TAHOE KEYS PROPERTY OWNERS ASSOCIATION

TAHOE KEYS LAGOONS AQUATIC WEED CONTROL METHODS TEST

DRAFT FINAL REPORT

PREPARED PURSUANT TO

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Prepared for
Tahoe Keys Property Owners Association

Prepared by
Dr. Lars Anderson

In association with
Sierra Ecosystem Associates

2311 Lake Tahoe Blvd., Ste. 8
South Lake Tahoe, CA 96150

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LIST OF ABBREVIATIONS AND ACRONYMS

AIP	Aquatic Invasive Plants (including non-native and nuisance plants)
AIS	Aquatic Invasive Species
APAP	Aquatic Pesticide Application Plan
BB	Bottom Barrier
BPE	Basin Plan Exemption
BMI	Benthic Macroinvertebrates
CalEPA	California Environmental Protection Agency
CMT	Control Methods Test
COC	Chain of Custody
DASH	Diver Assisted Suction Harvesting
DO	Dissolved Oxygen
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ESA	Environmental Science Associates
HABs	Harmful Algal Blooms
IMP	Integrated Management Plan
Lahontan Water Board	California Regional Water Quality Control Board, Lahontan Region
League	The League to Save Lake Tahoe
LFA	Laminar Flow Aeration
µg/L	Microgram per liter
mg/L	Milligram per liter
MMRP	Mitigation Monitoring and Reporting Program
MRP	Monitoring and Reporting Program
N/A	Not Applicable
NPDES	National Pollutant Discharge Elimination System
ONRW	Outstanding National Resource Water
ORP	Oxidation reduction potential
OP	Orthophosphate
Permit	Tahoe Regional Planning Agency Permit No. EIPC2018-0011
PAR	Photosynthetically Active Radiation
Project	Tahoe Keys Lagoons Aquatic Weed Control Methods Test
PPB	Parts per billion
PPM	Parts per million
QAPP	Quality Assurance Project Plan
RWT	Rhodamine Water Tracer
SAV	Submerged Aquatic Vegetation
SEA	Sierra Ecosystem Associates
TKPOA	Tahoe Keys Property Owners Association
TN	Total Nitrogen
TP	Total Phosphorus
TRPA	Tahoe Regional Planning Agency
UVC	Ultraviolet Light
VHC	Vessel Hull Clearance
WQO	Water Quality Objective in Lahontan Water Board Basin Plan
WQ	Water Quality

1.0 EXECUTIVE SUMMARY

Aquatic Invasive Species control is a top priority for Lake Tahoe and the Tahoe Keys is the top priority location for treatment in the region. From 2022 through 2024, the Tahoe Keys Property Owners Association (TKPOA) undertook the Tahoe Keys Lagoons Aquatic Weeds Control Methods Test (CMT) in the Tahoe Keys Lagoons to examine and evaluate the ability of separate and combined methods to “knock-back” and maintain the abundance of aquatic invasive plants (AIP) in the Tahoe Keys. Historic management tools and methods have not been sufficiently successful in allowing TKPOA to get the infestation under control and stop the invasive weeds from spreading into Lake Tahoe proper. For the past 50 years, mechanical harvesting has been the only large-scale method for AIP control. While harvesting helps remove weeds and nutrients from the water, it also creates thousands of plant fragments and disperses the plant reproductive structures in the channels, particularly the “turions” produced by Curlyleaf pondweed, that spurs new weed growth Excessive growth of AIP has had negative effects on water quality, native aquatic plants, native fish habitat, and recreation in the Tahoe Keys.

The overarching goal of the CMT is to determine what combination of methods are most likely to achieve a 75% large-scale knockback of weeds that TKPOA can maintain over time. The CMT is very unique as it included the first ever permitted limited use of EPA- approved aquatic herbicides in Lake Tahoe, and the first large scale open water testing of the UV light systems. Herbicides were only permitted as a one-time application in Year 1 of the test as a knockback tool, and all follow up maintenance tools used in Years 2 and 3 were non-chemical. The results of this test will ultimately inform a long-term strategy for how to better manage weeds in the Tahoe Keys and prevent their spread to other areas of Lake Tahoe.

An overview of the CMT results is presented in this Executive Summary, and the findings are fully described in the subsequent main report and appendices.
Key results include the following:

- The two larger-scale treatment methods, herbicides and UV light at the “C” wavelength (ultraviolet light or UVC), were successful in meeting the “knock-back” goals of the test by reducing invasive aquatic plant abundance by 75%.
- Herbicides were successful in achieving the initial knockback reduction of AIP by 75% in both the near-shore zones and mid-channel zones of the lagoons.
- UVC was also successful in achieving the initial knockback reduction of AIP by 75% in the mid-channel zones of the lagoons. (This method was not applied in near-shore zones due to logistic difficulties in maneuvering around and between dock and pier structures, and where water depths were too shallow.)
- For the smaller-scale treatment methods tested for maintaining the “knock-back”, diver-assisted suction harvesting (DASH) was most successful in the near-shore zones and UVC spot treatments were most successful in the mid-channel zones.
- Bottom barriers provided excellent control while in place (100% reduction in AIP abundance). However, once removed, AIP was observed to resprout quickly, even in the fall.
- The large increase in lagoon water levels from the first year (2022) to the third year (2024) provided more available habitat for AIP to expand in the larger volume of water in the mid-channel areas, as well as new near-shore zone habitat that had not received herbicide treatments in 2022.

- The high reproductivity and spreading capacity of Curlyleaf pondweed, and its threat to Lake Tahoe, suggests that its control needs to be the highest priority in the immediate future.
- LFA did not reduce AIP during all three years of the CMT. Curlyleaf pondweed abundance actually increased in year 3 in some of the LFA sites.

1.1 Background

Lake Tahoe is a deep, high elevation lake with exceptionally clear water and a 72-mile shoreline within California and Nevada. Lake Tahoe is designated as an Outstanding National Resource Water (ONRW) in recognition of its unique hydrologic and ecological characteristics, which provides special protection to maintain its extraordinary ecological and aesthetic values. Lake Tahoe supports social and recreational uses, the economy, and wildlife habitat. The lake's clarity, surrounding mountains, and year-round recreational opportunities represent major attractions for visitors from around the world.

The Tahoe Keys lagoons are located at the southernmost end of Lake Tahoe and include approximately 170 acres of relatively shallow waterways surrounded by about 1,500 homes (Figure 1-1). Two open channels allow free flow of water between the lagoon waterways and Lake Tahoe. The lagoon waterways are almost entirely infested with three invasive aquatic plants - Eurasian watermilfoil (*Myriophyllum* spicatum), Curlyleaf pondweed (*Potamogeton crispus*), and one native aquatic plant, Coontail (*Ceratophyllum demersum*) that has grown to problematic levels and is considered invasive for this environment. The open channels provide a direct pathway for the spread of these aquatic invasive plants (AIP) to the rest of Lake Tahoe. Improved containment of fragments has been achieved in recent years through boat back-up stations, public education, and experiments with double-bubble curtain 'barriers' at the channels.

The Tahoe Keys lagoons are a dynamic system where habitat conditions for aquatic plants and animals can vary dramatically due to changes in water levels and the presence of the aquatic invasive species (AIS). The rapid expansion of AIP such as Curlyleaf pondweed over the past 10 years underscores the need for effective AIP control in the Tahoe Keys lagoons and Lake Tahoe. The Tahoe Keys Property Owners Association (TKPOA) has used mechanical harvesting to cut and remove AIP in the lagoons. Harvesting removes some biomass and nutrients, improves boat passage, and potentially improves aesthetics, but also stimulates AIP growth and produces thousands of plant fragments that, if not captured by the harvester, spread within the lagoons and into Lake Tahoe. For example, Curlyleaf pondweed, the most rapidly spreading AIP, produces reproductive and dispersal structures called "turions" that are dislodged and spread during harvesting.

Due to the complexity and size of the AIP infestation, TKPOA with stakeholders' input (including public agencies, non-profit organizations, and members of the public) proposed a limited-scale test program that would help inform a long-term AIP control strategy. This test was called the Tahoe Keys Lagoons Aquatic Weed Control Methods Test (or CMT). This final report synthesizes the work completed over the three years of the CMT Project within the Tahoe Keys lagoons.

1.2 CMT Development and Goals

The CMT was planned and designed in collaboration with key stakeholders such as the League to Save Lake Tahoe, permitting agencies such as the Tahoe Regional Planning Agency (TRPA) and the Lahontan Regional Water Quality Control Board (Lahontan Water Board), and with a high level of public input and interest. The test was implemented by TKPOA to evaluate a wide range of different control methods and combinations of methods that could improve AIP management by demonstrating which tools could effectively knock back the large population of weeds and which non-chemical methods could sustain the knockback over time.

In 2022, Lahontan and TRPA completed a comprehensive Environmental Impact Report (EIR)/Environmental Impact Statement (EIS) and permitting process. This process established the framework for the CMT goals, control methodologies and approaches, resource protection measures and mitigations, monitoring, and reporting. The goals were to evaluate the ability of the CMT to:

- Reduce and maintain total AIP biomass by 75% ("biovolume") within treated sites.
- Increase the occurrence and percent composition of native plants relative to non-native plants.
- Achieve and maintain a minimum 3-foot vessel hull clearance (VHC) in test sites.
- Contain herbicides within the lagoon test areas and prevent herbicide movement into Lake Tahoe proper.
- Improve water quality in the test sites, such that water quality objectives set forth in Lahontan's Lake Tahoe Basin Plan are more frequently met.
- Submit annual CMT efficacy and monitoring reports by March 1 of each following year for the length of the Project and submit a Draft Final Report evaluating the CMT results.

Many natural resource protection measures were put in place to ensure the protection of the Keys waters, and Lake Tahoe. The CMT included intensive water quality monitoring and frequent and specific monitoring of herbicides and their degradants. To add further protection of Lake Tahoe, the CMT also required that areas where herbicides were to be applied be separated from the main West Lagoon by double turbidity curtains. These curtains were maintained until herbicide reached non-detect levels.

