Summer 2023 Control Methods Test (CMT) Implementation and Interim Results: Special Report[1]

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EXECUTIVE SUMMARY

Aquatic invasive plants (AIP) are an increasing environmental problem in the Tahoe Keys lagoons and in Lake Tahoe. Current mechanical harvesting in the lagoons does not adequately control AIP and can produce plant fragments that enter Lake Tahoe where they establish new populations. After decades of combatting the aquatic weed problem, the Tahoe Keys Property Owners Association (TKPOA) worked through a collaborative stakeholder process to develop the Control Methods Test (CMT) project to test a variety of AIP control methods to determine which combination may be most effective to effectively knock back and sustain control of AIP within the unique environment of the Tahoe Keys. The project is part of the Lake Tahoe's Environmental Improvement Program. Results of the CMT will help to develop improved long-term management of AIP in the Keys lagoons and reduce their incursion into Lake Tahoe.

The first year of the three-year Control Methods Test (CMT) began in 2022 with the goal of assessing the effectiveness of several different tools to significantly knock back AIP in certain test sites within the Tahoe Keys lagoons. The Year 1 (2022) CMT ("Group A") test methods included UV-light, Laminar-Flow Aeration (LFA) and the one-time use (2022 only) of two aquatic herbicides (Endothall and Triclopyr) permitted and approved by the Lahontan Regional Water Quality Control Board (Water Board) and the Tahoe Regional Planning Agency (TRPA). These treatment methods were applied between May and November along with an extensive environmental and effectiveness monitoring program. The goals of Years 2 and 3 are to determine what non-chemical methods may be most effective in maintaining the knockback achieved in Year 1.

Year 1 treatments resulted in a 75% reduction of AIP biomass in most test sites (herbicide treatments and UV-Only treatments). This level of AIP reduction met the criteria established in the CMT project for the use of "Group B," non-herbicide follow up methods in Year 2 (Bottom Barriers, Diver-Assisted Suction Harvesting ("DASH"), and UV-Spot Treatments). (Although LFA did not reduce AIP in Year 1, this treatment method is being tested for multiple years for effectiveness and therefore Group B methods were applied in some areas within one LFA site.) The CMT Year 2 implementation actions and preliminary results of Year 2 are provided in this report. The Year 1 CMT reports can be found at the following links:

Summer 2022 CMT Implementation Special Report

Tahoe Keys Lagoons Aquatic Weed Control Methods Test – Year 1 Preliminary Results

Tahoe Keys Lagoons Annual Macrophyte Control Efficacy Monitoring Report

Tahoe Keys Lagoons Aquatic Weed Control Methods Test: Annual Report – Year 1

[1]This serves as the interim report required in the APAP.

Purpose of Year 2 Control Methods Test (CMT)

The goal of the CMT in 2023 was to provide answers to four critical questions including:

1. Did 2022 Group A CMT Methods have continuing “carry over” control of AIP in 2023?
2. Did Group B methods (UV Spot Treatments, Diver Assisted Suction Harvesting, and Bottom Barriers) sustain control of aquatic weeds in sites where target invasive plant biomass was reduced by 75% in 2022?
3. What changes in nutrients and basic water quality were observed?
4. Did treatments enhance conditions for desirable native plants?

The intense monitoring of Year 2 CMT treatment effects resulted in collecting over 243,000 data points to help answer these questions. However, interpretation of Year 2 (2023) data, relative to Year 1 is complicated by the extremely different field conditions in 2023 compared to 2022. Larger volume and longer duration of snowmelt inflows into the lagoons in 2023 resulted in more than 4 feet deeper water than in 2022. The higher water levels created more habitat for aquatic plants because in 2023 approximately 15% more shoreline was covered by water in areas that had not received Group A treatments in 2022. Deeper water in 2023 also resulted in very low light penetration in several sites, which in turn reduced plant growth. However, the evaluation of Group B methods performed in Year 2 was based on the abundance of plants and species present as compared against areas within the same Year 1 test site, but outside the actual Group B spot treatment location. The criterion for success is sustained 75% reduction of target invasive plant biomass inside the specific Group B areas.

Carry Over CMT Year 1 Effects of AIP

By comparing “heat maps” generated by hydroacoustic scans in late summer of 2022 and 2023, it is clear that the reduction (greater than 75% knock back) in AIP density resulting from Year 1 treatments was largely sustained, particularly in herbicide-treated sites in Area A (Figure 1). The combined localized areas treated with Group B methods in Year 2 is very small compared to total area of test sites treated in Year 1 (See Figure 2). Note that in Figure 1, the color scale of the heat maps reflects Year 1 site-level success, not the Year 2, Group B treatment locations. Biovolume and species in 2022 and 2023 were assessed by physical rake sample and showed that even outside the 2023 Group B treatment areas, Eurasian watermilfoil was nearly eliminated in sites that had been treated only with Endothall or Triclopyr in Year 1. However, all target plants were more prevalent in the near-shoreline areas that had only become submersed in 2023 due to four-foot higher water levels.

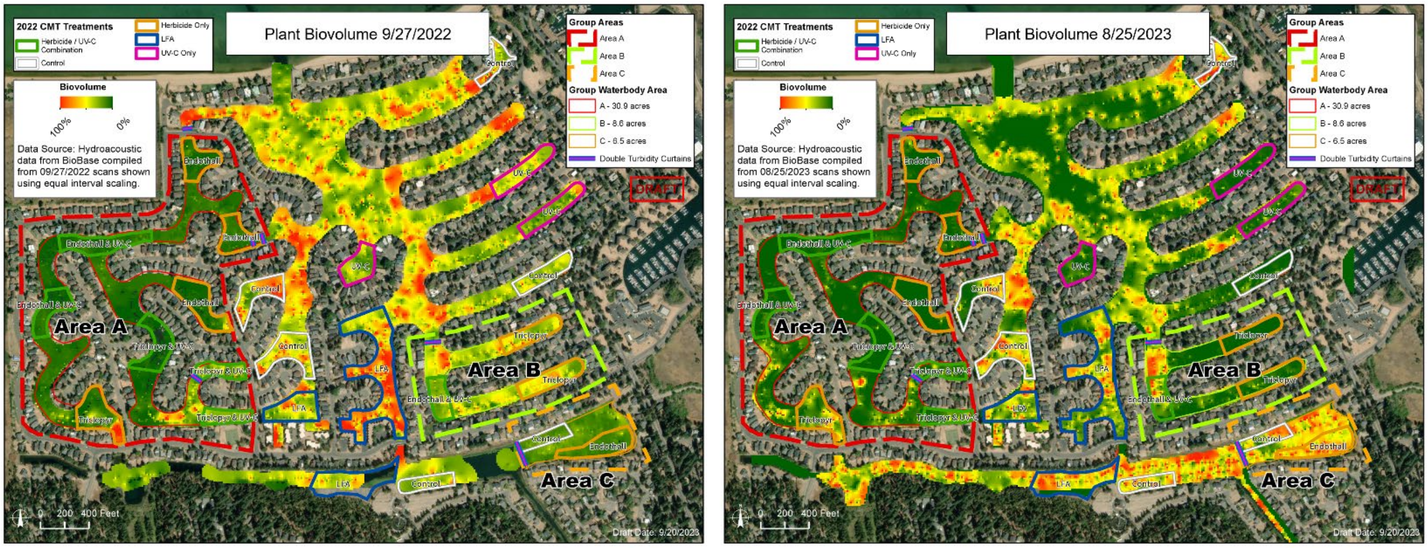


Figure 1. Comparison of submersed plant biovolume heat maps made on 9/27/2022 and 8/25/2023. Note sustained low biovolume (green areas) in CMT Year 1 (Group A) aquatic herbicide treatment sites on the west side (Areas A, B). Lake Tallac (Area C) did not have sustained control. UV sites had good control following Year 2 treatments (note pink outlined UV-Only sites).

Group B Treatment: Preliminary Assessment of AIP Control

<u>(Note: Bottom Barriers will be removed in October so monitoring results are not yet available.)</u>

Table 1 shows that most Group B methods (green arrows) achieved a good level of success (greater than 75% sustained reduction of AIP) and that some achieved partial success (ca. 50% reduction). Areas where a 75% reduction was not met were due to insufficient access for UV or some areas where there were gaps in UV exposure, or challenges due to movement of coontail into treatment sites. Coontail has no roots and can freely move into Group B areas previously treated by divers (DASH) or UV Spot Treatment. One critical determinant of Group B DASH treatments and UV Spot treatment success is the time interval between repeat treatments. For UV Spot treatments, exposures in early spring are effective but must be repeated at about 2-to-3-week intervals to control re-growth as well as potential establishment of plant fragments from outside the UV Spot Treatment area. As temperature and day-length increase, regrowth rates also increase. The relationship between lagoon water turbidity and Photosynthetically Active Radiation “PAR” levels needs to be determined to optimize the use of UV. For example, high turbidity and low light penetration would require longer UV exposures than in low turbidity conditions (clearer water) where light (including UV light) would more readily reach the target plants near the bottom.

Table 1. Summary of Group B Effectiveness

Group B Treatment Type	CMT Site	CMT Year One Treatment Type	Maintained Year One Control? Yes ↑ Partial → No ↓	Notes and Limitations
Bottom Barrier	3	Endothall only	TBD	Bottom Barriers are not removed yet
	5	Triclopyr only	TBD	
	8	Triclopyr only	TBD	
	10	Endothall combo	TBD	
	11	Endothall combo	TBD	
	13	Triclopyr combo	TBD	
	14	Triclopyr combo	TBD	
	19	Endothall only	TBD	
	26	LFA	TBD	
Diver Assisted Suction Harvesting (DASH)	1	Endothall only	↑	
	2	Endothall only	↑	
	3	Endothall only	↑	
	5	Triclopyr only	↑	
	8	Triclopyr only	↑	
	9	Triclopyr only	→	
	10	Endothall combo	↑	
	11	Endothall combo	↑	
	13	Triclopyr combo	→	Eurasian watermilfoil was controlled
	14	Triclopyr combo	→	Eurasian watermilfoil was controlled
	19	Endothall only (L.Tallac)	↑ →	DASH 19a is good; 19b partial control
	26	LFA	↑	
UV-C Spot (Four 1/2 Treatments)	1	Endothall only	↑	
	2	Endothall only	↑	
	3	Endothall only	↑	
	5	Triclopyr only	↑	
	9	Triclopyr only	↑	
	26	LFA	↑ →	Middle area is good; shoreline is partial
UV-C Combo (Group A) (Two Full Treatments)	10	Endothall combo	↑	
	11	Endothall combo	↑	
	13	Triclopyr combo	↓	Neither middle nor shoreline controlled
	14	Triclopyr combo	↑ ↓	Middle area good; shoreline poorly controlled
UV-C Only (Group A) (Four 1/2 Treatments)	22	UV only	↑	
	23	**One treatment only**	→	Note: Sites 22 and 24 were treated 4 times
	24	UV only	↑	

Changes in Nutrients and Water Quality

The levels of nutrients of concern in 2023 (nitrogen and phosphorous) were similar to 2022 except that phosphorous increased in July 2023 in some control and treated sites. Turbidity was much lower in Areas A and B compared with 2022. By mid-June, water temperatures were also similar to 2022. However, nearly twice the water volume entered the Keys Lagoons in 2023 compared to 2022 which complicates direct comparisons of CMT-treatment effects on nutrients and water quality in 2023.

Conditions for Desirable Native Plants

The herbicides used in Year 1, Endothall and Triclopyr, are selective, and do not affect desirable native species. *Elodea canadensis* is now more prevalent in the herbicide-treated sites through Year 2 of the test. No Group B methods are as selective as the Group A herbicides, although in clearer water conditions, DASH could be a very selective method if divers were able to avoid removing *E. canadensis* and other desirable native species.

Recommendations for CMT Year 3 and Future AIP in the Tahoe Keys Lagoons

The need for diligent and continued use of Group B methods throughout the summer and fall is evidenced from the large number of sprouting curlyleaf pondweed turions that were prevalent by mid-August 2023. The successful control of highly invasive curlyleaf pondweed depends on a strategy focused on preventing the formation of turions in spring-midsummer, and the control (by removal, covering, and UV exposures) of sprouting turions in late summer where feasible. Detailed measurements of bottom water temperatures and light levels in spring and early summer may help predict plant growth, particularly since inflow to the lagoons from snowmelt runoff to Lake Tahoe varies considerably from year to year. With the success of Year 1 and Year 2 of the CMT, the continuation of planned Group B methods and associated monitoring in 2024 are critical for obtaining sufficient field data to support the development of sustainable long-term management of aquatic plants in the Keys lagoons.

YEAR 2 CMT INTERIM REPORT

INTRODUCTION AND SCOPE OF THE REPORT

This interim report highlights preliminary results for CMT Year 2 from May 2023 through August 2023. As of August 31, 2023, monitoring, data analysis and final interpretations of the results are not complete, nor are the end of Year 2 treatment and monitoring actions for bottom barriers. The full report will be provided to the regulatory agencies (TRPA and Lahontan Regional Water Quality Control Board) by March 15, 2024 as required by the Lahontan Regional Water Quality Control Board National Pollutant Discharge Elimination System (NPDES) Permit Order R6T-2022-0004 (Lahontan Order) and required Amendments to the Aquatic Pesticide Application Plan (APAP) and the Tahoe Regional Planning Agency (TRPA) Permit EIPC2018-0011. TRPA Special Condition #2 incorporates Mitigation Monitoring and Reporting Program (MMRP) requirements, and Special Condition #3 that incorporates Waste Discharge Requirements (WDR) and Lahontan Order permit requirements.

Background and Goal of CMT Year 2

The first year of the three-year Control Methods Test (CMT) began in 2022 with the goal of assessing the effectiveness of several different tools to significantly knock back AIP in certain test sites within the Tahoe Keys lagoons. The Year 1 (2022) CMT (“Group A”) test methods included UV-light, Laminar-Flow Aeration (LFA) and the one-time use (2022 only) of two aquatic herbicides (Endothall and Triclopyr) permitted and approved by the Lahontan Regional Water Quality Control Board (Water Board) and the Tahoe Regional Planning Agency (TRPA). These treatment methods are applied from May to November along with an extensive environmental and effectiveness monitoring program. The goals of Years 2 and 3 are to determine what non-chemical methods may be most effective in maintaining the knockback achieved in Year 1.

