technology should be used along with other techniques and technologies in an effective and comprehensive manner.

Next Steps

- Further UV-C light treatment applications and projects should be implemented and monitored for a period of 2-3 years to investigate the full potential of this tool.

- As stated above, applying UV-C light treatment in the late growing season (i.e., October) could help control regeneration from mature turions. Laboratory studies investigating the use of UV-C light to control multiple stages of curly-leaf pondweed have been initiated by University of Nevada, Reno and results are expected in 2020.

- Tahoe RCD is currently developing environmental review documents that will include UV-C, along with other non-chemical control techniques, as a method of lake-wide, programmatic control for Lake Tahoe and its tributaries.

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14 Appendices

Appendix A: Monitoring Plan

Appendix B: Grant Deliverables – Reports

Appendix C: Grant Deliverables – Raw Data Files

Appendix D: Project Photo Documentation

Appendix E: Project Permit Approvals

Appendix F: Grant Deliverables - Omitted Attachments