1.3 Methods and Implementation

The CMT was designed as a three-year project limited to the West Lagoon and Lake Tallac Lagoon of the Tahoe Keys. During the first year, three primary treatment methods were implemented to attain a 75% reduction of weeds: 1) two aquatic herbicides (Endothall and Triclopyr), 2) ultraviolet light at the "C" wavelength (UVC), and Laminar Flow Aeration. Laminar Flow Aeration (LFA) was tested in all three years of the CMT, although one of the sites was first installed in 2019 and the other two sites were installed late in the first year of the CMT. These three methods (herbicides, UVC, and LFA) are categorized as CMT Group A treatments and were used alone and in combinations (e.g., herbicide + UVC) at different times and locations from 2022 through 2024. The details on locations, types, and timing of methods are provided in the Year 1 CMT Annual Report (see Appendix A. Descriptions and Links for CMT-Related Documents). The CMT methods are summarized in Table 1-1 and Figure 3-1.

In Years 2 and 3 of the CMT, the non-herbicide Group A treatment methods (i.e., UVC and LFA) were tested for their ability to maintain AIP reductions achieved in the first year. In addition, three small-scale treatment methods ("Group B treatments") were added to assess their effectiveness at helping to maintain the 75% reduction in AIP achieved in the Group A sites in Year 1. These methods were spot treatments of UVC, Bottom Barriers (BB), and diver assisted suction harvesting (DASH). The details of locations, types, and timing of methods are provided in Year 2 and Year 3 CMT Annual Reports (see Appendix A for document links).

In the first year of the CMT (2022), herbicides were applied only once in the late spring in select test sites, while UVC was used throughout the season. Areas were also established with LFA operations. These test methods were replicated in sites that represented typical AIP distributions. To prevent the movement of herbicides to Lake Tahoe, the three herbicide application areas were isolated with four sets of double turbidity curtains. In the following two years of the test, Group B methods were used at Group A locations to assess their ability to help maintain the knock-back achieved during Year 1. The Group B methods were applied in small areas with the Group A sites. The type and size of Group B methods were selected to include the replicated treatments in the different Group A sites (Table 1-1). The criteria and decision tree for applying specific Group B methods are provided in the Year 1 CMT Report (Appendix A).

Table 1-1. CMT Group A and Group B Methods

CMT Year	Group A Methods (Non-herbicide and herbicide methods)	Group B Methods (All non-herbicide) Applied within Selected Larger Group A Sites	Un-treated "Control Sites"
1	UVC Only Sites, Laminar Flow Aeration (LFA) Sites, Triclopyr and Endothall Herbicide Sites alone and in Combination with UVC Treatments	None used in Year 1	4 Sites
2	Continuation of UVC Only, UVC Combination, and LFA Sites	Spot-UV Treatments, BB, DASH	4 Sites
3	Continuation of UVC Only, UVC Combination, and LFA Sites	Spot-UV Treatments, BB, DASH, Sequential Spot-UV and DASH Treatments	4 Sites

1.4 Monitoring and Evaluation of CMT Methods Effectiveness

A comprehensive and detailed monitoring program was completed to assess the effects of CMT methods on water quality variables and AIP (Appendix B. Monitoring Frequencies and Locations). To ensure objectivity and confidence in data collection and analysis, TRPA hired independent contractors to perform high frequency water quality sampling to assess herbicide presence, and to determine the effectiveness of CMT methods on AIP. TKPOA staff conducted bi-weekly hydroacoustic scans to assess changes in biovolume of AIP (Appendix C. All Hydroacoustic Scans). Several approaches were used to assess AIP responses to CMT Group A UVC, LFA, and herbicide applications and Group B non-herbicide treatments as summarized in Table 1-2. Approximately 230,000 monitoring data points were collected during the CMT. Over 7,000 rake samples of aquatic plants were taken each year to measure AIP responses to CMT methods. A detailed description of monitoring methods is provided in Year 1 CMT Report (Appendix A).

Table 1-2. Summary of Methods Used to Assess AIP Responses to CMT Methods

Data Obtained from Physical Rake Samples	Data Obtained from Hydroacoustic Scans	Data Obtained from Combining Rake Samples and Hydroacoustic Scans
AIP Abundance, species present, frequency of occurrence, health condition of plants, and number of Curlyleaf pondweed turions	Biovolume of AIP, Plant height, VHC, Water Depth, and Water Volume	Species -Specific Biovolume, Relative Biovolume of AIP within lagoons, and proportion of each species to total Biovolume

1.5 Results of CMT

The detailed results from each year of the CMT were presented in the CMT Annual Reports submitted to Lahontan and TRPA and are available through web links in Appendix A. The key results from the three-year CMT Project relative to Project goals are summarized in Table 1-3 and are described in detail in the full report and appendices following this Executive Summary.

Table 1-3. Group A Summary Results (2022-2024) Relative to Project Goals

	Years Applied	Goal: Maintain 75% Knock-back	Goal: Maintain 3-Foot VHC	Goal: Increase Desirable Native Plants
Group A Single Methods (2022 - 2024)				
Herbicide Only				
Endothall (targets all AIP: Eurasian watermilfoil, Curlyleaf pondweed, and Coontail)	Year 1 only	Yes (Years 1 to 2)	Yes (Years 1 to 3)	Yes
Triclopyr (targets Eurasian watermilfoil)	Year 1 only	Yes (Years 1 to 3)	Yes (Years 1 to 3)	Yes
UVC Only (affects all aquatic plants)	Years 1 to 3	Yes (Years 1 to 3)	Yes (Years 1 to 3)	No
LFA (intended to target all AIP)	Years 1 to 3	No	No	No
Group A Combination Methods (2022 - 2024)				
Herbicide Near-Shore Zone with UVC Mid-Channel				
Endothall	Year 1 only	Yes (Year 1)	Yes (Year 1)	Yes
Triclopyr	Year 1 only	Yes (Years 1 to 3)	Yes (Years 1 to 3)	Yes
UVC	Years 2 and 3	Yes (Years 2 and 3)	Yes (Years 2 and 3)	No
LFA with UVC Mid-Channel	Years 2 and 3	No AIP reduction	No AIP reduction	No

Table 1-4. Group B Summary Results (2023-2024) Relative to Project Goals. These results only pertain to the localized areas where Group B methods were applied, not the entire CMT Site defined by Group A methods.

	Years Applied	Goal: Maintain 75% Knock-back	Goal: Maintain 3-Foot VHC	Goal: Increase Desirable Native Plants
Follow-Up Group B Single Methods (2023 - 2024)				
Bottom Barriers (While in place, affects all aquatic plants)	Years 2 and 3	Yes	Yes	No
DASH (targets all AIP)	Years 2 and 3	Yes	Yes	Partial
Spot-UV (affects all aquatic plants)	Years 2 and 3	Yes	Yes	No
Follow-up Group B Combination Methods (2023 - 2024)				
UVC Sequential to Bottom Barriers (one treatment)	Year 3	Yes	Yes	No
DASH Sequential to Bottom Barriers (one treatment)	Year 3	Yes	Yes	Partial

1.6 Climatic Environmental Conditions

Lake Tahoe and the Tahoe Keys lagoons are subject to a range of seasonal and year-to-year effects from weather including extreme air and water temperatures changes, wind, snowfall, and variable accumulated “snowpack” and resulting spring runoff that flow into the lake and affect Tahoe Keys lagoons water levels. During the CMT, these variables were apparent with storms, and particularly large snowpacks and runoff in 2023 and 2024. These events affected the CMT treatment methods and AIP in several ways summarized below.

- Increased water levels between Year 1 and Year 3 expanded AIP habitat in near-shore zones that were not exposed to herbicide in Year 1. These areas were above water during the drought in 2022 and, once inundated, provided increased areas for AIP growth in near-shore zones by Year 3, including untreated Control sites. (See Section 11.1 for additional information.)
- Deeper water in Years 2 and 3 favored growth of Curlyleaf pondweed, which increased in abundance in Year 3 in Control and LFA sites, especially in deep mid-channel areas. (See Sections 11.1 and 11.2 for additional information)
- Storms and high winds in the spring of 2022 disturbed some double turbidity curtains allowing very low level, short-term movement of herbicides past two curtained areas. This was quickly remedied within 24 hours by securing curtains and by adding additional curtains and herbicide did not reach Lake Tahoe. (See Appendix D. Turbidity Curtains Vicinity Aquatic Plant Analysis Report for additional information.)
- Aquatic habitat impacts from the CMT were limited and restoration was achieved in both the West and Tallac lagoons for all sensitive resources evaluated. Laboratory analyses for lagoon sediments were non-detect for Triclopyr and its degradants in 2022, and for Endothall and its degradants in 2024. (See Appendix A for the Biological Restoration and Sediment Monitoring Reports)

- Most near-shore zones were not accessible for UVC treatment due to the presence of piers, docks, rip-rap shorelines, parked boats, and where the water depth was too shallow.

1.7 Herbicide Movement and Levels

Triclopyr and Endothall were applied either as whole-site applications or only along the near-shore zones. In both instances, treatment areas adjacent to the application were isolated from the rest of the West Lagoon by double turbidity curtain barriers. The movement and level of herbicides within the application site and in adjacent water was monitored extensively by a TRPA-supported, independent, highly qualified, and Lahontan-approved contractor. The results of this monitoring are summarized below, and detailed reports are accessible through document links in Appendix A.