The goal for Year 2 of the Control Methods Test (CMT) is to use “Group B” non-chemical treatments (table 2) to sustain successful control (reduction) of aquatic weeds achieved with “Group A” methods used in Year 1 (2022). Year 1 CMT employed replicated treatments including one-time applications of two herbicides (Endothall and Triclopyr), repeated treatments with UV-C light and use of Laminar Flow Aeration (LFA). Monitoring throughout Year 1 showed that certain Group A methods resulted in a 75% or greater reduction in target plant biovolume and sustained “Vessel Hull Clearance” compared to untreated control sites. The 75% level of reduction was the criteria for applying Group B methods in Year 2. Most CMT treatments met these criteria and Eurasian watermilfoil was nearly eliminated in the Endothall and Triclopyr sites by fall, 2022. The full report from Year 1 treatment is available on the TKPOA website at the following link: https://keysweedsmanagement.org

Coordination and Implementation of Group B Methods and Monitoring

As in Year 1, Year 2 CMT required a multitude of treatment actions and monitoring activities that had to be coordinated and carefully managed to ensure compliance with permitting requirements and to provide useful data. The continued effective collaboration among TKPOA, TRPA and The League to Save Lake Tahoe (League) was essential to successful completion of Year 2 CMT. In addition to the Group B treatments, certain Group A (UV and LFA) treatments were continued in Year 2. TKPOA staff and contractor crews continued to hold daily pre-field work meetings to cover safety procedures and the daily work objectives. The Monitoring Work Group (MWG) continued to meet either weekly or every other week and several one-off meetings were often held to resolve questions about monitoring schedules and to provide the updated maps essential to identifying Group B spot treatment areas based on most current macrophyte surveys. In addition, timely home-owner notifications were made to identify specific locations where divers or UV-vessels would be operating. A total of five contractors and the TKPOA staff, plus analytical laboratories for nutrients and Harmful Algal Blooms (HABs) assessments were well coordinated, and the proper Chain of Custody (COC) forms were completed. Daily activities were documented and uploaded to a shared Dropbox.

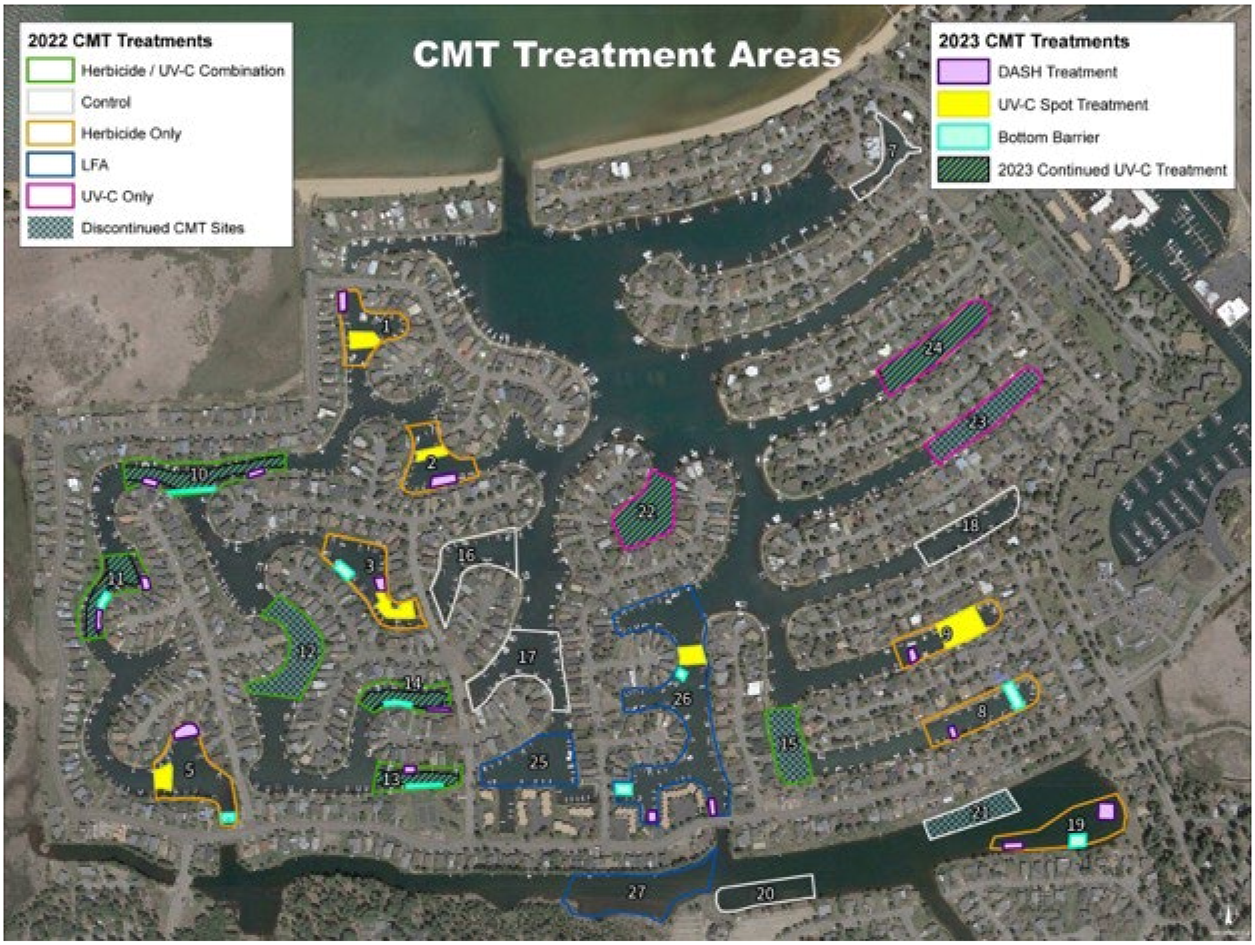


Figure 2. CMT Treatment sites and Year 2 Group B treatment areas: Diver Assisted Suction Harvesting (DASH), UV-Spot Treatment, Bottom Barriers.

Hydrologic and Bathymetric Conditions in Year 1 (2022) versus Year 2 (2023)

The CMT is a field-oriented, aquatic weed management methods test that does not incorporate actions to control “natural” year to year environmental variations such as storms and other climatic events, or seasonal hydrologic and bathymetric changes. (The only exception was the installation of turbidity curtains in specific areas during 2022.) Importantly, the 2022 and 2023 field conditions were very different. The winter snowpack in 2023 was nearly four times that of 2022 which resulted in almost twice the volume of water inflow to the lagoons from Lake Tahoe in 2023. Water levels in Lake Tahoe and the Keys in 2022 were extremely low compared to 2023 (Figure 3). The 2023 mid-summer water in the Keys was about 4-5 ft deeper than in mid-summer of 2022. By early June 2023, water temperatures at mid-depth 2023 were about the same as in 2022 (Figure 4). However, the onset of plant growth in 2023 appeared to be delayed by about 2 to 3 weeks compared with 2022, probably due to increasingly deep water which reduces light availability for photosynthesis (See “PAR” section and Figure 19).

Another important consequence of higher water levels in 2023 was the inundation of approximately 10% to 15% additional submerged shoreline habitat for plant growth compared to 2022. The newly re-submerged sediments (hydrosoils) were also a probable source of additional nutrients and seed banks that resulted in more growth in the nearshore areas, including plant fragments that could easily drift to those areas. Seed or propagules such as buried rhizomes or curlyleaf pondweed turions present in the newly re-submerged shorelines would not have been exposed to Group A methods (e.g., herbicides or UV) in 2022 so their growth was not controlled.

The hydrologic and bathymetric differences between 2022 and 2023 no doubt added to field variations and complicates year-to-year comparisons of treatment effects. However, these differences also provide an interesting opportunity to note responses of the aquatic plants to changing conditions. For example, in 2023, Rake Fullness, a physical measure of aquatic plant abundance, was about half the level observed in 2022 when just untreated “control” sites were compared (Figure 5). The decreased Rake Fullness, a measure of plant abundance, was most likely due to less light (PAR) reaching the bottom which inhibited photosynthesis. Therefore, the interpretation of results of CMT Year 2 needs to account for these differences, particularly plant growth in “newly” available shoreline habitat as well as deeper water.

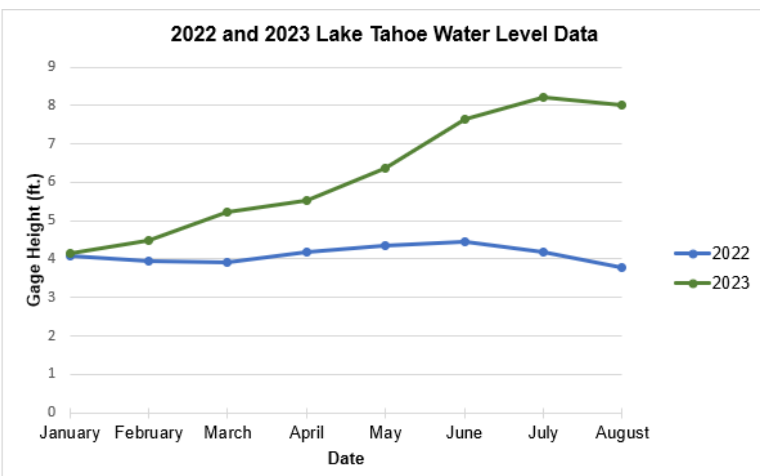


Figure 3. Comparison of Tahoe City USGS Gage Lake Tahoe water levels in 2022 (Year 1 CMT) and 2023 (Year 2 CMT).

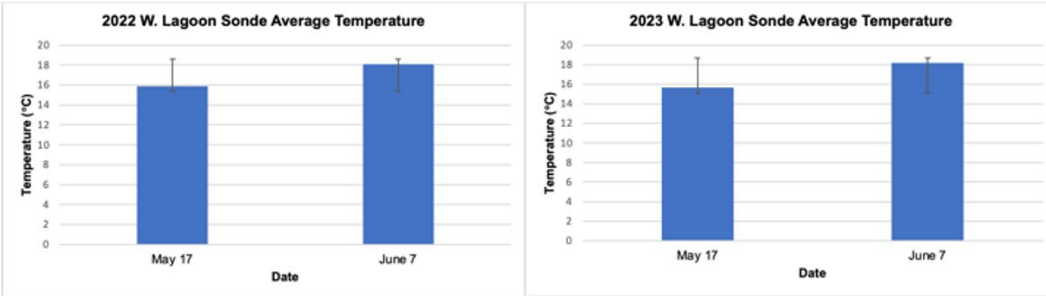


Figure 4. Comparison of average spring and early summer mid-depth water temperatures in 2022 and 2023. Data are from CMT Sites 1,5,8,9,15,17.

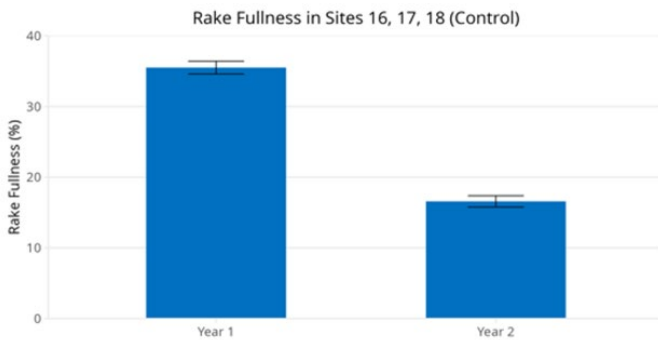


Figure 5. Comparison of average "Rake Fullness" as a measure of aquatic plant abundance in three untreated control sites (16,17,18) in the West Lagoon in 2022 and 2023. (Data are from all rake samples done in both years within the control sites.) example of rake sampling in control sites is shown in Figure 6.

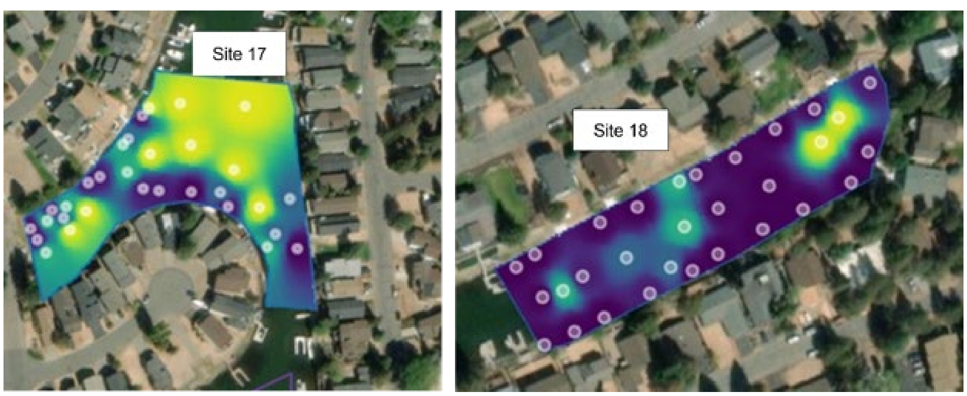


Figure 6. Examples of physical rake sampling points in Control Sites 17 (left) and 18 (right). The Rake fullness data from the samples were used to generate a "Rake Sample Heat Map", similar to heat maps generated from hydroacoustic scans. See Figure 1 also)

Selecting Year 2 CMT "Group B" Treatment Sites

To determine the success of post-winter effects of Year 1 efficacy, hydroacoustic scans and surveys for aquatic plant biovolume and species composition in all CMT sites began in May 2023 and continued at bi-weekly intervals. (It is important to note that the physical (rake) sampling and hydroacoustic scans provided data on depth and this data can help separate "newly exposed" shoreline from 2022 submerged shoreline areas.) The spring and early summer physical plant surveys and hydroacoustic scans provided the basis for selecting the timing and specific areas for Bottom Barriers, Diver Assisted Suction Hand Removal (DASH) and UV-Spot Treatments. The intent was to select sufficient “Group B” treatment areas with representative conditions that had some re-growth of target plants, and where two or more types of Group B methods could be used. Group B methods were also used in LFA site 26 as a supplemental “combination” test. Figure 2 shows the locations of all Group B methods used and continued UV-Only and LFA (Group A) treatments. Duplicate sites were selected for each method, and treatments were repeated at 3 to 4-week intervals. (Note: This cadence will continue through October 2023.) Combination Herbicide/UV sites that did not receive UV treatments in Year 1 were treated with UV in Year 2. Two UV-Only Sites 22 and 24, which had been treated in Year 1 were retreated at 3 to 4-week intervals in Year 2; UV-Only Site 23 was only treated once in Year 2, and then discontinued due to resource limitations. The originally designated Combination Site 12 and Site 15 were deemed unusable for Group B (2023) treatments due to some incursion of herbicides from adjacent areas and anomalies in plant growth such as abundant plant growth along treated shallow areas. As in 2022, intensive monitoring of water quality and nutrients were continued in 2023. Since no herbicides were used in 2023, and since 2022 monitoring showed “non-detect” in water samples, no additional herbicide monitoring was conducted in 2023. The summary Group B treatment areas within CMT Sites and dates of Group B treatments are shown in Table 2. A summary of monitoring activities to date (August 31, 2023) is provided in Table 3.

Table 2. Summary of Group B Treatment Sites

Group B Treatment	CMT Site	Treatment Type	Planned Sq. ft.	Implemented Sq. ft. (to-date)
Bottom Barriers (BB)	3	Endothall only	6,000	3,068
	5	Triclopyr only	3,500	2,305
	8	Triclopyr only	10,000	6,305
	10	Endothall combo	4,500	3,068
	11	Endothall combo	3,000	2,538
	13	Triclopyr combo	5,874	2,489
	14	Triclopyr combo	3,000	2,343
	19	Endothall only	4,900	4,418
	26	LFA	9,000	5,384
Total Bottom Barriers Square Footage			**49,774**	**31,918**
Total Bottom Barrier Acreage			**1.14**	**0.73**
Diver Assisted Suction Harvesting (DASH)	1	Endothall only	5,075	3,566
	2	Endothall only	6,200	5,770
	3	Endothall only	3,000	2,897
	5	Triclopyr only	4,000	6,205
	8	Triclopyr only	2,040	1,775
	9	Triclopyr only	2,100	2,327
	10	Endothall combo	4,100	4,214
	11	Endothall combo	4,450	4,629
	13	Triclopyr combo	2,100	1,889
	14	Triclopyr combo	2,280	3,012
	19	Endothall only	5,800	9,148
	26	LFA	2,000	4,564
Total DASH Square Footage			**43,145**	**49,996**
Total DASH Acreage			**0.99**	**1.15**
UV-C Spot (Four 1/2 Treatments)	1	Endothall only	9,000	8,874
	2	Endothall only	10,000	4,047
	3	Endothall only	20,000	10,829
	5	Triclopyr only	6,375	7,707
	9	Triclopyr only	25,000	25,560
	26	LFA	10,000	9,028
Total UV-C Spot Square Footage			**80,375**	**66,045**
Total UV-C Spot Acreage			**1.85**	**1.52**
UV-C Combo (Group A) (Two Full Treatments)	10	Endothall combo	39,204	39,204
	11	Endothall combo	29,620	29,620
	13	Triclopyr combo	21,780	21,780
	14	Triclopyr combo	17,424	17,424
Total UV-C Combo Square Footage			**108,028**	**108,028**
Total UV-C Combo Acreage			**2.48**	**2.48**
UV-C Only (Group A) (Four 1/2 Treatments)	22	UV only	65,340	65,340
	23	UV only	69,696	69,696
	24	UV only	78,408	78,408
Total UV-C Only Square Footage			**213,444**	**213,444**
Total UV-C Only Acreage			**4.90**	**4.90**
Total Year 2 UV-C Acreage			**9.23**	**8.90**
Total 2023 Group B Acreage			**3.98**	**3.40**

Group B Treatment Methodologies and Protocols

Bottom Barriers

Bottom barriers are typically used to cover localized areas infested with AIP. The locations for bottom barrier installations were identified on plot maps provided to divers and to monitoring crews. Two types of bottom barrier material were used: Modified, yellow “turbidity” curtains (cut to fit selected areas); and commercial black “pond bottom liner”, cut to fit. The turbidity curtain material is impermeable to gas whereas the commercial pond bottom material allowed transfers of gas with the water column. The decay of covered plants typically generates gases (for example CO_2, H_2S) and this required the impermeable turbidity curtains to be “burped” (releasing gas), and in some instances, small openings were made to release gases as well. Divers installed the barriers and secured them in place with rebar and anchors. (Note that turbidity curtains that had been re-purposed for use as bottom barriers had heavy chains attached along one edge.) The corners of the barriers were georeferenced (GPS) and the NE corner was marked with an underwater label. The integrity of the barriers was checked bi-weekly and other monitoring crews reported if abnormalities were observed. The barriers will be removed in early October 2023 and those areas will be surveyed for AIP abundance (Rake Fullness) and species present in mid-October and again in early November.

Diver Assisted Suction Hand Harvesting (DASH)

The DASH method is used to remove and collect AIP from localized infestations. Maps for DASH sites were provided to the dive team and monitoring crews. The dive crew also used shoreline (docks) landmarks and GPS to confirm removal boundaries. Suction-assisted hand harvesting used a pumped-venturi, suction generating flow system so that divers could direct hand-pulled plant material into the end of the suction tube that deposited the plants into a fine mesh (1/8 in. pore) “sock” retained in a receiving box at the water surface. The “sock” captured plant material and allowed water to pass through. Once the “sock” was filled to its capacity, the contents were transferred to 40-gallon plastic pails and weighed. During a DASH event, separate sub-samples of the removed plants were saved in 5-gallon pails for drying to later count the amount of turions removed. During the DASH operations, a topside crew member used a hand-held screen net to remove floating fragments generated by divers’ actions. Divers could usually finish clearing a 2,000 sq ft area within a day.

UV-Only and UV-Spot Treatments

Two light-array sizes of UV-equipped vessels were used: 8ft X40 ft and 16 ft X 40 ft. The larger array vessel was used for center sections of UV Combination Sites 13, 14, 10, 11 and follow up (continued) Group A, UV-Only Sites 22 and 24; the smaller vessel array was used mainly for spot treatments and for nearshore-dock areas. The duration of exposure in one array zone varied between 5 and 10 minutes; repeat Group B treatments and UV-Only site treatments were done at 3 to 4-week intervals with exposure durations of about 10 to 15 minutes. Generally, the full-site (UV Only) treatments required 4 to 5 days; combination treatments took 3 to 4 days and Spot-UV treatments (Group B UV) took one half- to one day depending on the size. The Spot UV treatment areas were delineated by GPS-generated polygons so that re-treatments and monitoring for nutrients and macrophytes could be done in the correct locations (See Table 2 for dates of UV treatments).

Laminar Flow Aeration (LFA) (Additional Sites)

The LFA system is comprised of air compressors and series of anchored air diffusers that constantly produce a stream of bubbles in the water column. The LFA system mixes the water column and increases oxidation of organic material and may reduce availability of nutrients that encourage the growth of algae. In addition to Site 26 in which LFA was installed in 2019, Sites 25 and 27 had LFA systems installed in late 2022 (Figure 2). All three LFA sites have operated continuously. Note that two Group B Spot UV Treatments and two Bottom Barrier installations were also made in LFA Site 26 (Figure 2).

Monitoring in Year 2

As in Year 1, protocols for monitoring macrophytes, nutrients and water quality were delineated in the Quality Assurance Project Plan (QAPP) as part of the approved NPDES APAP. To date, over 243,000 data points have been recorded.

Adjustments were made in timing of monitoring activities based on dates when Group B methods were applied, and on their repeat cadence. A brief description of the monitoring methods is provided here. A summary of data points and other monitoring activities is presented in Table 3. It should be noted that bottom barriers were just removed in early October so the macrophyte sampling in those areas will be done in mid-October and early November.

Table 3. Summary of CMT Year 2 Monitoring Activity and Data Points Collected Through August 31,2023

Monitoring Activity:	Frequency/ Timing:	Notes:	Data Points through August 2023:
Macrophyte Rake Sampling – Physical rakes, plant condition rankings, and photos (Group A)	Herbicide/Control/UV only: Biweekly Combo: Monthly LFA: 2x a year	Excludes rake fullness which was determined from photos	21,205
Macrophyte Rake Sampling - Physical Rakes, plant condition rankings, and photos (Group B)	Biweekly	Excludes rake fullness which was determined from photos	1,949
Hydroacoustic Scans	Biweekly	Each scan produces 1000s of data points	10 scans
Standard Water Quality Monitoring	Weekly	N/A	6,665
Continuous Water Quality Monitoring (MiniDOTs)	Hourly	Excludes daily and weekly averages	211587
Nutrient Grab Sampling (Group A)	Control/Combo: Weekly UV only: Monthly LFA: 2x a year	Excludes Reinstate samples	672
Nutrient Grab Sampling (Group B UV Spot)	Weekly	Excludes Reinstate samples	136
HAB Sampling	Biweekly after visual observation	Includes sampling required by the LFA project	108
Turbidity Monitoring (Group B)*	4x per diver workday	Excludes bottom barrier removal data	196
Light Level Monitoring (PAR)	Monthly	Excludes averages derived from measurements	900
Muck Depth Monitoring	1x a year	To be measured in October 2023	N/A
Percent Organic Sampling	2x a year	Second monitoring event planned for October 2023	8
BMI Sampling**	1x a year for test sites; twice a year for control sites	Each sampling event produces 100s of data points.	25 sampling events
		Total:	243,461

*This number will increase when monitoring is completed following DASH and removal of bottom barriers.
**BMI sampling may occur twice: Spring and Fall for consistency with Year 1 monitoring.

Macrophytes

Bi-weekly Hydroacoustic scans were made using a boat-mounted Lowrance HD system. Data from the scan was uploaded to a third-party mapping service (BioBase) and the biovolume and "heat maps" were received. To provide a synoptic assessment, multiple scanned areas were "merged" to generate overall heat-maps.

Physical Rake Sampling. For each CMT Group A Site, 30 rake samples were taken representing mid-channel (deep water) and shoreline (shallower water) at bi-weekly (14 day) intervals as in Year 1. For the smaller, specific Group B treatment areas within CMT Group A sites, the number of post-treatment rake samples per area was increased to provide a good representation of plant populations and species abundance. For each separate rake sample, Rake Fullness, percent of species occurring and condition ("health rating") of each species were recorded and a digital image was taken of the rake sample as in Year 1. (Note that compared with shallower water in Year 1 (2022), water depths of several mid-site areas exceeded 15 ft, and some were nearly 20 ft deep and required a long, telescoping rake pole.).

It is important to note the "Rake Fullness" is a measure of total plant abundance (all species) and is aligned with "Biovolume" from hydroacoustic scans, while "Frequency of Occurrence" provides the relative incidence (presence) of each species in a sample. In other words, samples can vary greatly in Rake Fullness but have very similar or very different proportions of different species present.

Nutrient Sampling

A peristaltic pumping system was used to obtain composite water samples in UV-treated sites (UV-Only and UV-Spot Treatment areas). Sampling protocols were the same as Year 1 and included rinseates and redundant (duplicate) sampling. Nutrient sampling in LFA sites was also continued as in Year 1.

Water Quality (DO, temperature, pH, Conductivity, Turbidity)

Hand-held data sondes were used to record water quality variables as in Year 1, except that in Year 2, the frequency was weekly rather than three times per week in each site. The higher frequency of sampling in Year 1 was due to increased monitoring requirements associated with the use of aquatic herbicides in Year 1. Anchored "miniDOT" loggers recorded continuous hourly data for DO and temperature at the surface and near the bottom in each CMT site and the stored data was downloaded weekly. Examples of this data in the report are presented as weekly averages.

Diver-related Turbidity Monitoring

As required under the CMT permits, turbidity levels were monitored during bottom barrier installation and removal, and during DASH activity.

Harmful Algal Blooms (HABs)

Routine water samples were taken in LFA sites as part of the Waste Discharge Requirements (WDR). Note: WDR's are separate monitoring actions for compliance with Water Board permit: Executive Order No. R6T-2014-0059.) Additional samples were taken in other CMT sites whenever signs of HABs were observed visually. Samples were analyzed by a certified laboratory for presence of cyanobacteria and level of cyanotoxins.

Photosynthetically Active Radiation (“PAR”)

Although not required under existing permits, PAR was measured monthly to compare underwater light levels associated with some of the CMT treatments and untreated “controls”. A LICOR spherical PAR detector was used to measure light just below the surface, just above the bottom, and in some areas at 0.5 m intervals to obtain a more detailed PAR profile. Since light is a major driver of plant growth, this data may help explain changes in species composition and abundance of macrophytes at different depths, and particularly in very deep areas resulting from high water levels in 2023.

PRELIMINARY CMT YEAR 2 TREATMENT RESULTS

Nutrient Levels

Fewer nutrient samples were taken in 2023 than in 2022; the increased sampling in 2022 was associated with monitoring effects of herbicide treatments in 2022. (This difference is seen in the Figures that describe the various nutrient levels in 2022 and 2023. (Note: Although nutrient sampling continues, the available data for this report is only through late July due to the time required for lab analyses.) The final annual report will include all nutrient data.

The greater inflow of snowmelt into the lagoons in 2023 probably resulted in lower water column nitrogen and phosphorous levels in spring 2023 compared to spring 2022 (See examples of data in Figures 7-9). These levels, however, were still well above those in Lake Tahoe proper. As the 2023 season progressed, nutrient levels increased in the lagoons in general, but increases were not associated with continued use of the UV-Only (Group A) method. The Increased nutrients may be due to normal senescence of AIP mid-late summer.

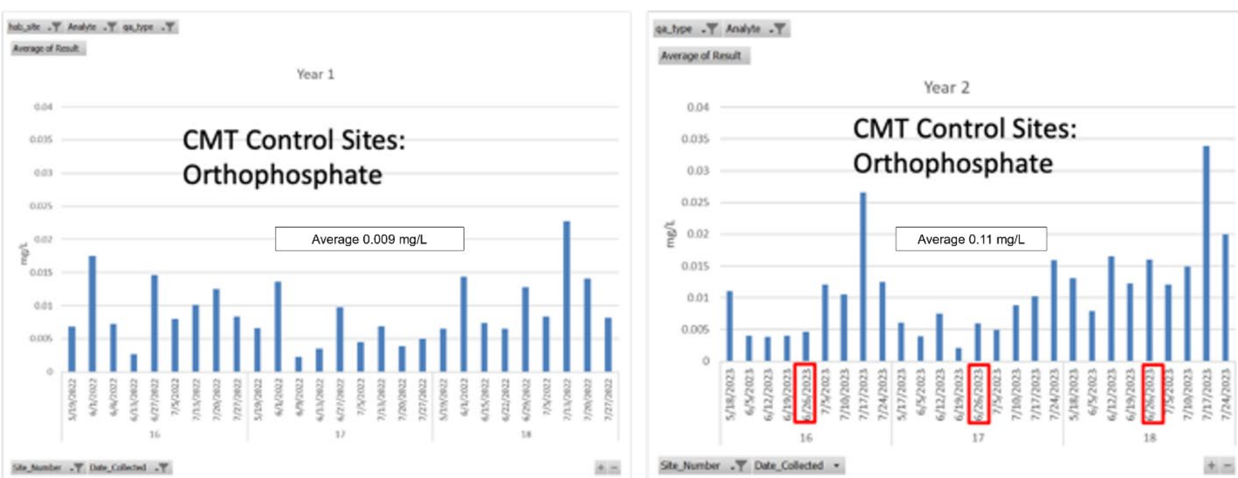


Figure 7. Comparison of orthophosphate in CMT Control Sites in 2022 and 2023.