- No herbicides or residuals entered Lake Tahoe or reached the West Channel.
- Endothall was at “non-detect level” in water (5 parts per billion or ppb) in about 45 days.
- Triclopyr was at non-detect level in water (1 ppb) in about 100 days.
- The slow rate of Triclopyr degradation required the double turbidity curtains to remain in place most of the Year 1 recreation season, which greatly restricted typical mixing of lagoon waters. Stagnant water conditions likely contributed to the formation of harmful algal blooms (HABs) and further slowed the breakdown of Triclopyr since degradation is sunlight-dependent and increased turbidity from HABs greatly reduced light levels.
- No adverse effects on fish, wildlife, or other non-target biological resources such as benthic macroinvertebrates (BMI) were observed in herbicide-treated sites or other lagoon areas from other treatments for the duration of the three-year CMT.

1.8 Nutrients and Water Quality

Aquatic plants and algae require nutrients for growth, and they accumulate these nutrients as they grow. However, when the plants and algae decompose during seasonal die-back, or when they decompose after using aquatic herbicides, UVC, or mechanical harvesting, they release nutrients such as nitrogen and phosphorus. The released nutrients can enter the water and stimulate algae growth. During the CMT, levels of nutrients in the water were measured frequently in the herbicide treated sites, UVC sites, and LFA sites. The results are summarized below.

- A pattern of increased nutrients during the middle to late summer was common in all CMT sites for all three years, including untreated Control sites. This is likely due to late summer/fall aging and breakdown of AIP.
- In Year 1, increases in Total Nitrogen (TN), Total Phosphorus (TP), and Orthophosphate (OP) were observed in Endothall-treated sites, and to a lesser degree in Triclopyr-treated sites, and in some Spot-UV treatment sites. Decomposition of AIP following Year 1 CMT treatments likely caused these increases. In Years 2 and 3, most nutrients in UVC sites were comparable to untreated Control sites.
- None of the CMT treatments affected water temperature during the three-year CMT.
- Endothall-treated sites had somewhat lower dissolved oxygen (DO) levels than untreated Control sites, but all CMT sites showed naturally occurring decreases in DO (less than 5 milligrams per liter or mg/L) in the bottom areas, including Control sites. No differences between Endothall sites and Control sites were observed in Years 2 and 3.
- Endothall and Triclopyr applications reduced pH ranges to more closely meet the Water Quality Objectives (WQO) of pH 8.4 (Appendix A), while Control sites and LFA sites constantly had pH levels above the WQO by mid-summer.

1.9 Effectiveness of CMT Methods

Table 1-2 summarizes methods used to assess Group A and Group B control methods. Hydroacoustic scans provide AIP biovolume (abundance) data on a Lagoon-wide scale, and physical rake samples provide highly localized and detailed information on the amount of AIP in a treated site as well as the prevalence and amount of each AIP and native species. Local sampling is important to understand how AIP grows and how the CMT methods affect plants in mid-channel (deep areas) and near-shore zone shallower areas. This sampling method also reveals how each AIP or native plant responds to the different Group A and Group B methods. The summary provided here is based on rake sampling and “rake fullness”, as a measure of abundance, and data obtained for each species present.

1.9.1 Group A Methods

- Endothall Only applications in Year 1 achieved 75% reduction in Eurasian watermilfoil for 2 years in mid-channel areas and partial (55 to 65%) reduction in Year 3. Endothall reduced Eurasian watermilfoil in near-shore zones by 75% in Year 1.
- Triclopyr Only applications in Year 1 reduced Eurasian watermilfoil by 75% for 3 years in mid-channel areas and for 2 years in near-shore zones.
- Triclopyr-Only applications in Year 1 also reduced Curlyleaf pondweed by 75% for 3 years in mid-channel areas and for 2 years in near-shore zones.
- UVC Only was not consistently effective in Year 1, but subsequently reduced AIP by 65-75% in Years 2 and 3 in mid-channels as operational treatment methods were improved.
- UVC Combination treatments in mid-channels were moderately effective in Year 2 (55 to 60% reduction) and more effective in Year 3 (65 to 75% reduction).
- LFA did not reduce AIP over the three-year CMT and appeared to enhance the growth of Curlyleaf pondweed in Year 3.

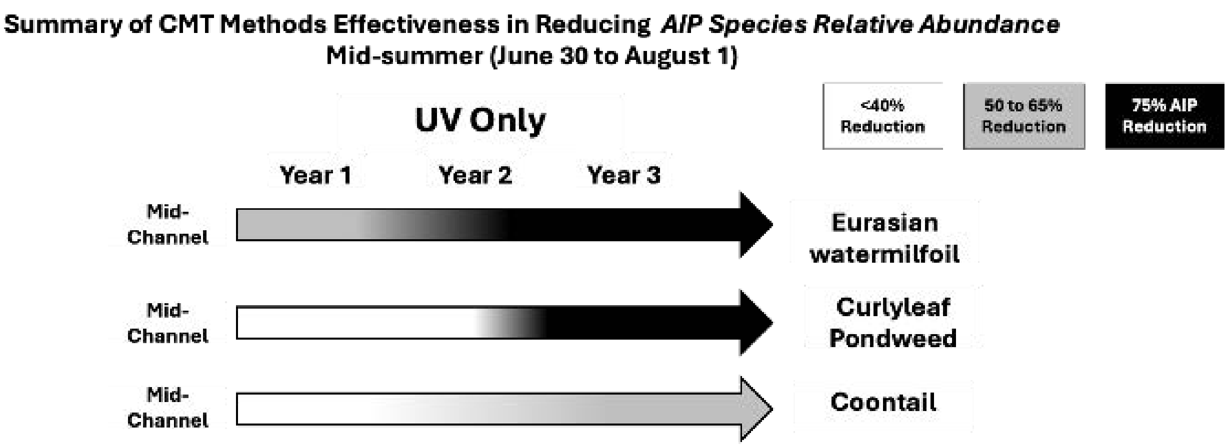


Figure 1-1. Effectiveness of UVC Only Method.

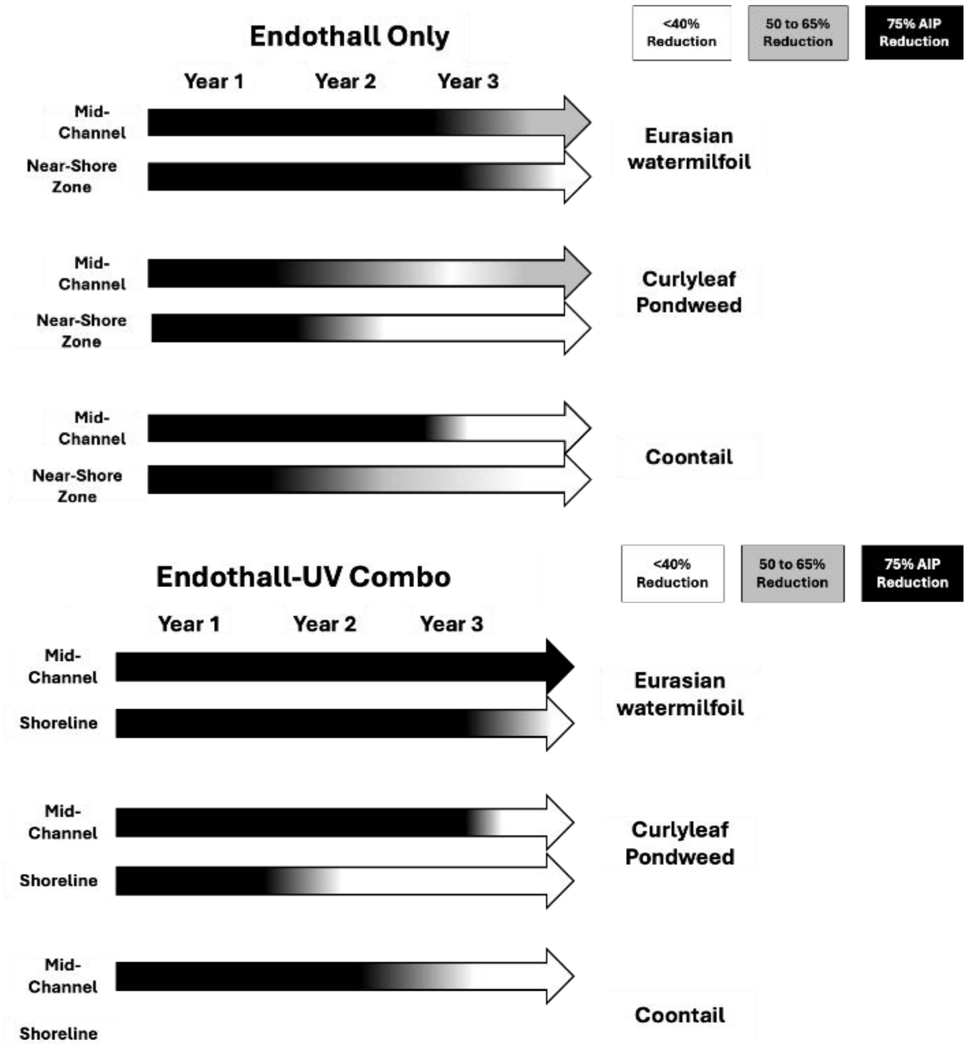


Figure 1-2. Effectiveness of Endothall Only and in Combination with UVC.