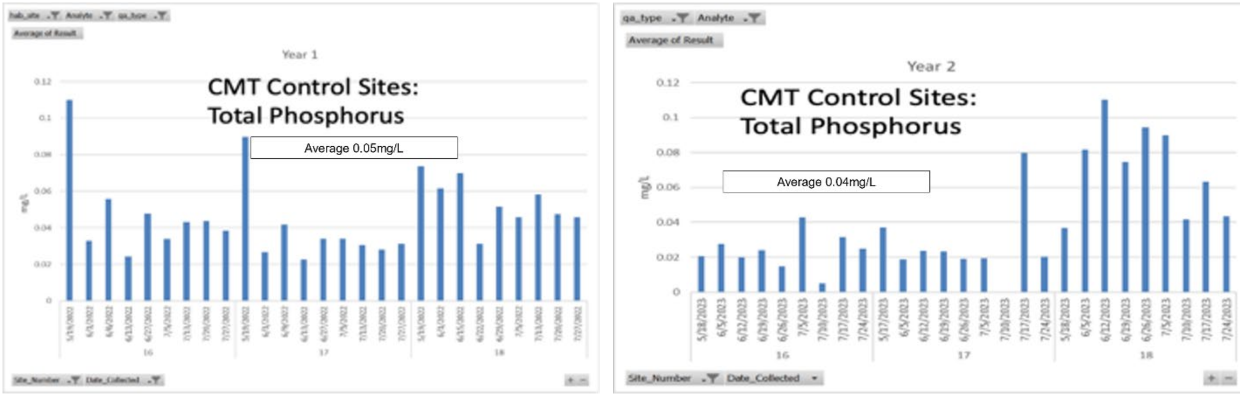


Figure 8. Total Phosphorus in Control sites in 2022 and 2023.

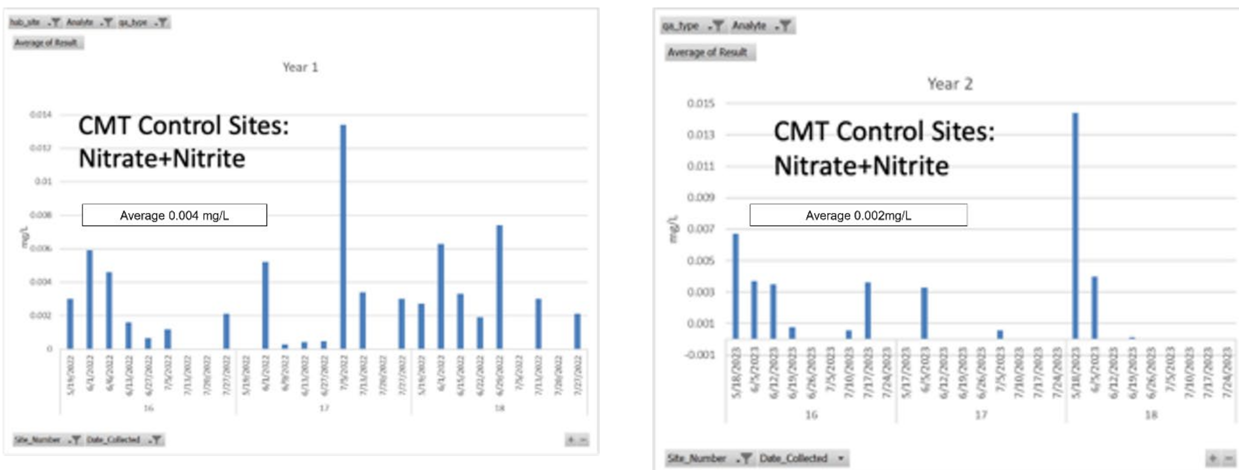


Figure 9. Total nitrate+nitrite in CMT control sites in 2022 and 2023.

Water Quality

Water temperature was very similar in spring 2023 compared to 2022 (Figure 4). However, due to the very large volume of snowmelt in 2023, there was much deeper water in Lake Tahoe and in the Keys lagoons in 2023 (Fig. 3). In most CMT sites, decreases in dissolved oxygen (DO) began in early to mid-July and DO was particularly low near the bottom in all CMT sites. Examples are provided for Control Site 17 and prior Endothall (2022) Site 1 (Figure 10). Dissolved oxygen in LFA Site 26 was fairly similar compared with other CMT sites but DO was consistently somewhat higher mid-depth and near the bottom of the water column, which would be expected since the water column in LFA sites is constantly aerated (Figure 11). Generally, the small areas of Group B Methods (Spot UV or DASH) did not appear to be associated with depressed DO or increased pH compared to other sites.

As in 2022, pH at times exceeded the standard thresholds (water quality goals) typically applied to Lake Tahoe proper (See examples in Figure 12). Higher pH in Controls can be explained by photosynthesis in macrophytes and would be expected to increase as growth of macrophytes (and algae) increases during the summer compared to treatments that reduced plant biomass (e.g., Sites 1 and 22).

Turbidity in the lagoons gradually increased during the summer of 2023 and reached a peak in July but did not approach the high levels observed in 2022 (Figure 13). This pattern is typically due to gradual increased growth of suspended algae (phytoplankton). Turbidity did not substantially increase when DASH was used; however, natural background turbidity in DASH sites was sufficiently high enough to reduce visibility for divers and prevent them from selectively removing only target plants.

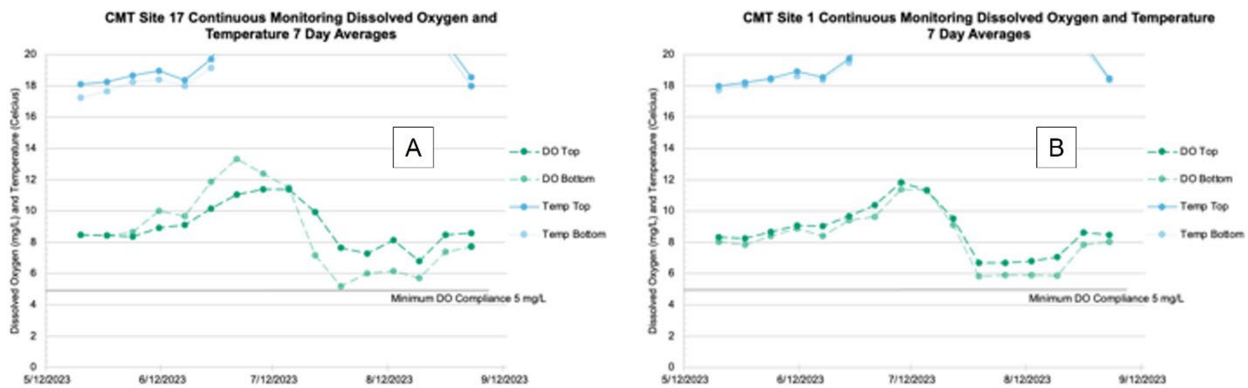


Figure 10. Dissolved oxygen and temperature in CMT Control Site 17 (A) and Prior Endothall Site 1 (B) in 2023.

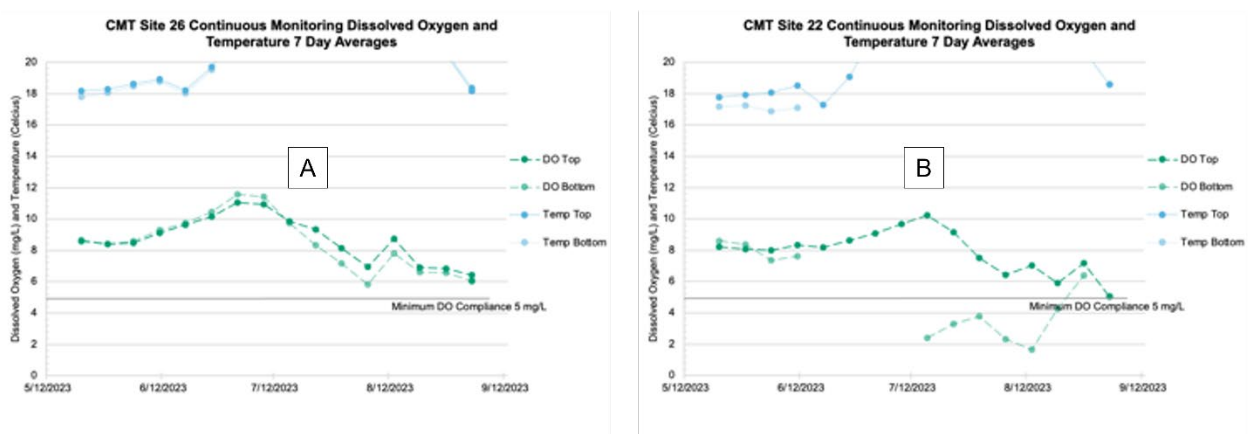


Figure 11. Dissolved oxygen and temperature in CMT LFA Site 26 (A) and UV-Only Site 22 (B) in 2023

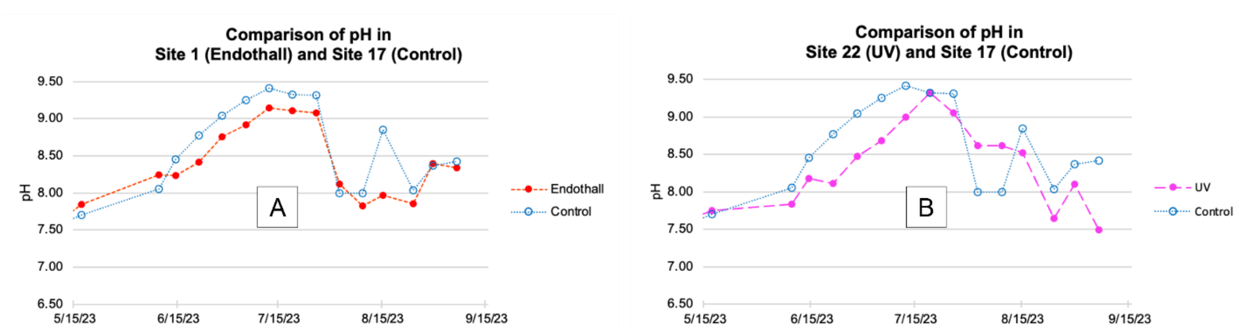


Figure 12. Examples of pH in Endothall Site 1 (A) and UV-Only Site 22 (B) compared with Control Site 17.

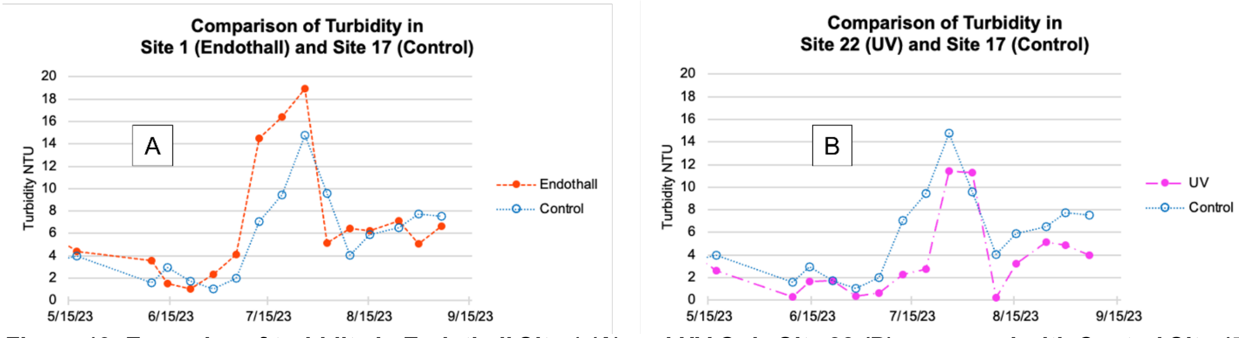


Figure 13. Examples of turbidity in Endothall Site 1 (A) and UV-Only Site 22 (B) compared with Control Site 17.

Harmful Algal Blooms (HABs)

The visual incidence of potential HABs (resembles bright green "paint" on the water surface) in 2023 was far less frequent and also less severe than that observed in 2022, and the few occurrences in 2023 appeared much later in the summer. On only two occasions did visual detection require sampling to determine presence of cyanobacteria or cyanotoxins: cyanotoxin levels were low but did require transient "Caution" signage. In 2022, cyanotoxin levels required "Warning/Danger" signage. The higher incidences of cyanotoxins in 2022 were likely due to a combination of the long-term (>3 months) deployment of turbidity curtains, and the very warm, low water levels, coupled with some nutrient releases from decomposing macrophytes following herbicide treatments.

Photosynthetically Active Radiation ("PAR") Levels

Light levels are typically greatly reduced (attenuated) with water depth due to absorption of sunlight energy by water, and by both dissolved and particulate material in the water column. By comparing near-surface PAR levels to PAR near the bottom (where plants initially grow), the depth at which rapid submersed aquatic plant growth occurs (>75-100 µmols/m^2/sec PAR) can be determined. In sites where PAR was measured, this threshold was not achieved below 12-14 ft (Figure 14). The low PAR is consistent with the lack of significant biomass (for example low "Rake Fullness") in macrophyte survey points that were below 14 ft deep. The low PAR level also underscores the effect of the higher water year in 2023 on plant growth; greater water depths by August (4 to 5 feet deeper) impeded the growth and spread of macrophytes in the deepest areas.

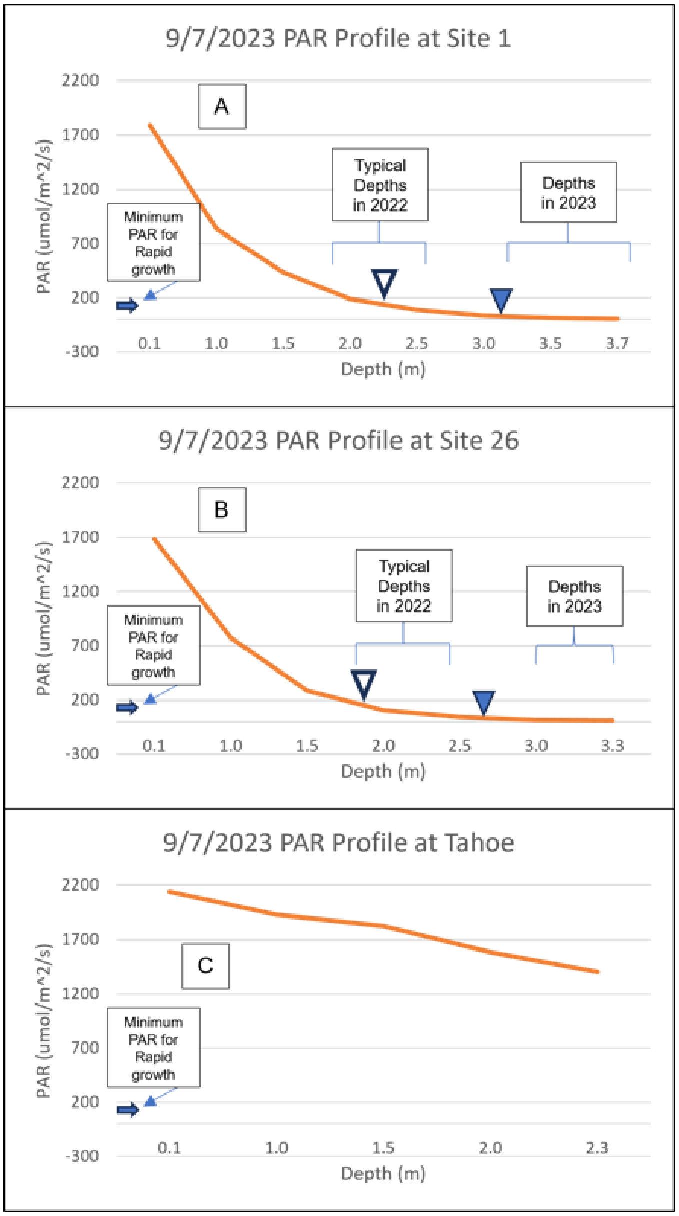


Figure 14. Level of Photosynthetically Active Radiation (PAR) by depth: A, Site 1 Endothall (2023); B, Site 26 (LFA); and the contrast of these light profiles with very clear water in Lake Tahoe, C (2023). Solid blue arrow shows threshold depth for submersed plant growth 2023; open arrows shows the likely threshold depth for rapid plant growth in 2022.