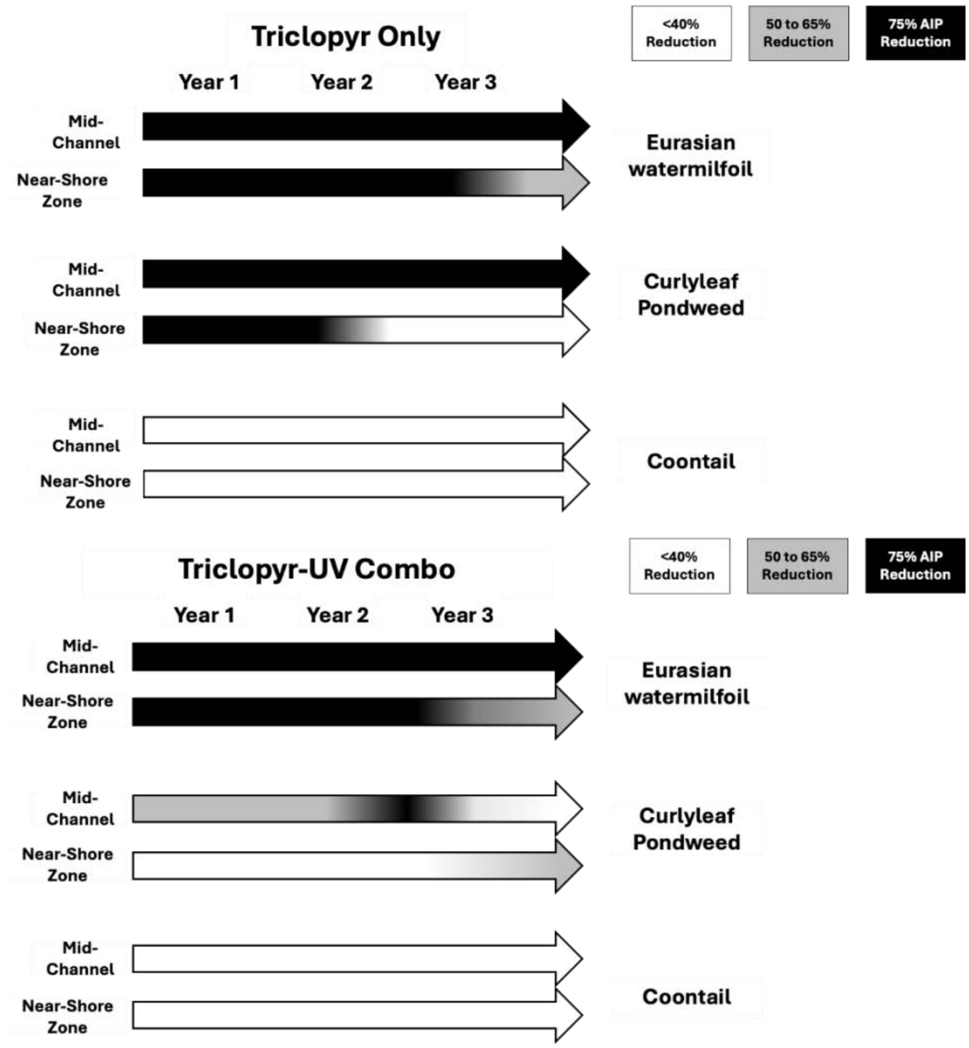


Figure 1-3. Effectiveness of Triclopyr Only and in Combination with UVC.

1.9.2 Group B Methods

- Spot-UV treatments effectively maintained 75% control of AIP in most Group B sites after Group A treatments. Coontail often moved into previously treated areas (Coontail is primarily an unrooted, floating species).
- DASH was variably effective at maintaining 75% control in Group B sites after Group A treatments depending on water clarity and density of AIP. DASH effectiveness was limited by turbidity (diver visibility) but was able to remove large numbers of Curlyleaf pondweed turions, which may reduce this AIP population in subsequent years on a small-scale.
- While in place, BBs were very effective at maintaining 75% control in Group B sites after Group A treatments, but when removed, Curlyleaf pondweed turions in the seed bank sprouted and other AIP were found where the barriers had been placed. The adaptive management decision to test sequential Spot-UV treatments showed promise for post-barrier removal control of the sprouted turions.

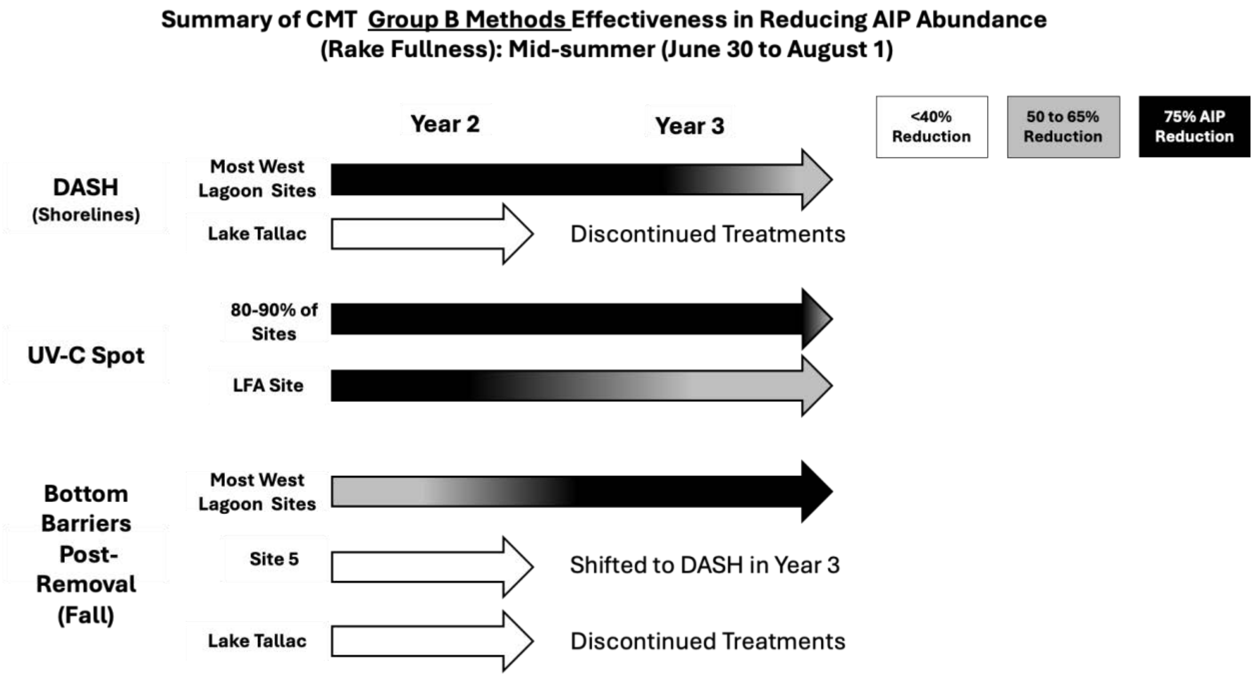


Figure 1-4. Effectiveness of Group B methods

1.10 Implications of CMT Results for Management of AIP

The CMT has provided valuable field-based data, and AIP species-specific data not only on the responses to Group A and Group B methods, but also on AIP population distribution, AIP reproductive and dispersal capacities, and the abilities of AIP to adapt to changing conditions such as water levels and "new" habitat. Developing effective AIP management will rely on these data since they inform us of critical points in seasonal growth and reproductive patterns where management tools can be used optimally.

- Two distinctive habitats support AIP growth in the Keys lagoons: shallow near-shore zones between the dock ends and water's edge, and deeper mid-channel areas. Seasonal and year-to-year changes in Lake Tahoe water levels affect the size and volumes of AIP habitats for these two lagoon habitats. The utility of the test methods depends on their applicability in these habitats, and the scale (size of treatment area) of their use. Therefore, control methods must be appropriately tailored to the habitat, scale, and the target AIP.
- The increase in water levels from 2022 to 2024 reduced treatment success and increased AIP species occurrence between mid-channel and near-shore zones due to both: 1) exposed soil near-shore zones that did not receive Group A treatments in Year 1, and 2) deeper water levels and greater lagoon water volume in Years 2 and 3 that increased available AIP habitats.
- The CMT results demonstrate that only methods that are sufficiently large size, or that achieve a large scale of effectiveness, and that treat both near-shore zones and mid-channel areas, can provide long-term 75% reduction in AIP. If either the control method is insufficient, or if the area is too small, or if low water levels prevent treatment of exposed soil near-shore zones, then surrounding un-controlled AIP will re-infest treated areas within weeks or months, or in subsequent years when water level increases as it did in 2022 and 2023.

- If AIP is not controlled in both mid-channels and near-shore zones, then lagoon-wide management cannot be achieved because AIP in uncontrolled habitat will grow and disperse. The size and volume of mid-channel and near-shore zone habitats depend on lake level. Therefore, spring projections of lake levels are needed to guide the types and locations of treatments to achieve sufficient reduction in AIP. For example, higher water levels that occurred in 2023 and 2024 provided more habitat that was untreated in 2022 for AIP growth.
- The urgency to control Curlyleaf pondweed is paramount. Data confirms significant recent abundance increases due to its enormous reproductive and dispersal capacity in both the Tahoe Keys lagoons and in Lake Tahoe. Data from rake samples and observations during DASH treatments suggest that 10 to 15 million Curlyleaf pondweed turions are formed annually within approximately 100 acres of the West Lagoon. If only half of this “turion pressure” results in new plants, Curlyleaf pondweed will continue to overwhelm other AIP (if not controlled), and restrict desirable native plants such as Elodea, which are already a very small (<5 %) portion of the lagoons’ aquatic plant populations.
- Future management will depend on integrating all effective and practical methods to effectively target AIP; tailoring methods will be important to address seasonal and annual water level changes and the different habitats: near-shore zones and mid-channel areas.
- The CMT included some of the most intensive monitoring ever reported for field use of aquatic herbicides, UVC and LFA, and the other AIP control methods that were tested. The development of future management strategies and methods should identify what monitoring is sufficient, but not excessive or redundant, to track results as well as protect environmental conditions. The CMT provides a very useful basis to determine optimal future monitoring.

2.0 INTRODUCTION

This Draft Final Report presents the results of the 3-year CMT Project implemented in the Tahoe Keys lagoons from 2022 through 2024. The report describes existing conditions in the lagoons, the design of the test project, what methods were tested, how data was collected to monitor the test methods, how effects were evaluated on water quality and target and non-target species, and the overall results regarding the success of the various methods tested both alone and in combination with other methods.

The sections below explain the local aquatic plants and the history of AIP management in the Tahoe Keys lagoons. The status of the aquatic plant infestations and pre-CMT Project management practices are also presented.

2.1 Aquatic Invasive Plants (AIP) in the Tahoe Keys Lagoons

The CMT was conceived and designed to generate field data to guide and support the development of science-based methods to reduce the increasing impacts of AIP in the approximately 170-acre Tahoe Keys lagoons (Figure 2-1). No records provide the sources, dates, locations, or events that marked the initial introductions of the first detrimental AIP, Eurasian watermilfoil, or the later appearance of Curlyleaf pondweed in Lake Tahoe or in the Tahoe Keys lagoons. The history of non-native invasive species in Lake Tahoe dates back at least to the 1920s when lake trout were introduced, followed by decades of periodic, purposeful, and unintended AIS introductions (Wittmann et al. 2015, Anderson et al. 2025).

Rapidly increasing numbers of visitors and residences in the Tahoe Basin in the early 1900's through the mid-1900's provided the pathways for AIS introductions from local and remote “source” populations of AIS (Wittmann 2008). With multiple boating access points around Lake Tahoe, the introductions of AIP could have occurred at anytime and anywhere until 2008 when mandatory boat inspections for AIS were started. The inspection program has been successful to date in stopping the introduction of quagga and zebra mussels as well as new invasive aquatic plants. However, the legacy of prior free access to Lake Tahoe waters and the resulting introductions of AIP created the need for AIP management in the Tahoe Keys lagoons and Lake Tahoe.

2.2 Current Tahoe Keys AIP Containment and Management

The first documented presence of Eurasian watermilfoil along the shores of Lake Tahoe was in 1995 (Anderson and Spencer 1995), and the first record of Curlyleaf pondweed was in 2003 (Anderson et al. 2025). However, the detrimental impacts of these AIP, and excessive growth of the native plant, Coontail, were already recognized by the early 1970s when AIP harvesting began in the Tahoe Keys lagoons.

Mechanical harvesting, used for the past 50 years in the Tahoe Keys lagoons, is not sufficient to mitigate AIP impacts, nor has this method reduced the threat of AIP to Lake Tahoe. While mechanically harvesting AIP can provide boating “pathways” in channels clogged with AIP, this method also stimulates plant growth and produces thousands of plant fragments and other reproductive structures that can move within the Keys lagoons and into Lake Tahoe where new infestations can start (Anderson 2014). Also, harvesting is mainly effective in open channels, but does not remove AIP in shallower, poorly accessible near-shore zones between docks. Unmanaged near-shore zones provide habitat that support growth and further dispersal of AIP. The shallow near-shore zones are particularly problematic since boat movement in and around docks can easily dislodge and fragment AIP. In other words, effective strategic management of AIP has not been achieved with harvesting.

The increase in AIP abundance over the past 20 years (Figure 2-2), and the dramatic increase in Curlyleaf pondweed prevalence over the last 10 years (Figure 2-3) underscore the inability of harvesting to reduce or contain AIP populations. The detrimental production and dispersal of AIP fragments prompted several attempts to mitigate this threat and contain fragments over the past 10 years. Some methods have been helpful but are still undergoing reviews for effectiveness. The most effective “containment” approaches are strategies and methods that minimize growth of AIP in habitats that support reproduction and dispersal, particularly for Curlyleaf pondweed.

Figure 2-1. Overview of the Tahoe Keys Lagoons and CMT Project areas: The circles show the general locations within the West Lagoon and Lake Tallac where the CMT methods occurred.

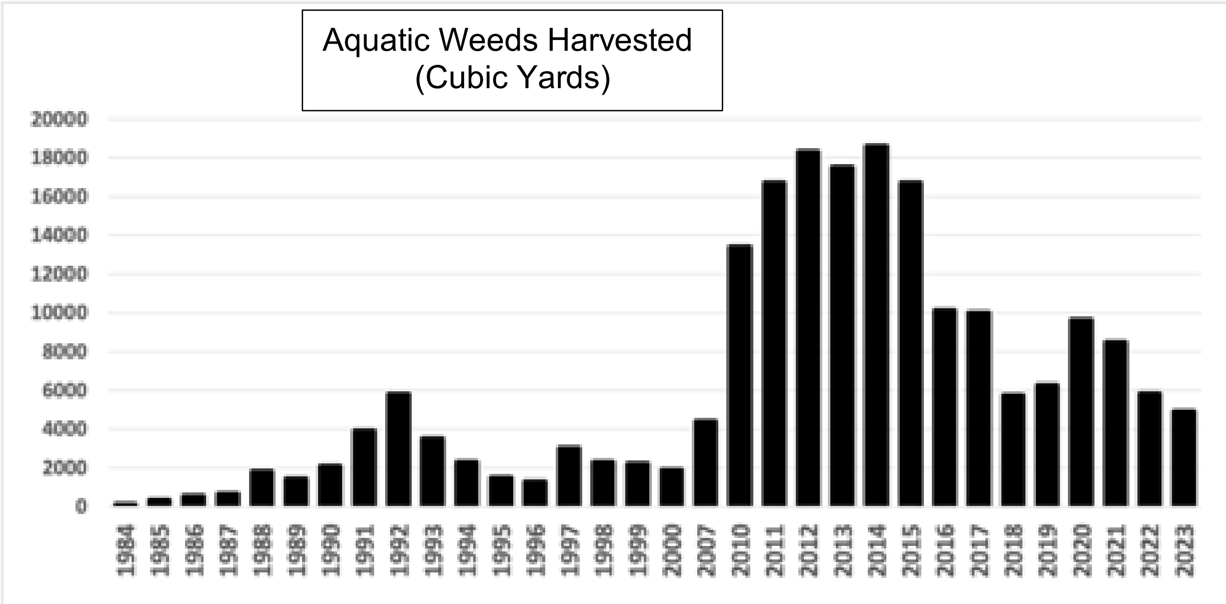


Figure 2-2. Historic annual harvest yield trends of AIP in the Tahoe Keys lagoons.
(Source: TKPOA Staff 2024)

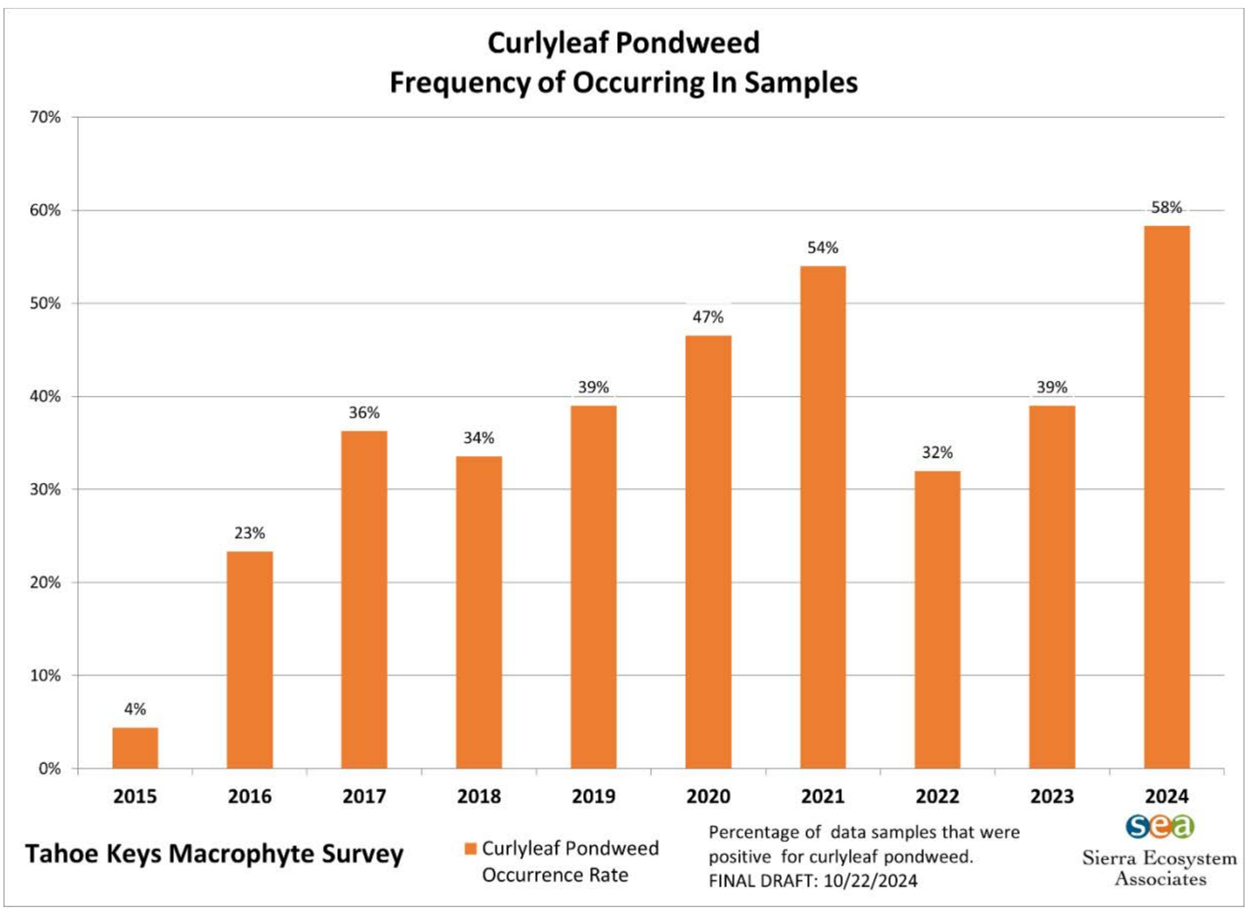


Figure 2-3. Ten-year trend in Curlyleaf pondweed frequency occurrence in the Tahoe Keys lagoons. (Note Curlyleaf pondweed was first detected in 2003.)
(Source: Sierra Ecosystem Associates)

3.0 CMT DESIGN GOALS, OBJECTIVES, AND IMPLEMENTATION

The impetus for the CMT was the recognition by TKPOA, TRPA, and the League that current mechanical harvesting was inadequate to control AIP, and that other approaches combining multiple tools might be integrated and combined to greatly improve AIP management and reduce threats of AIP movement to Lake Tahoe (Gettys et al. 2020). The potential to test aquatic herbicides became possible in 2015 when Environmental Protection Agency (EPA) approved a 2012 change in Lahontan regulations, known as the Basin Plan Exemption (BPE) process. Before 2015, the option to use aquatic herbicides was prohibited by the Lahontan Water Board "Basin Plan". The BPE amendment included an authorized administrative mechanism, and criteria for approval of a "Basin Plan Exemption" to the general prohibition on using aquatic herbicides.