MACROPHYTE MONITORING RESULTS

Sustained Effectiveness of Year 1 CMT Group A Methods

Year 2 CMT monitoring included spring 2023 assessment of Year 1 (Group A) treatment effects on target plants to provide a baseline and to determine locations for Group B treatments. As noted, before, plant growth in control sites was generally lower than in 2022 (Figure 5). However, the assignment of Group B methods was based on comparisons of plants (amount and species) within each site and 2023 Control sites. Plant biovolume was low in mid-May, which is normal due to the combination of very cool snowmelt water inflow from Lake Tahoe as well as short daylengths. However, the sustained low biovolume in late spring and summer compared to untreated control sites was due to successful CMT treatments in 2022. By late August 2023, there was abundant aquatic plant growth in untreated (control) sites and in some locations that were near sites previously treated in 2022. Most of the Endothall-treated sites and the two UV-Only sites that continued to receive UV exposures in 2023 (Site 22 and Site 24), retained low plant biovolume. Last year's Endothall and Triclopyr treatment sites sustained a near-absence of Eurasian watermilfoil from May through the end of this reporting period, including most of Area A (Figures 1 and 2).

The contrast in overall aquatic plant abundance and locations between early May and late August in 2023 is readily apparent from the hydroacoustic scan-generated "heat map" shown in Figure 15. Although Group B treatments contributed to some localized reductions in specific sites (see sections below), it is clear that Year 1 Group A treatment effectiveness persisted well into 2023 even within locations where Group B methods were not used. For example, in Area A (Figure 1) DASH and UV-Spot treatments totaled 1.55 acres compared with 12.3 acres in Area A that had been treated using Group A herbicide methods in Year 1. Group B methods used in Area A were only 12.6% of the herbicide-treated area. Therefore, the large-scale (site-wide) sustained reduction in biovolume was due primarily to Year 1 methods. Within Year 2 treatments sites, much of the higher plant density occurred in the near-shore areas that had not been treated in 2022 because these areas were not underwater. In other words, the much higher water in 2023 created additional habitat for plants that may have had "buried" rhizomes, turions (curlyleaf pondweed) or viable seed in these newly submerged shoreline sediments. The new "available" shorelines also provided open areas for the spread of adjacent plant populations during the summer, or recruitment from floating fragments.

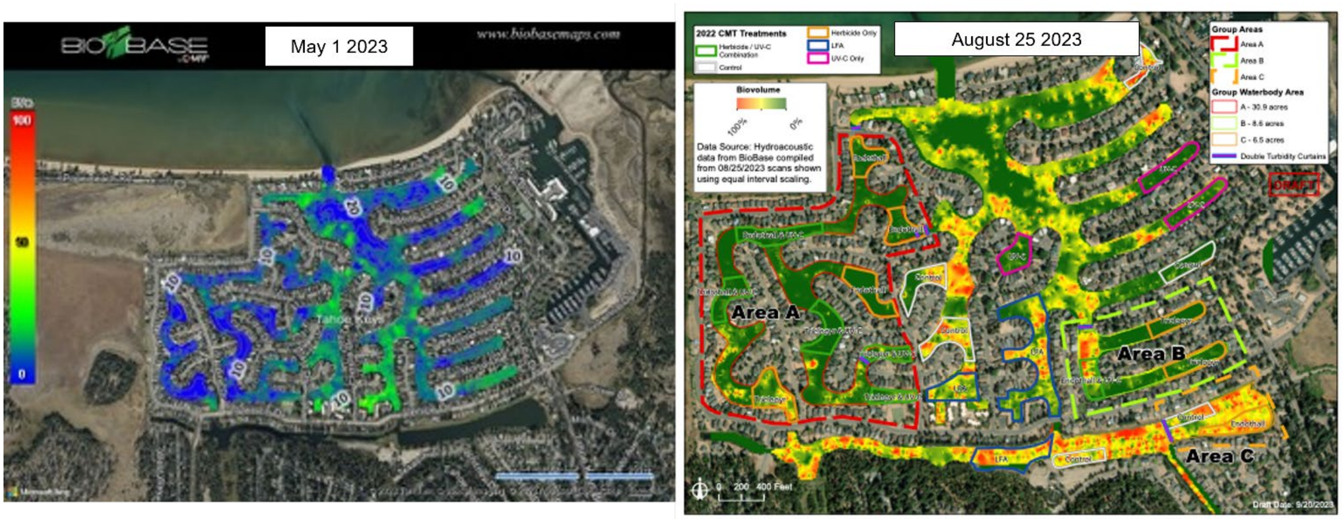


Figure 15. Comparison of hydroacoustic scan-generated "heat maps" in spring and mid-summer in Tahoe Keys West Lagoon. Note the sustained low level of plant density (green areas, August 25) in the CMT-treated areas and in untreated deep-water areas just south of the West Channel.

Endothall (Treated in Year 1 Only)

Examples of Year 1 Endothall treatments and Year 2 monitoring are provided in Figure 16 for Site 1, and the 3-month average frequency of plant occurrence in Figure 17 for Sites 1,2 and 3. Note that in 2023, with no further herbicide treatments, the density of all target plants remained lower than in untreated controls on most sampling dates.

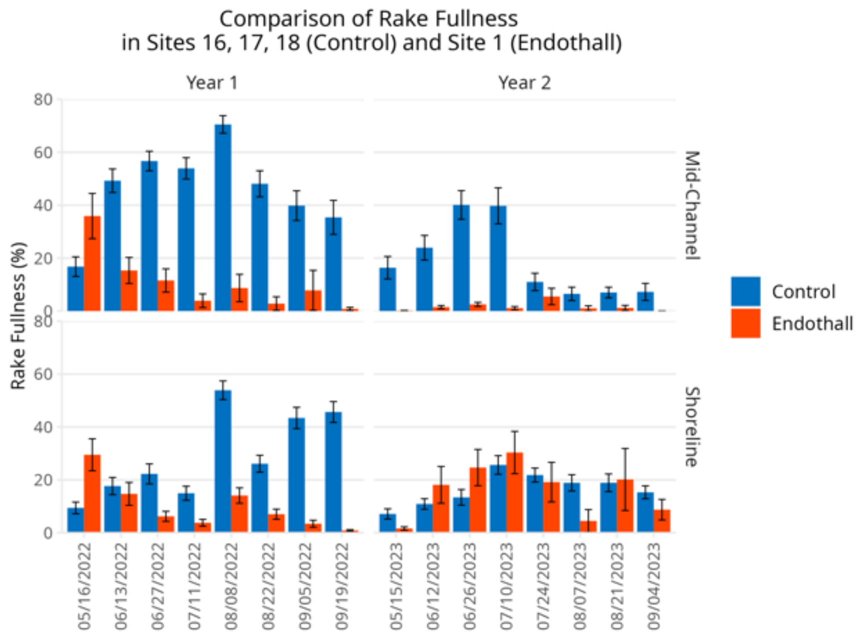


Figure 16. Rake Fullness (plant abundance) in Sites 1 that was treated with Endothall-Only in 2022. (Note: The "Shoreline" areas were only submersed in 2023 due to high water levels and were not exposed to herbicide treatments in 2022. This allowed growth of AIP in the non-treated shorelines.)

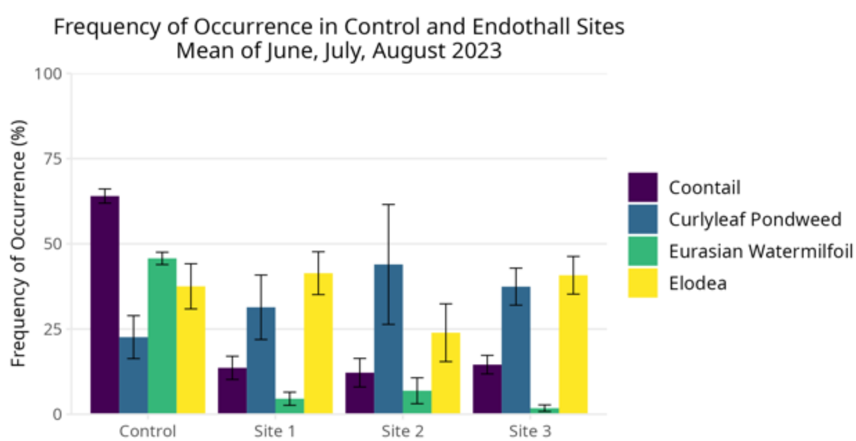


Figure 17. Three-month average (June, July, August) frequency occurrence of plants in Year 1 Endothall-Only treated sites in 2023 compared to control Sites 16,17,18.

Triclopyr Treated in Year 1 Only

In the Triclopyr-only treatments (Sites 5,8,9) Eurasian watermilfoil remained nearly absent in both 2022 and 2023 (Figure 18). There was very little difference in frequency of occurrence between the deeper middle area and shallow shoreline areas. Note that since Triclopyr does not control the other targeted aquatic weeds (coontail and curlyleaf pondweed), total Rake Fullness was about the same as untreated control sites.

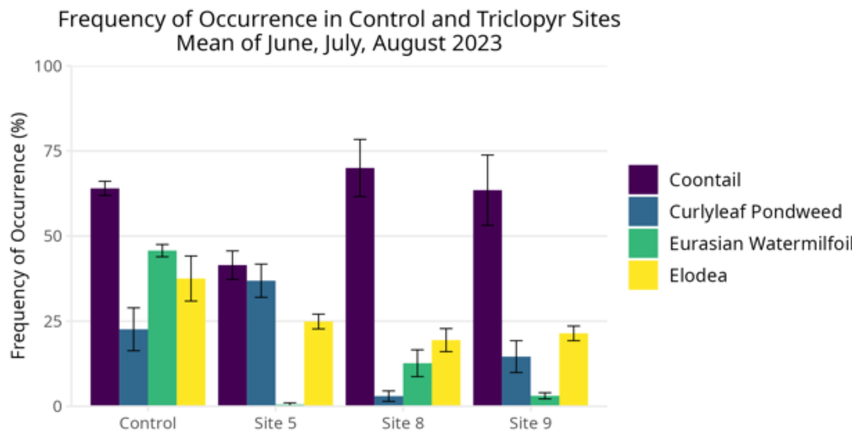


Figure 18. Three-month average (June, July, August) frequency of occurrence of plants in Year 1 Triclopyr-Only treated sites in 2023 compared to control Sites 16,17,18.

UV-Only Sites Treated Year 1 and Year 2

Full site treatments with UV began in 2022 and were continued in 2023 in Sites 22 and 24 at 3-to-4-week intervals. (Note: Site 23 received only one UV treatment early in Year 2 and was then discontinued due to limitations on resources.) The UV system is most efficient in open water where plant exposure to UV is reliable and where positioning of the UV array is not impeded by various structures, shallow areas, and moored or docked vessels. To assess UV effectiveness, the Rake Fullness data (as surrogate for biomass) were used to compare middle and nearshore plant biomass following UV treatments in Site 22 and Site 24. The graphs for Sites 22 and 24 summarize UV treatments results and illustrates that shoreline areas were less well controlled with UV and that middle, open areas can be better controlled by UV. When the shoreline data are included as areas also targeted for control, the UV overall treatments are clearly not as effective. These Rake Fullness data also are consistent with the hydroacoustic scans of Site 22 and show that the UV treatments were effective in reducing plant density in both 2022 and 2023 in the middle site areas (Figures 19 and 20). However, the nearshore samples showed that the Rake Fullness in and around dock areas was higher. The 3-month average frequency of occurrence (Figure 21) shows that coontail was consistently the dominant species. The effectiveness of UV in Site 22 can also be seen in the detail (closeup) of the hydroacoustic scan from August 25, 2023 (Figure 22-B). The scans also produce a visual representation ("side view") of Site 22 as shown in Figure 23. Note the clear demarcation of untreated areas where plant profiles are abundant compared to sparse plants as the scanning boat entered the UV treated area of Site 22.

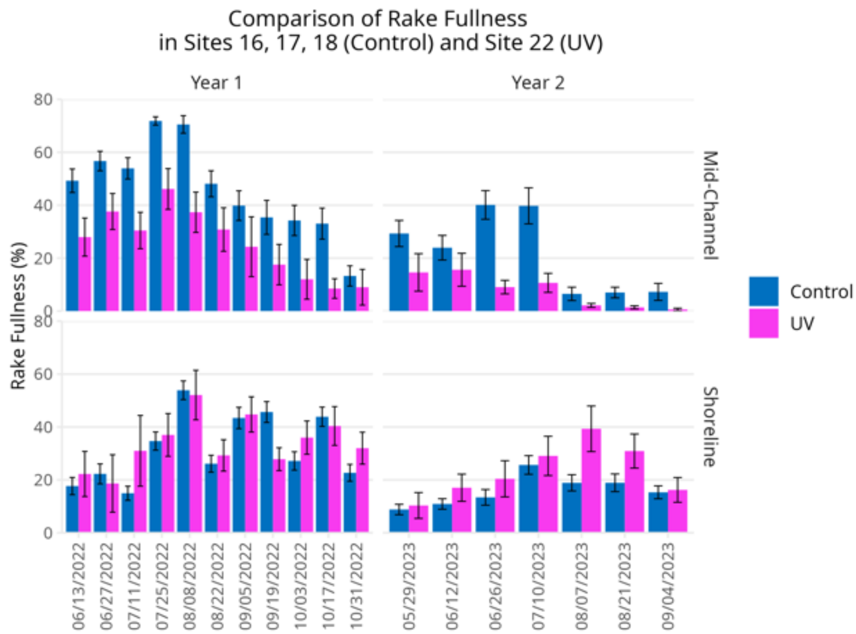


Figure 19. Effect of UV-Only treatment on Rake Fullness in Site 22. Rake data are separated by mid-site and shoreline areas.