In 2017, TKPOA developed an initial project and plan to test the use of aquatic herbicides in the Keys lagoons for AIP control. This plan was subsequently modified through extensive stakeholder review and input. However, due to the unique conditions in Lake Tahoe, and the fact that the plan included a first-time ever use of aquatic herbicides in Lake Tahoe, a full EIR/EIS was prepared in 2019 to assess potential environmental effects of the project. The completed EIR/EIS and further modified CMT were considered by the Lahontan Water Board and TRPA Governing Board and approved/permitted in early 2022. (See links to documents in Appendix A.)

The key goals and objectives of the three-year CMT were based on TKPOA's final permit application (TKPOA 2019), mitigation and monitoring conditions of the EIR/EIS, and permit requirements issued by Lahontan and TRPA for testing AIP management methods. The CMT project included three key approaches: (1) the single and combined use of multiple non-herbicide methods; (2) one-time use of two aquatic herbicides, both alone and in conjunction with non-herbicide methods; and (3) extensive environmental monitoring. The use of multiple methods for weed control in general, including aquatic weeds, is the foundation of "Integrated Pest Management," which can optimize efficacy and cost-effectiveness.

The multiple methods tested for control of AIP in the CMT were deployed in a three-year sequence. In the first year (2022), "Group A" methods were implemented consisting of UVC light, Laminar Flow Aeration (LFA), and the one-time use of two aquatic herbicides: Endothall and Triclopyr. The objective of the Group A methods was to reduce, or "knock-down" AIP abundance by 75% compared with untreated areas.

In the second year (2023), non-herbicide Group A methods (UVC and LFA) were continued, and additional Group B methods were also employed including DASH, BBs, and UVC "Spot Treatments". Group B methods were deployed to determine if the 75% reduction achieved by the herbicide in Year 1 could be sustained where the Group B methods were used within the larger Group A sites. The locations within the Group A Sites, and types of Group B methods, were determined by monitoring the AIP populations using extensive rake sampling. The sizes of Group B areas were typically a small part of an entire Group A site because the logistics and costs for deploying DASH and Bottom Barrers weighed against applying these methods at scales comparable to Group A methods (See Appendix E. Treatment Acreage Tables with Dates). Nonetheless, several replications of the Group B methods allowed for seasonal and annual assessments of their effectiveness (See Figure 3-1). As explained later, Group B methods were also tested in Year 2 and Year 3 in Group A sites where 75% knock-back had not been achieved.

To ensure objectivity in the CMT monitoring, TRPA employed independent contractors to assess changes in water quality conditions, the effectiveness of treatment methods on AIP, and the fate and movement of aquatic herbicides. The CMT, EIR/EIS, and agency permits (Lahontan 2022, TRPA 2022) identified the following criteria for successful outcomes of AIP control methods used:

- Reduce by 75% and maintain the total AIP biomass ("biovolume") within treated sites.
- Increase the occurrence and percent composition of desirable native plants relative to invasive and nuisance plants.
- Achieve and maintain a minimum 3-foot VHC in test sites.
- Contain herbicides within the lagoon test areas and prevent herbicide movement into Lake Tahoe proper.
- Improve water quality in the test sites, such that water quality objectives set forth in Lahontan's Lake Tahoe Basin Plan are more frequently met, thereby improving water quality and AIP control effectiveness including:
    - Reduction in suspended nitrogen, phosphorus, and total dissolved solids in the fall months during aquatic plant senescence;
    - Improvement in clarity of the water as measured by turbidity;
    - Improved water column pH stability in all test areas to achieve pH values between 7.0 and 8.4; and,
    - Improved recreational and aesthetic values.
- Submit annual CMT efficacy and monitoring reports by March 1 of each following year for the length of the Project and submit a Final Report evaluating the results of the CMT.

3.1 Summary of CMT Design Objectives

With the above goals and requirements, the CMT was designed to provide sufficient, reliable data on the potential effectiveness and utility of the Group A and Group B methods and their integrated use while carefully assessing the effects that these methods may have on water quality, non-target native plants, and wildlife and benthic-dwelling invertebrates in the lagoon bottom sediments. The implementation of the test methods and the extensive environmental monitoring and results are described in the following sections of this report.

The overall strategy, yearly actions, and objectives over the three-year project period are summarized in Figure 3-1. The CMT was designed to be flexible and adaptable to changes in AIP populations and hydrologic conditions of the lagoons. The adaptive component of the CMT was supported by an extensive monitoring program (See Section 4).

The CMT methods and approaches are further described in Sections 3.2 (Group A Methods) and 3.3 (Group B Methods).

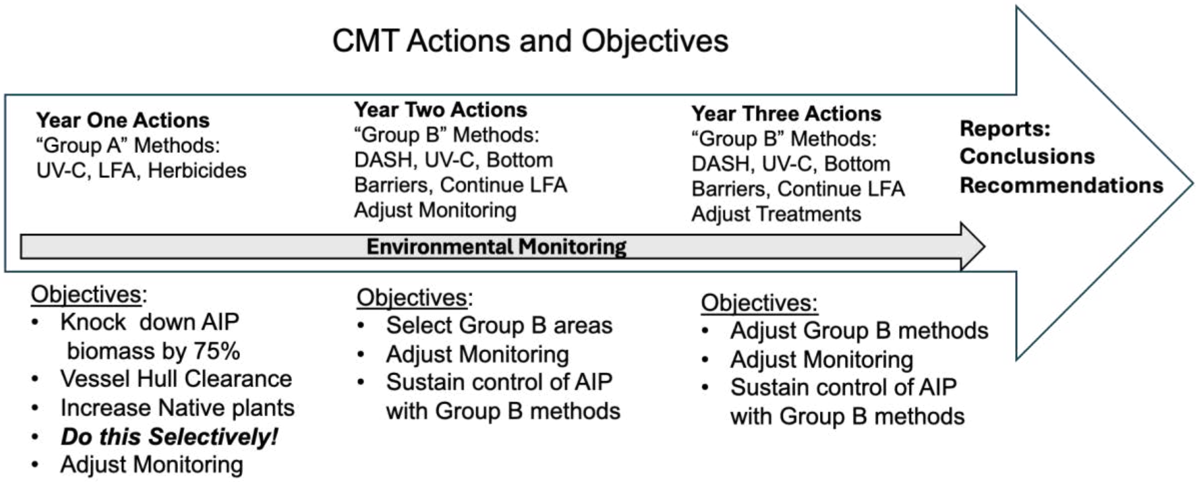


Figure 3-1. Summary of the year-by-year actions and objectives of the CMT.

3.2 Group A Methods

The CMT was designed to provide data on the effectiveness of and effects from several non-herbicide methods, the one time-use of aquatic herbicide applications, and combinations of non-herbicide methods and herbicides. In Year 1, Group A methods included two types of herbicides: Endothall (used at 2 parts per million or ppm) and Triclopyr (used at 1 ppm), applied either to entire sites (1 to 1.5 acres each in the West Lagoon and a 2-acre site in Lake Tallac), or as part of a "Combination Herbicide/UVC" treatment (See Figures 3-2(b) and 3-3). For combination sites, the herbicides were only applied to near-shore zones from the edges of the shore to the ends of docks. The mid-channel areas of these sites were treated using UVC in Years 2 and 3. (See Figures 3-2 and 3-3).

Group A methods used in Years 1, 2 and 3 also included use of UVC-only methods in the mid-channel areas of three sites (Sites 22,23,24; see Figures 3-2(c), 3-5 and 3-6(a). These treatments continued for three years with the exception of Site 23, which was not treated with UVC in 2023 due to lack of resources. The UVC-only treatments were repeated 3 to 4 times during June to October in order to sustain control of AIP. The duration of UVC light-array exposure varied from 5 minutes to 15 minutes and included some overlap of exposed areas to ensure complete coverage of AIP. Note that near-shore zone areas were not treated.

Another Group A method, Laminar Flow Aeration (LFA), was applied over the 3-year CMT in the West Lagoon (Sites 25 and 26) and in Lake Tallac (Site 27) (Figures 3-5 and 3-2 (d)). In this method, air is pumped from a land-based compressors to a series of submersed diffusers on the bottom that produce streams of bubbles. The intent of FLA is to increase the level of DO near the bottom and in the water column and potentially reduce available nitrogen and phosphorus that can be released in low DO. LFA also mixes the water column, which can prevent the formation of a temperature "barrier" or boundary between surface water and bottom water that typically forms in mid-summer. The boundary often results in low DO near the bottom. The LFA CMT sites were monitoring for temperature, DO and nutrients as well as the abundance and type of AIP present.

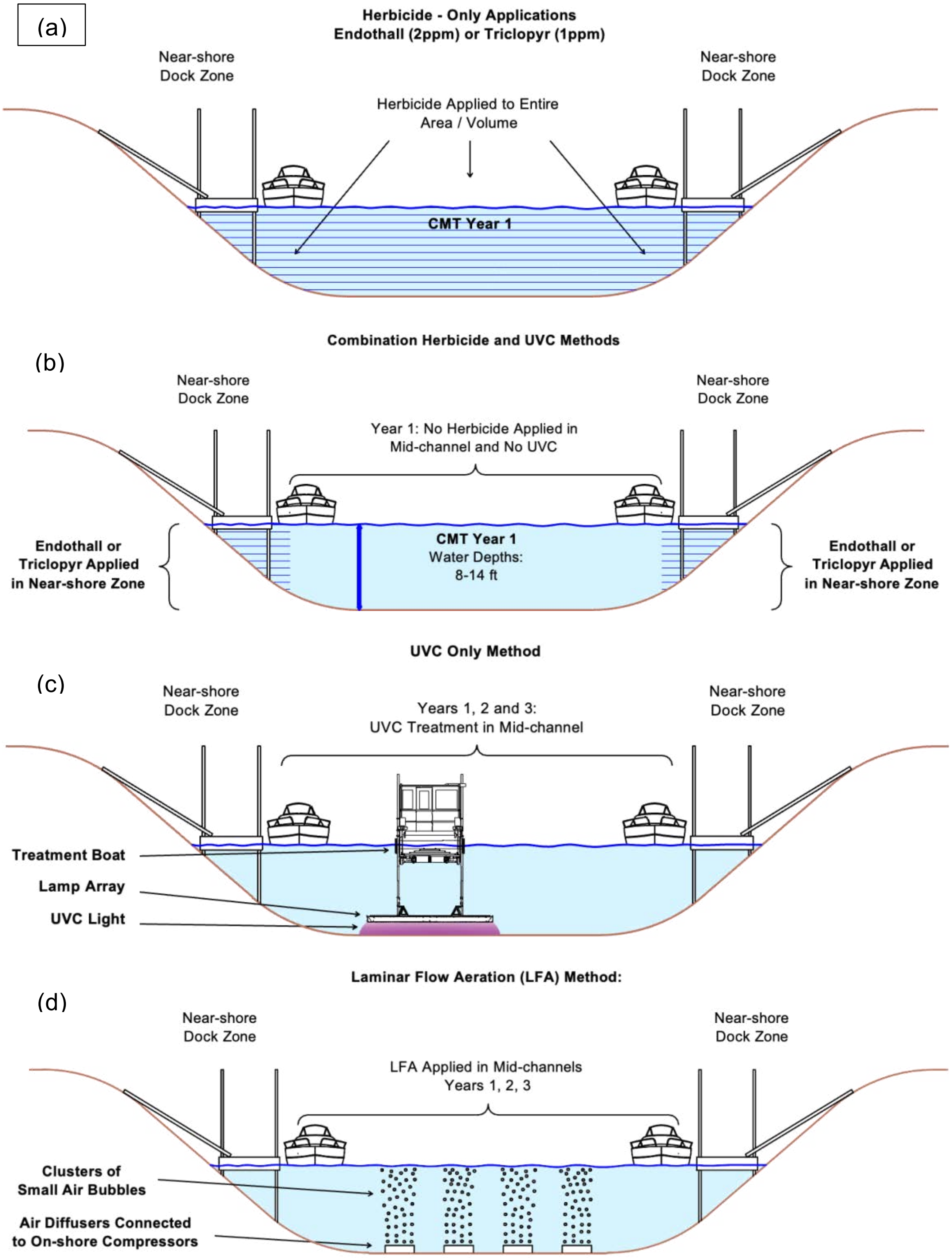


Figure 3-2. Design for implementing CMT Group A methods in West Lagoon CMT sites. (a) Herbicide applications to entire site (Year 1 only); (b) Combination methods: Herbicide applications in near-shore zones only in Year 1, and UVC treatments in mid-channels Years 2 and 3; (c) UVC Only in mid-channels (Years 1, 2 and 3);(d) LFA in mid-channel sections of sites (Years 1, 2 and 3) (See Figure 3-5 for locations of the Group A methods.)

Figure 3-3. Example (aerial view) of CMT Combination site: UVC was used in mid-channel area (Years 2 and 3); Endothall or Triclopyr was applied to the near-shore zone area in 2022.

In CMT Year 2, non-herbicide Group B methods were used in the Group A sites with 75% AIP reductions to determine if these methods could sustain control of the AIP. For Year 3, Group B methods were continued, or modified in size or location, to further assess their ability to maintain 75% AIP reduction. Refer to Appendix F. Record of Treatment Intervals for details regarding the timing of the UVC, DASH, and BB treatments. The Group B site locations are shown in Figures 3-7 and 3-8. Examples of Group B treatments are provided below in Section 3.3.

The herbicides Endothall and Triclopyr were selected for testing because they have been widely used for several decades in similar mid- to high elevation lakes in the western United States to manage the target AIP in similar habitats. These herbicides were approved for this type of use by the U.S. EPA and California Environmental Protection Agency (CalEPA) over 40 years ago and they have been reviewed and re-registered periodically as required by US EPA.

These herbicides have little to no effect on Elodea (*Elodea canadensis*), a beneficial native plant at Lake Tahoe. Triclopyr is highly selective for controlling Eurasian watermilfoil, but does not affect Coontail. (Note that Curlyleaf pondweed is not listed as a plant controlled by Triclopyr on the current product labeling. However, the data generated in the CMT strongly suggests that Triclopyr provided excellent control of Curlyleaf pondweed.) Endothall controls all three target AIP. Triclopyr was included in the CMT because this herbicide moves from exposed shoots and leaves of Eurasian watermilfoil into the plant's roots and rhizomes, which can result in long-term control. In contrast, Endothall primarily only affects the above-ground plant parts directly exposed to the herbicide. The data for these observations are provided in the Annual Efficacy Reports (See Appendix A).

In addition to the selectivity of these herbicides, their projected "half-life" (based on published records) of a few days for Endothall and 7 to 10 days for Triclopyr suggested that their effective concentrations (dose) would be limited in time, but with adequate contact time to control the target AIP. As indicated in this report, the half-life was much longer than the projected half-life. In addition to the predicted relatively short half-life of these herbicides' active ingredients, the installation of double-curtain barriers at strategic locations were designed to further ensure that the herbicides would not reach Lake Tahoe (See Section 3.4).

Group A methods (including herbicides, LFA and UVC) have limitations and potential/known environmental impacts that affect some native plants, release nutrients following degradation of targeted AIP, and potentially stimulate algal growth, including cyanobacteria, which can result in HABs (Table 3-1). However, proper use of these methods, and adherence to EPA and Cal/EPA aquatic herbicide labeling, coupled with proper training of applicators, can minimize the likelihood of adverse effects.

Table 3-1. Summary of Group A Methods Use and Limitations

	UVC	LFA	Herbicides
Habitat	Best efficacy and efficiency in Mid-channel, open areas; very poor efficiency and lack of access in near-shore zones	Mid-channel areas; not suitable for shallow, near-shore zones due to potential dislodging by boats and swimmers	Use in mid-channel or near-shore zones equally well.
Selectivity	Non-selective, but some submersed plants may be less sensitive to UVC	May affect algae but does not affect or reduce AIP	Depends on herbicide used; Endothall and Triclopyr are selective for control of AIP in the Keys lagoons.
Frequency of Use	Three to-four-week intervals (shorter intervals are better) Used during entire AIP growing season.	Continuously in use all year.	One time in spring and possibly one time in fall. Each herbicide application takes 1 to 2 days.
Potential Water Quality Effects	Nutrient release from decomposing AIP. Potential brief increase in turbidity near UVC lamp arrays.	Usually improves dissolved oxygen levels and mixes water column.	Release of nutrients from decomposing plants; spills or potential movement from treatment areas
Aesthetic and Social Acceptance	Generally good; potential navigational interference.	Air compressor noise requires expensive acoustic shielding	May restrain vessel movement during applications; may require closing areas during applications
Monitoring Actions	Turbidity during operation; post-treatment nutrient sampling; dissolved oxygen.	Maintenance of air compressor and diffusion systems.	Herbicide active ingredient levels; nutrient sampling post-application; dissolved oxygen
Permits or Approvals Required	TKPOA, Vessel Registration	TKPOA, ACOE	NPDES (Lahontan), TRPA, Certified Applicator, Certified analytical laboratory, Vessel registration.

3.3 Group B (Non-Herbicide) Follow-up Methods

Non-herbicide AIP control methods were incorporated in the CMT to determine if successful reduction in AIP abundance achieved by the one-time (Year 1) herbicide applications or by UVC or LFA could be sustained in the following two years. Four Group B methods were chosen to assess effectiveness and applicability to the scale of the CMT test sites (Table 3-2).

The four Group B methods have limitations and potential or known environmental impacts including practical scale (infestation size) or area (e.g., below docks) of use, and potential detrimental effects on water quality, desirable native plants (such as *Elodea canadensis*), and the benthic environment (Table 3-2). As with Group A methods, Group B methods were replicated in several sites to obtain data on their ability to control targeted AIP in both near-shore zones and mid-channel areas. As part of the adaptive design of the CMT, Group B methods could be adjusted in size, type and location based on monitoring of AIP populations. Detailed descriptions of these methods are described in the Quality Assurance Project Plan (QAPP) (See Appendix A).