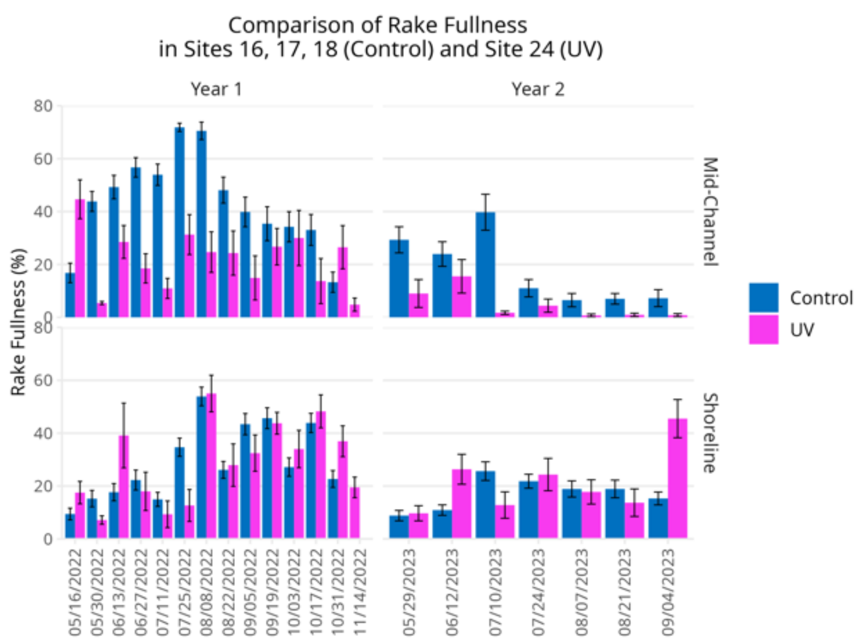


Figure 20. Effect of UV-Only treatment on Rake Fullness in Site 24. Rake data are separated by mid-site areas and shoreline areas.

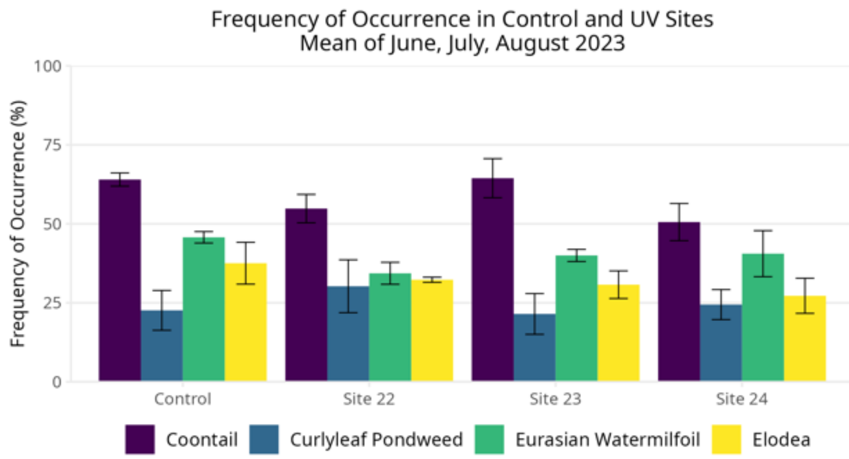


Figure 21. Three-month average (June, July, August) frequency occurrence of plants in UV- Only sites in 2023 compared to control Sites 16,17,18. (Note: Site 23 only received one UV treatment in June.)

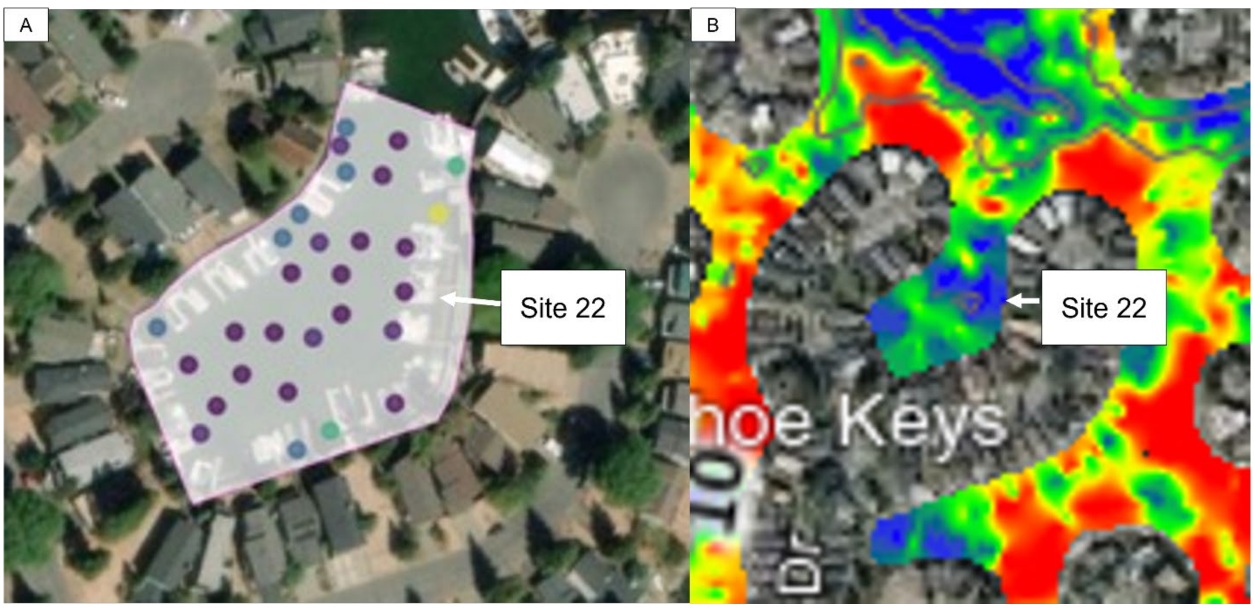


Figure 22. Example of rake sample points in Site 22 (UV-Only): A, location of rake samples in Site 22 August 22, 2023; B, hydroacoustic scan showing low plant biovolume (blue/green areas) in Site 22. Note the high biovolume (red areas) in untreated areas surrounding Site 22.

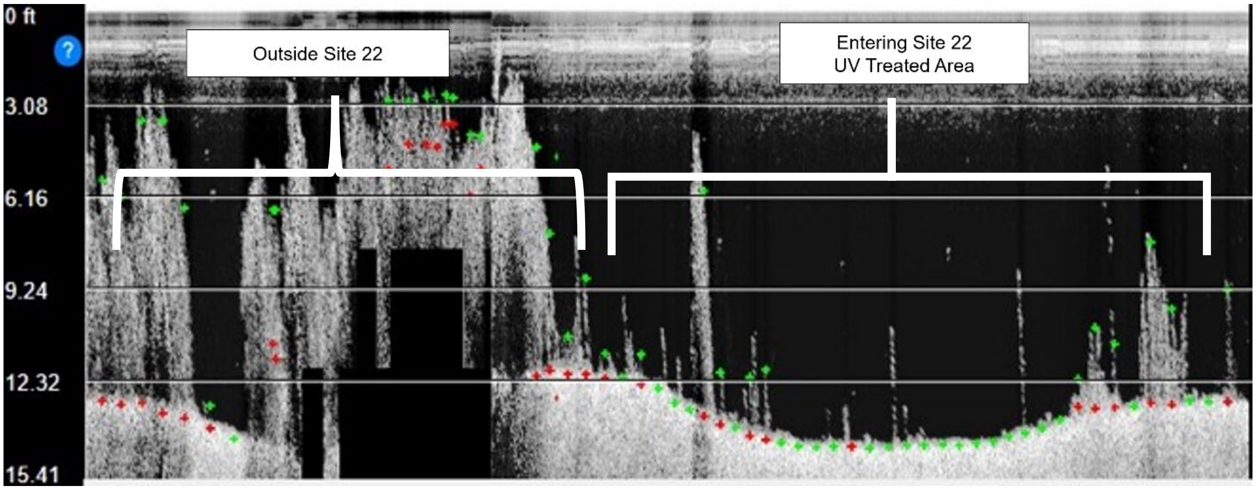


Figure 23. Hydroacoustic scan-generated side-view image in UV-Only Site 22 just outside (left side of image) with dense plants compared to sparse plants resulting from UV-treatments in the area on the right side of the image.

Combination Sites

Combination treatment sites were designed to have both shoreline herbicide applications and mid-channel UV treatment in 2022. However, due to lack of access to these sites until September 2022, only the shoreline herbicide applications were completed in the Combination sites. In 2023 (Year 2), the middle sections (mid-channel) of the combination sites were treated with UV at 2-to-4-week intervals (See Tables 1 and 2).

Endothall-UV Combination Sites

Sites 10 and 11 sustained reduced biovolume (Rake Fullness) during 2023 (Figure 24). These data also show that during Year 2, Eurasian watermilfoil remained absent during the summer (June, July, August average) (Figure 25). Although frequency data for Site 15 is shown, this site received no UV treatments in 2023 because the plant growth along the shallow areas of this site was not sufficiently controlled by Year 1 treatments to meet the criteria of 75% reduction in biovolume

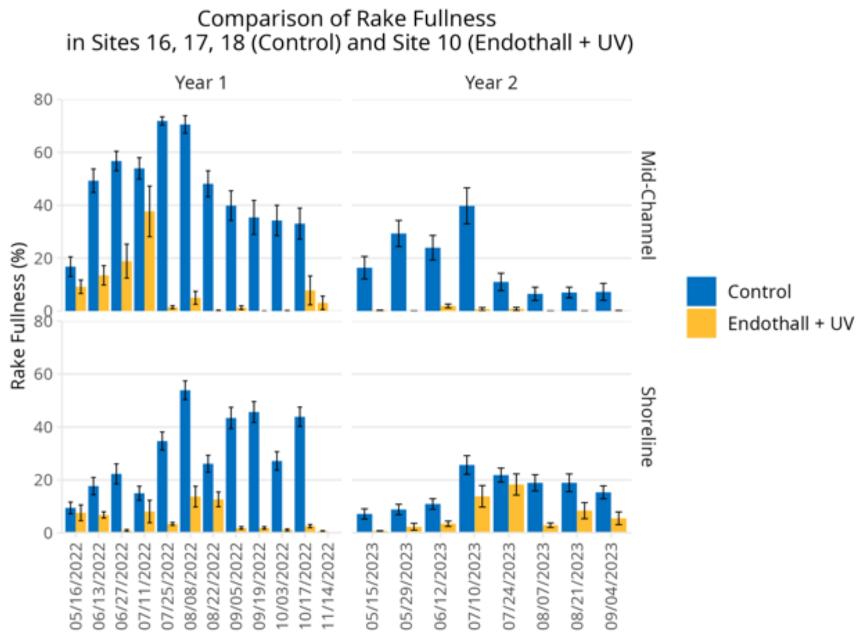


Figure 24. Rake Fullness in Combination Endothall-UV Site 10 compared with untreated Control Sites.

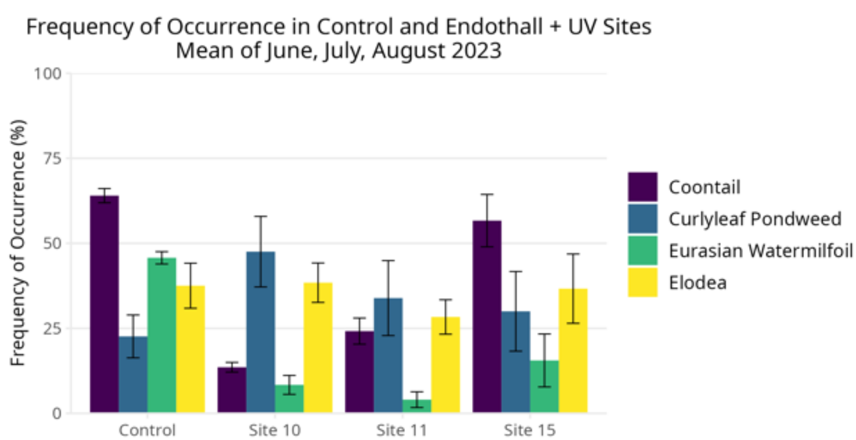


Figure 25. Three-month average (June, July, August) frequency of occurrence of plants in Endothall-UV Combination sites in 2023 compared to control Sites 16,17,18. (Note: Site 15 was not treated with UV.)

Triclopyr-UV Combination Sites

Rake Fullness in Site 13 overall was not consistently reduced, however, the UV treatments in the mid-channel areas of these sites reduced Rake Fullness (Figure 26). This is an important result because Year 1 Triclopyr treatments in the shorelines only affected Eurasian watermilfoil but allowed other target and (desirable) native plants to grow. The UV treatment, which affects all submersed plants, helped maintain lower biomass of all target plants in the mid-channel areas. The data also show that the near absence of Eurasian watermilfoil was sustained in these sites that had shoreline applications of Triclopyr in 2022 (Figure 27).

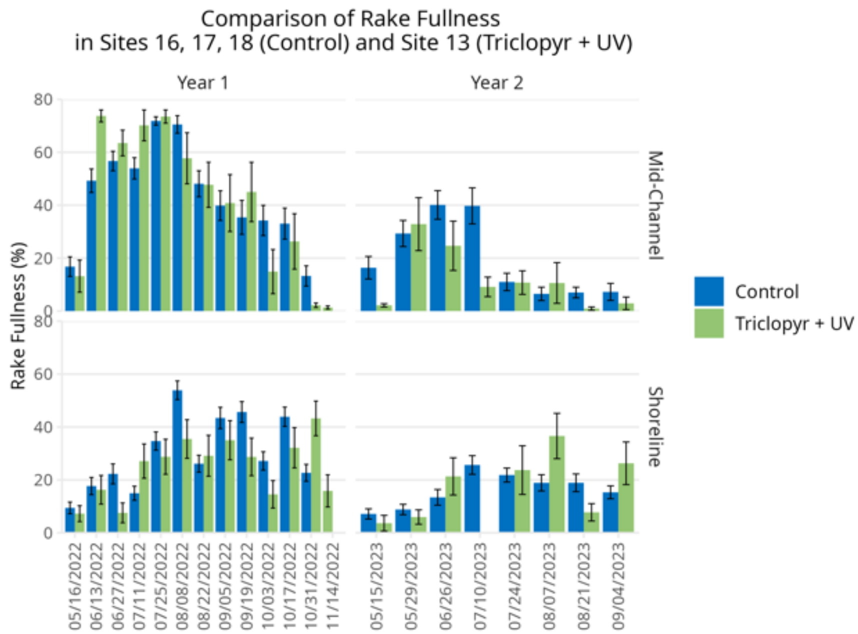


Figure 26. Rake Fullness in Triclopyr-UV Combination sites compared with untreated control sites.

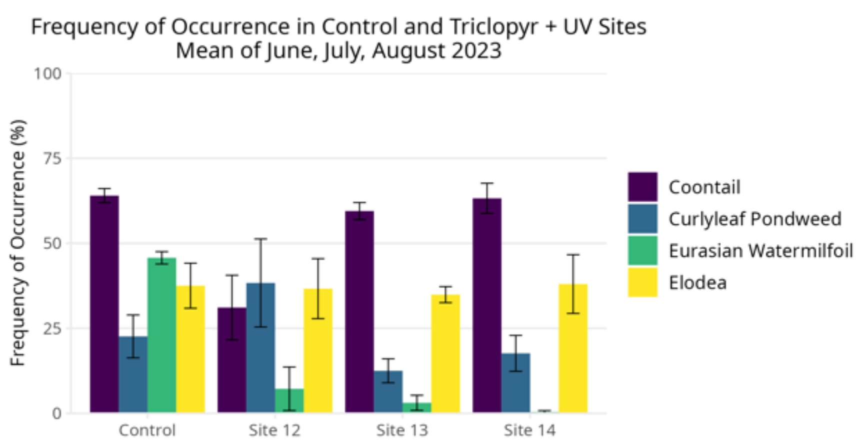


Figure 27. Three-month average (June, July, August) frequency of occurrence of plants in Triclopyr-UV Combination sites in 2023 compared to control Sites 16,17,18. (NOTE: Site 12 was not treated with UV.)

Effects of Year 2 CMT on Native *Elodea canadensis* Occurrence

The average frequency of occurrence of *E. canadensis* (Figures 17,18,21,25, and 27) changed very little compared to controls in 2023. However, in some UV sites (e.g., Site 24) there was some reduction in *E. canadensis* in late summer. For UV-Only Site 22, the negative effect on *E. canadensis* was mainly in Year 1 mid-channel areas, and in Year 2, only in June in the mid-channel areas of the site.

YEAR 2 CMT GROUP B EFFECTIVENESS

At this time, only data from DASH and UV-Spot treatments are discussed since Bottom Barriers were just removed. Subsequent macrophyte monitoring of Bottom Barrier areas will not be completed until the end of October or early November.

UV-Spot Treatments

Table 2 describes sites and sizes of spot treatments. These UV treatments were repeated 4 times at 2 to 3-week intervals. The treatments worked well based on rake sampling and in particular, Site 5, 9, and 10 showed that spot treatments could reduce and sustain low plant densities. The primary limitation in this method is difficulty in accessing shallow areas and areas between docks, piers, pilings and around docked boats. Nutrient levels were monitored but were similar to 2022 and did not appear to be affected by the UV treatments or decomposing plants within the small areas. Rake samples showed that species frequency of occurrence was not affected by the spot treatments. (See section below with examples).

DASH Treatments

These treatments were primarily done in the near shore areas between outer edges of docks and the shoreline (e.g., bulkheads or rip rap). However, DASH areas in Site 19 (Lake Tallac), Site 8 and Site 9 included offshore (deeper water) areas (Table 2; Figure 1). During DASH operations, a crew also removed freed plant fragments using a pole-mounted screen. DASH was repeated twice (separated by one month) and the lower biomass removed in the second treatment showed that divers had removed most of the plants during the first treatment. At each DASH location, captured plants were contained in several 40-gal. containers and their fresh weight was recorded. The primary DASH limitation was poor visibility due to high turbidity. This prevented efficient, selective removal of target plants and therefore some desirable native *E. canadensis* was removed as well. As with UV-Spot Treatment, DASH did not change the species frequency of occurrence. Plants in the DASH sites with an area of about 2,000 sq ft could be removed in 4 to 6 hours.

Comparison with “Non-Group B” Areas

In order to assess the effects of Group B treatments, the biovolume or Rake Fullness sampling and species composition in the Group B areas were compared to rake samples taken in the rest of the “Non-Group B” treatment areas within the same Year 1 site. In the graphs of the data presented below, the Rake Fullness within the Group B areas are compared to both the CMT Control sites, and to the “Non-Group B” areas of the corresponding site. Since Lake Tallac is a separate body of water, Group B rake-derived data were also compared with Control Site 20 in Lake Tallac as well as the “Non-Group B” treatment sites within Site 19.

SUMMARY OF GROUP B EFFECTIVENESS

For each Group B spot treatment location within a CMT Group A site, the Rake Fullness post-Treatment was compared with Rake Fullness within the corresponding Year 1 site, and with the average of Rake Fullness in West Lagoon control sites 16,17,18. For Site 19 (Lake Tallac), Rake Fullness in each DASH area was compared with rake fullness in Lake Tallac Control Site 20, as well as in non-Group B areas within Site 19.

The results are summarized in Table 1 which shows that most Group B methods were able to sustain a 75% reduction within the specific Group B area treated. However, some UV treatment areas were not well controlled partially due to poor access to nearshore areas, or due to some delays in treating Triclopyr Only sites where plant growth (except Eurasian watermilfoil) had become well established. Site 23 had only one UV treatment due to resource limitations but did achieve partial control in some areas within the site. In general, DASH and UV Spot treatments were effective in most sites.

EXAMPLES OF YEAR 2 GROUP B EFFECTIVENESS

The following CMT sites are highlighted to illustrate the results of Group B methods used in 2023. Bar graph designations: In the following bar graphs, Rake Fullness in CMT Control Sites (average of Sites 16,17, and 18) are shown as "Controls" (blue bars); data from within the specific site but OUTSIDE the Group B treated area are designated "Site" (red bar); data from each specific Group B treated areas is designated "DASH", or "UV-Spot Treatment" (open bars). Therefore, two comparisons of Group B treatment effects can be made: (1) effectiveness of Group B treatments compared with CMT Control Sites; and (2) effectiveness compared to plant conditions just within the corresponding Year 1 site.

Site 5

Year 1 Triclopyr-Only (Figure 28A). This site has three Group B Methods: Bottom Barriers (to be removed in September); DASH and UV-Spot. Figure 28A shows the locations of the three Group B methods and August 28 Rake Sample points. Note the increased cluster of rake sampling with the DASH and UV-Spot Treatment areas.

The average values for percent "Rake Fullness" on August 28 were DASH- 3.25%; UV-Spot Treatment- 0.0%; Non-Group B- 9.5% (Note that Site 5 is a deep site with areas that are 14 to 20 ft deep.) This suggests that the UV-Spot Treatment was nearly 100 % effective and that DASH removed more than 65% of plants compared with "non-DASH" areas within Site 5.

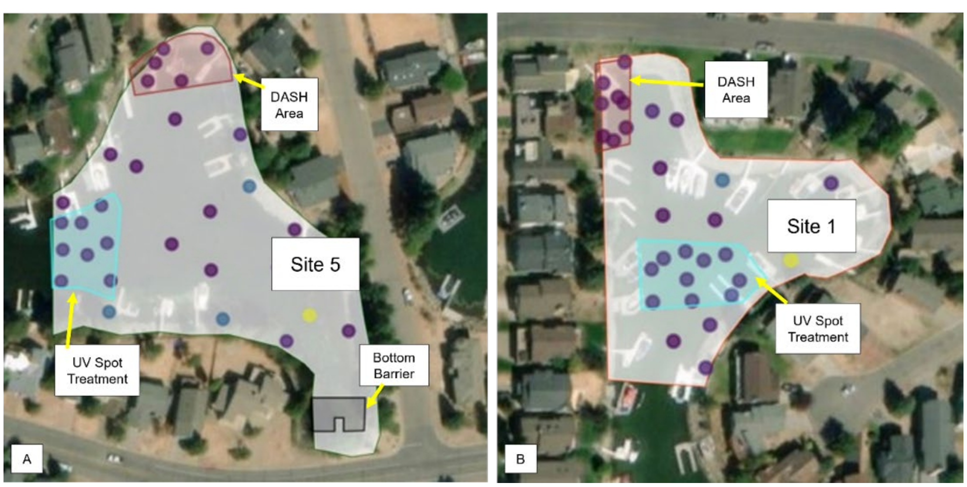


Figure 28. A, B. Site 5 (A) (Triclopyr-Only Year 1) and Site 1 (B) (Endothall-Only Year 1); Shaded polygons show Group B treatment areas. Rake points shown are for August 28, 2023 (Site 5) and August 22, 2023 (Site 1).

Site 1

Year 1 Endothall-Only (Figure 28 B). This site had DASH and UV-Spot treatments. The Rake Fullness percent values for Site 1 were: DASH-2.75%; UV Spot Treatment- 0.6%; Non-UV-1.4% (Mid-site); Non-DASH- 23.0% (Shoreline) (Figure 29). This suggests that the UV Spot Treatment reduced the mid-site (deep areas) by about 50% and that DASH reduced shoreline plant density by almost 90% compared to other shoreline areas. In both sites, plant condition (health) was good (4-5 rating), including *E. canadensis*. The effectiveness of DASH in Site 1 is clear from the hydroacoustic scan-generated "side-view" image shown in Figure 30. The denser profile of plants just outside DASH in Site 1 contrasts with the very sparse profile where divers removed them.

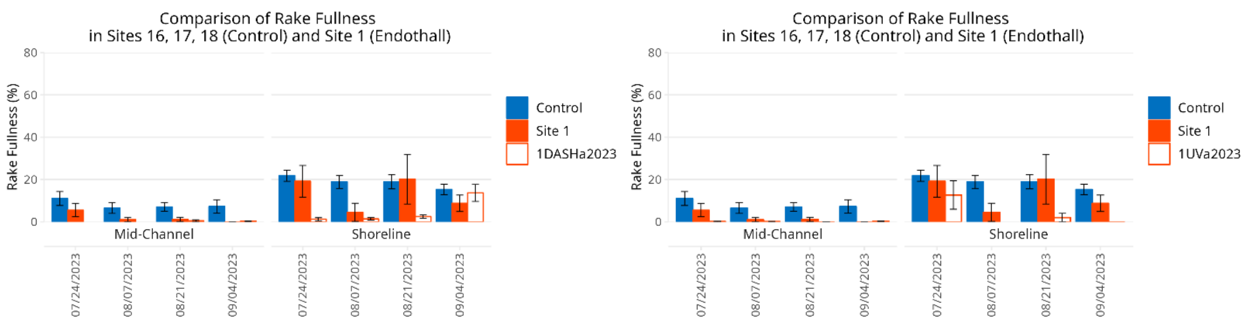


Figure 29. Rake Fullness in Site 1 DASH area (left graph) and Site 1 Spot UV treatment (right graph).

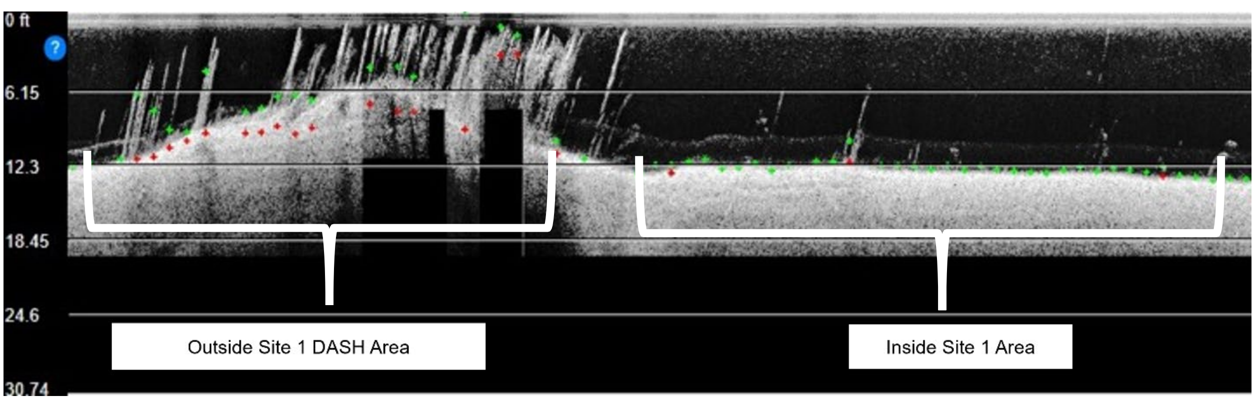
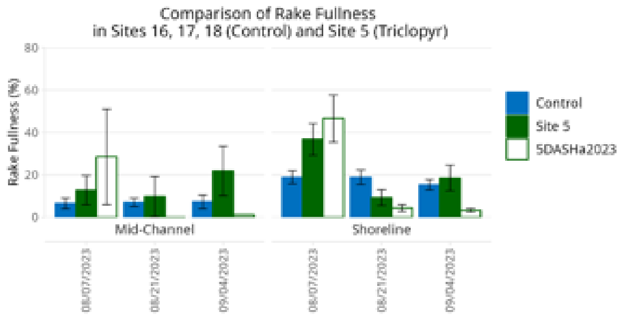


Figure 30. Hydroacoustic scan-generated side-view image just outside DASH area in Site 1 (left side of image) with dense plants compared to sparse plants in the DASH-treated area on the right side of the image.

Site 5

Site 5 had a DASH and UV-Spot Treatment area (See Figure 28 A). DASH was effective in reducing biomass in the shoreline and associated near shore areas (Figure 31 left graph). UV Spot was very effective in mid-areas where UV exposures were most consistently applied, but shoreline areas were less consistently controlled (Figure 31 right graph).



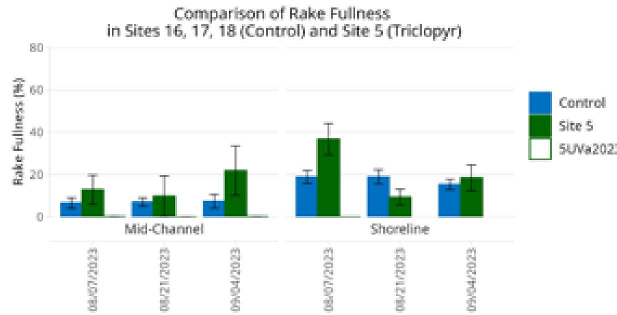


Figure 31. Rake Fullness in Site 5 DASH area (left graph) and Site 5 UV-Spot Treatment area (right graph).

Site 19

Year 1 Endothall-only (Lake Tallac). This site had two DASH areas: (a) was located "off-shore" and (b) was located mainly near-shore with some extended areas off-shore (Figure 32). To compare the "non-DASH" rake fulness, the Site 19 Year 1 treatment area samples were compared with the off-shore DASH Area "a" off-shore rakes samples excluding DASH "b". DASH "b" was compared with only the near-shore sampling. Rake samples showed that coontail was the dominant species within Site 19, and in the DASH sites. Rake Fullness for Non-DASH nearshore areas was 28% and DASH Area B had a Rake Fullness of 22% indicating that very little coontail was removed by August 28 2023. The Non-DASH areas off-shore had a Rake Fullness of 23% and DASH area a had a Rake Fullness of 42%. This suggests that DASH was not very effective in reducing coontail density; however, since coontail has no roots, it is possible that in the two weeks between DASH and rake sampling, coontail could have moved into the DASH areas.

However, the hydroacoustic scan done August 24, 2023 shows that plants in Lake Tallac had become dense, but there are two "green" areas in Site 19 that correspond to the DASH treatments, which indicates that the biovolume was reduced by DASH. (Figure 34). The Rake Fullness data from the DASH areas are shown in Figure 33.

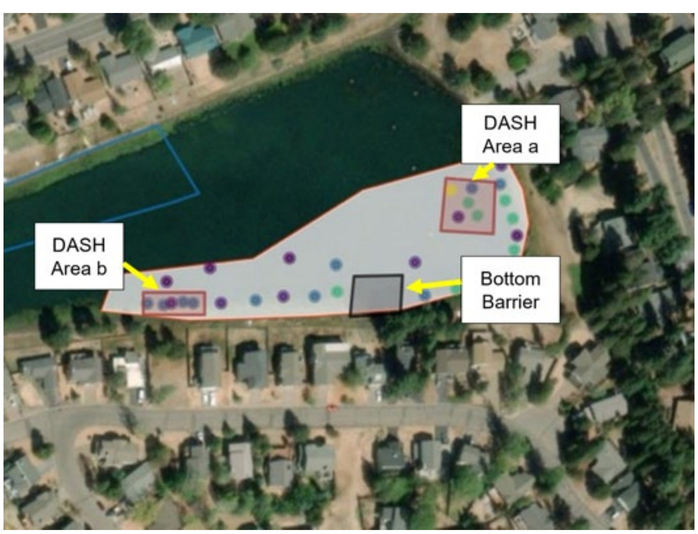


Figure 32. Site 19: Year 1 Endothall-Only (Lake Tallac). This site had two DASH areas and one Bottom Barrier area. Rake samples shown were taken August 28, 2023. Note that DASH Area a was mainly offshore in deeper water; DASH Area b was mainly along the shallow shoreline.

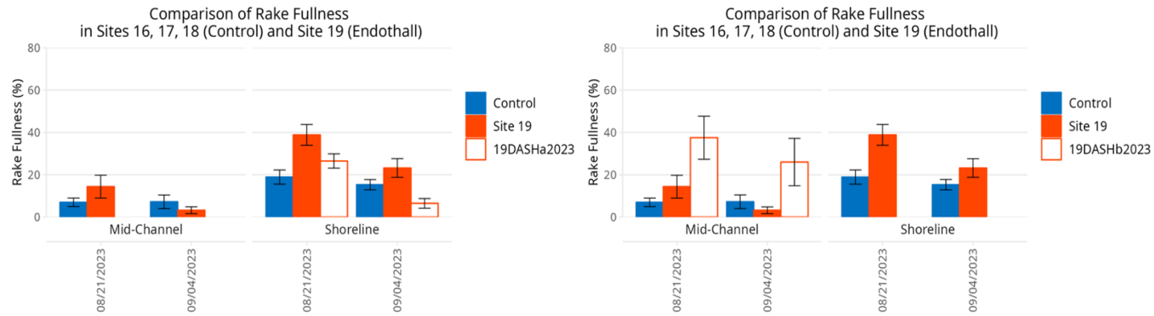


Figure 33. Rake Fullness in Site 19: Two Lake Tallac DASH areas ("a" left graph; "b" right graph).

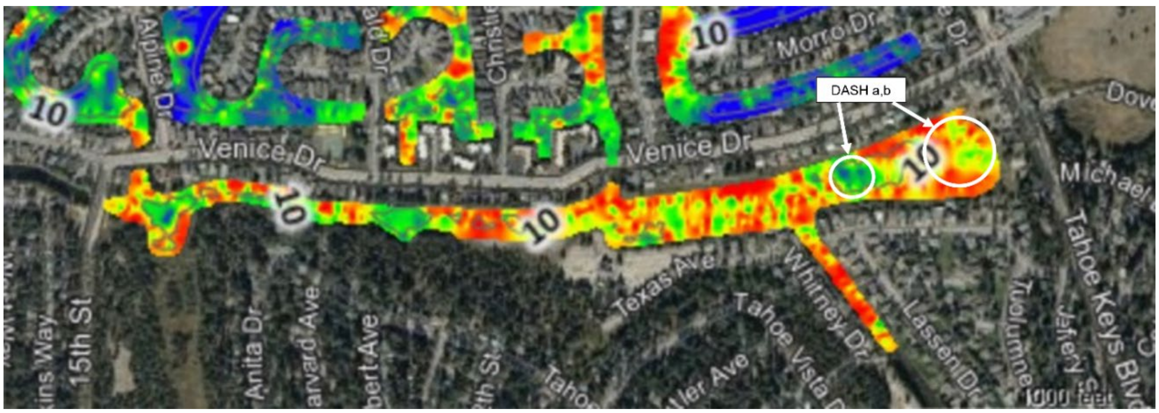


Figure 34. Hydroacoustic scan of Lake Tallac made August 24, 2023. The circles show the locations of the two DASH areas and the relatively low biomass (green) compared to the rest of Site 19. (See Figure 1.)

Site 8

Sites 8 (Year 1 Triclopyr-Only) had DASH and Bottom Barrier methods. (Figure 35). The September 5, 2023 sampling in Site 8 showed that DASH reduced plant Rake Fullness to 0% compared with Rake Fullness of 16.0% in the non-DASH area. The DASH was very effective in removing aquatic plants within the designated area (Figure 36) (Note: The Bottom Barrier in Site 19 was removed in early October and will not be surveyed for AIP abundance and presence until late October and early November.

Figure 35. Site 8 (Year 1 Triclopyr-Only) showing DASH area and Bottom Barrier area. The sample points are from September 5, 2023. Note the cluster of sample points within the DASH area.

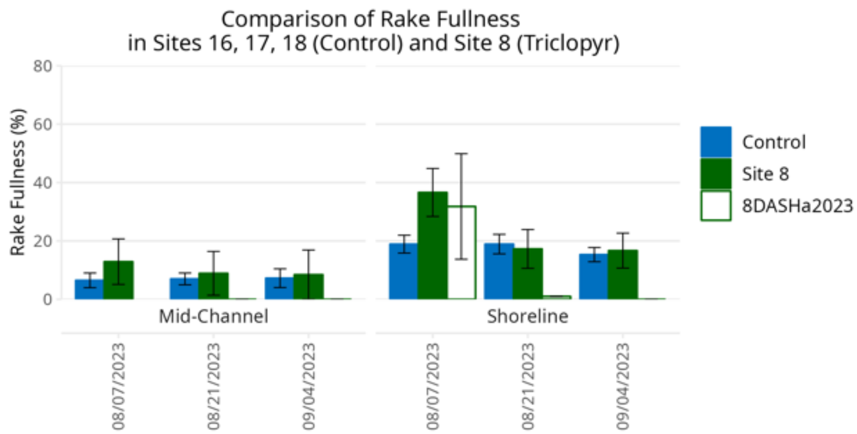


Figure 36. Site 8 Rake Fullness comparing DASH site with Non-DASH within Site a ("Site 8" in legend), and West Lagoon Control sites 16,17,18 ("Control" in Legend).

Site 9

Site 9 (Year 1 Triclopyr-Only) had a DASH area and large UV Spot Treatment area (Figure 37). The rake samples taken September 5, 2023 showed that Rake Fullness in the UV Spot area was reduced to near zero compared to the surrounding Non-UV mid-channel Rake Fullness of 26 (Figure 38). If the rake samples in Non-UV areas included the shoreline zones, then the UV Spot treatment only reduced the Rake Fullness to 9.0% from 26%. This illustrates the enhanced UV efficacy typically achieved in the mid-channel areas of sites, compared to shallower shorelines where structures may limit UV- vessel access.

Figure 37. Site 9 (Triclopyr-Only Year 1) showing the DASH area and UV Spot area and rake sample points on September 5, 2023.

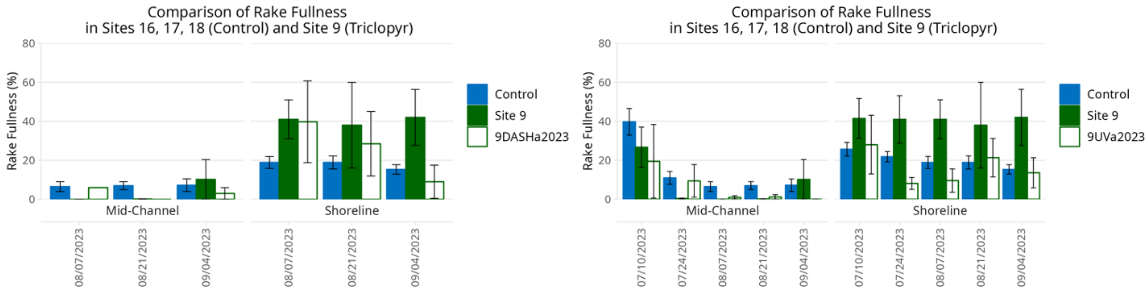


Figure 38. Site 9 Rake Fullness following DASH treatment (left graph) and UV Spot treatment (right graph).

SUMMARY AND CONCLUSIONS

(Note: The assessment of Bottom Barrier effectiveness will be summarized in a supplemental Interim Report.)

The goal of the CMT in 2023 was to provide answers to four questions.

1. Did 2022 Group A CMT Methods have continuing "carry over" control of AIP in 2023?
   Yes, AIP reduction was sustained in herbicide-treated sites, especially Eurasian watermilfoil which remained nearly absent in 2023.
2. Did Group B methods (UV Spot Treatments, Diver Assisted Suction Harvesting, and Bottom Barriers) sustain control of aquatic weeds in sites where target invasive plant biomass was reduced by 75% in 2022?
   Yes, in almost all DASH and UV Spot Treatments in mid-channel zones. Less control was achieved in shoreline areas that were never treated with Group A methods in 2022.
3. What changes in nutrients and basic water quality were observed?
   Levels of phosphorous and nitrogen were highly variable and increased in some treated and control sites in July.
4. Did treatments enhance conditions for desirable native plants?
   The desirable native plant *Elodea canadensis* was either unaffected or increased somewhat, particularly in sites that had been treated with Endothall in Year 1. DASH had variable effects on *E. canadensis* prevalence primarily due to poor visibility which impaired divers' ability to exclude native plants efficiently. *E. canadensis* prevalence was slightly reduced in some UV-Only sites.

Answering these questions is complicated by the extremely different field conditions in 2023 compared to Year 1 2022. The higher snowmelt inflows to the lagoons for a longer time in the Keys resulted in more than 4 feet deeper water in 2023 than in 2022. The deeper water submerged areas that had received no Group A treatments in 2022 and also created more habitat for aquatic plants along the shorelines. Newly submersed shoreline probably mobilized additional nutrients locally though there was no specifically localized monitoring to determine this. The abundance of shoreline plants also suggests that the newly submerged shoreline conditions may have also promoted seed germination or sprouting of buried curlyleaf pondweed turions. The general nutrient monitoring showed few major differences between 2022 and 2023 except that Ortho Phosphate increased in July in several sites. Turbidity was lower in most sites compared with 2022 and was much lower in the sites within Area A (west side of the West lagoon). However, the deeper water resulted in very low light (PAR) penetration in several sites, which in turn, no doubt, reduced plant growth. The 2023 conditions -aside from any small-scale Group B methods success- led to aquatic plant biomass (density) in untreated "Control" CMT sites in 2023 that was half that of Year 1, 2022. Due to water depth, localized nutrient conditions or cooler temperatures, the frequency and toxicity of HABs was also far lower in 2023 than in 2022.

Although there are clearly year-to-year hydrologic and water quality variations, Year 2 Group B effectiveness was assessed by comparing current year (2023) plant surveys in control sites, as well as plant sampling in areas outside Group B areas but within the corresponding same Group A site. The criterion for success is the sustained 75% reduction of plant biomass inside the Group B areas compared with outside the areas.

The summary (Table 1) shows that most Group B methods achieved a good level of success and that some achieved partial success (ca. 50% reduction). The few challenges were associated with insufficient access for UV or some areas of "skipped" UV exposure, or challenges in sustaining low levels of "mobile" coontail. Coontail has no roots and can freely move into previously cleared DASH areas or UV-treated areas. The other critical component of Group B DASH and UV Spot treatment success is the interval between repeat treatments. For UV Spot treatments, exposures in early spring are effective but must be repeated at about 2-to-3-week intervals to control re-growth as well as potential immigration of plants from outside the UV spot area. As temperature and day-length increase, regrowth rates also increase. The relationship between turbidity (or PAR levels) needs to be determined in order to optimize the use of UV.

Notwithstanding Group B methods used in 2023, it is clear that Group A methods employing a one-time use of Endothall and Triclopyr had continued effectiveness that resulted in near absence of Eurasian watermilfoil in those sites throughout 2023. The exception to the excellent control of Eurasian watermilfoil appears to be in the shallower shoreline areas that were not submerged in 2022 and therefore did not receive any herbicide exposure. In these areas, Eurasian watermilfoil, curlyeaf pondweed and coontail were more prevalent.

Although curlyleaf pondweed was reduced in the Group B sites, the persistence of this plant, particularly in the newly submerged near-shore areas, coupled with abundant production of turions, underscores the need for repeated effective treatments and for regular monitoring throughout the spring and summer to locate new stands of the plants as soon as possible. Strategically controlling both the formation of turions (spring-midsummer control) and control (removal, covering, UV exposures, and other treatments) of sprouting turions, where feasible, will be critically important for sustained management of this plant.

One of the goals of the CMT is to improve conditions that favor desirable native plants, which in the Keys is primarily *Elodea c*anadensis, and to some extent, *Najas* (naiad), such as *N. flexilis.* Both Endothall and Triclopyr "release" *E. canadensis* because it is not affected by these herbicides. The frequency of occurrence data show that *E. canadensis* was more prevalent in the herbicide-treated sites, even in 2023 when no herbicides were used. None of the Group B methods provide as much selectivity, although in clearer water conditions, DASH could be a very selective method if divers avoided removing *E. canadensis* or Naiad species.

With the success of years one and two of the CMT, the continuation of planned Group B methods and associated monitoring in 2024 is critical for obtaining sufficient field data to support the development of sustainable long-term management of aquatic plants in the Keys lagoons.

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