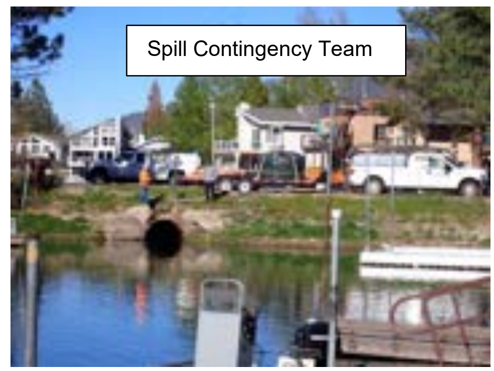
Table 3-2. Summary of Group B Methods Use and Limitations

	Diver Assisted Suction Harvesting (DASH)	Bottom Barrier	Spot-UVC	Sequential (post-barrier removal DASH or UVC)
Habitat	Near-shore zones and some mid-channel areas	Near-shore zones and some mid-channel areas	Mid-Channel areas; some accessible near-shore zones	Locations where Bottom Barrier were placed and removed
Selectivity	Partially: Best when visibility is good.	No selectivity: Usually kills plants beneath the barrier may kill or harm invertebrates beneath barrier	No selectivity: Usually kill plants that are exposed to the UVC	DASH: Yes, if visibility is good. UVC: No selectivity.
Frequency of Use	Two-to-four-week intervals (shorter intervals are better)	Usually, one time installation in Spring and removal in fall	Two-to-four-week intervals	One or two times after Bottom Barrier Removal
Potential Water Quality Effects	Turbidity, benthic organisms, AIP fragment releases	Reduced or zero DO beneath the barrier, temporarily removes habitat for benthic organisms.	Release of nutrients from decomposing plants; detrimental to desirable native plants.	DASH: AIP fragment release; UVC: Release of nutrients from decomposing plants
Aesthetic and Social Acceptance	Generally good; requires safety precautions for divers and signage and security	Transient interference with near-shore zone use during installation and removal	May disrupt vessel access periodically	Limited effects due to short duration of activity and declining recreational
Monitoring Actions	Turbidity, capture of AIP fragment; rake sampling for efficacy	Integrity of barriers, post-removal turbidity, macrophyte efficacy	Turbidity, Nutrients, macrophyte efficacy	DASH: Turbidity and Macrophyte efficacy UV: Nutrients and
Permitting or Approval Required	TKPOA, Divers Certifications, Vessel Registration	TKPOA, WDR's; Diver Certifications; maximum 5 acres.	TKPOA, Vessel Registrations	TKPOA, Diver Certifications, Vessel Registration

3.4 Mitigation Designs and Actions

To ensure that no herbicide or herbicide degradant was able to reach Lake Tahoe, strategically placed double-turbidity curtains were installed to restrict water flow from treated areas toward the main open water area in the West Lagoon and toward the West Channel (see Figure 3-4). The curtains effectively partitioned the West Lagoon into two boating “excluded” areas A and B, and one boating excluded area in the Lake Tallac Lagoon area C (Figure 3-4). The plan was to remove the curtains about a month after herbicides were applied, depending on monitoring results. For reasons discussed in the Results (Section 5), curtains remained in place until late September.
In addition to turbidity curtains, and as another precaution to prevent herbicides from entering Lake Tahoe, applications were only made during net lake level rise with inward flow of water from Lake Tahoe through the West Channel into the West Lagoon. Snowmelt runoff from streams feeding Lake Tahoe (CNRFC 2022) and net flow of water from Lake Tahoe into the Keys through the West Channel was monitored to ensure net flow occurred when herbicides were applied. (Appendix A)

During herbicide applications, a Spill Response Team was deployed near each of the application sites to contain cleanup of any possible spills. *Note: No spills occurred during any of the herbicide applications.* To mitigate observed declines in DO, contingency aeration systems were deployed in each herbicide application site (see Appendix A). As determined from DO monitoring, limited (transient) instances of depressed DO occurred during the herbicide applications, but substantial reductions in DO were measured from one to three months following the herbicide applications. Data suggested that this was the result of limited mixing of the lagoons, increased summer temperatures, and seasonal plant senescence typical in the lagoons (See Appendix G. Dissolved Oxygen Evaluation Report). This pattern of mid- to late-season drops in DO in the lagoons was also documented in the years preceding and following the herbicide applications, as well as in areas where no herbicide applications or other CMT treatments occurred (See Section 5.2).



3.5 Ensuring Objective and Reliable Data Collection and Analysis

Errors in data collection and analysis, or “false” readings from instrumentation are not uncommon in complex, multiyear field projects such as the CMT. However, the CMT design and the permitting compliance requirements together minimized the potential for these occurrences through careful instrument calibrations, records of field activity, data recording, reviews of monitoring data and actions, a Quality Assurance Project Plan (QAPP), and the use of “Chain of Custody” (COC) forms for all samples sent for laboratory analysis. These actions ensured the integrity of the CMT monitoring program. Only certified/licensed Laboratories, laboratories approved by the Lahontan Water Board and TRPA, were contracted to conduct analyses for nutrients, herbicides (and their degradants), and HAB-forming cyanobacteria and cyanotoxins. The annual reporting was reviewed by multiple agencies and project partners including TKPOA, TRPA, The League, and individual contractors.

The CMT also incorporated several actions to help ensure consistent data collection, data interpretation, and conclusions. With the range of habitats in the Tahoe Keys lagoons, the variation in AIP populations, and the year-to-year changes in water levels and other environmental conditions, the CMT was designed as an adaptive test approach to allow for necessary adjustments over the three-year project (2022-2024). The methods tested were replicated at three sites for each Group A method and at least 3 areas for each Group B method. Locations were selected to provide representative conditions of AIP presence and abundance. Replicated untreated “reference” Control sites were established and monitored to compare untreated AIP areas with areas treated by CMT methods (see Figure 3-5). The control sites also provided valuable information on seasonal changes in AIP and on their response to changes in water depths.

The emphasis on objectivity in data collection for efficacy, herbicides, nutrients, and water quality is reflected by the use of independent contractors to monitor the level and movement of herbicides (and their degradation products), conduct nutrient sampling and the physical rake sampling and assessments of CMT method efficacy, and collect continuous data on DO and temperature with data loggers (See Section 4.0).

3.6 Implementation of CMT Methods

The testing of the various methods required a broad range of contractors and logistical coordination with the monitoring entities. The Lahontan and TRPA EIR/EIS and permits specified timing and frequencies for mitigation, monitoring, and reporting of each of the test methods. Presented below are summaries for Group A and Group B methods.

3.6.1 Group A Herbicide Applications and Mitigations

The CMT sites for the one-time herbicide applications, UV Only treatments, and continuous LFA operations were selected to represent the range of AIP populations and habitat types from open water areas to “dead-end” coves within the West Lagoon. Endothall was also applied in a single site in Lake Tallac within an area excluded by a double turbidity curtain barrier to assess its effectiveness in this stormwater basin setting. The locations of Group A Endothall and Triclopyr herbicide application sites are shown in Figure 3-4 and summarized in Table 3-2.

Herbicide applications were made as permitted beginning on May 25, 2022. Applications were “staggered” every other day to ensure proper water quality and herbicide monitoring was conducted (i.e., no herbicides were applied on May 26, 28, or 30, 2022).

The key mitigation action for herbicide application was installation of double turbidity curtains to restrict the potential movement of herbicides from the West Lagoon toward Lake Tahoe and away from the treatment area in the Lake Tallac Lagoon. The curtains in the West Lagoon were also delineated with physical barriers (“Boating Restricted” areas) to minimize vessel traffic (Figure 3-4). A temporary boat ramp was installed in “Area B” and other access points were added in the West Lagoon to provide launch points that enabled monitoring crews and their boats safe unobstructed routes to monitoring locations. Other adjustments were made in response to extreme winds partially dislodging two sets of double turbidity curtains within a few days after herbicide applications. An additional set of curtains was installed adjacent to one location, and reinforcement of the second curtain anchorage was completed. These events are further described in the CMT Year 1 Annual Report (Appendix A). Appendix D of this report evaluates the limited transient effects of the herbicide movement that temporarily extended beyond the curtain boundaries.

Over the course of the CMT, adjustments were made to all methods to accommodate changes in the conditions of the Tahoe Keys West Lagoon and Lake Tallac Lagoon. Another major adjustment was extending the deployment of turbidity curtains to over three months due to longer than expected degradation times for Triclopyr to reach non-detect levels. Typically, Triclopyr has a half-life of 7 to 10 days and is degraded by light (photodegradation). However, due to increased turbidity in Triclopyr-treated sites, photodegradation was impeded which prolonged the time needed to reach non-detect levels (1 part per billion) to over 100 days. In compliance with the NPDES permit, curtains were left in place until neither Endothall nor Triclopyr were detectable in the water.

Homeowners were notified of activities through a variety of methods including individual emails, door hanger' notices, and signage posted throughout common areas. The planned Spill Response Team completed the Rapid Response preparedness plan and deployed response equipment during all herbicide applications. No spills occurred. Aeration devices were activated in each CMT/Herbicide site from June 27th to July 7th in 2022 to mitigate depressed DO in the lagoons.

Table 3-2. Summary of One-time Herbicide Applications (Year 1, 2022).

Site Number	Treatment	Herbicide	Herbicide Rate (final concentration)	Application Date	Application Day
8	Herbicide only	Triclopyr	1.0 ppm	5/25/22	1
9	Herbicide only	Triclopyr	1.0 ppm	5/25/22	1
15	Combination	Endothall	2.0 ppm	5/25/22	1
No Applications				**5/26/22**	
1	Herbicide only	Endothall	2.0 ppm	5/27/22	2
2	Herbicide only	Endothall	2.0 ppm	5/27/22	2
3	Herbicide only	Endothall	2.0 ppm	5/27/22	2
No Applications				**5/28/22**	
5	Herbicide only	Triclopyr	1.0 ppm	5/29/22	3
10	Combination	Endothall	2.0 ppm	5/29/22	3
11	Combination	Endothall	2.0 ppm	5/29/22	3
No Applications				**5/30/22**	
12	Combination	Triclopyr	1.0 ppm	5/31/22	4
13	Combination	Triclopyr	1.0 ppm	5/31/22	4
14	Combination	Triclopyr	1.0 ppm	5/31/22	4
19 (Lake Tallac)	Herbicide only	Endothall	2.0 ppm	5/31/22	4

(Source: TKPOA APAP Amendment 2 dated May 24, 2022 and Aquatechnex Report) *Note: All applications were done in concert with the injection of Rhodamine WT tracer dye (<10 ppb), which was monitored using a flow-through fluorometer to detect potential movement of herbicides. (Appendix A for access to this report.)

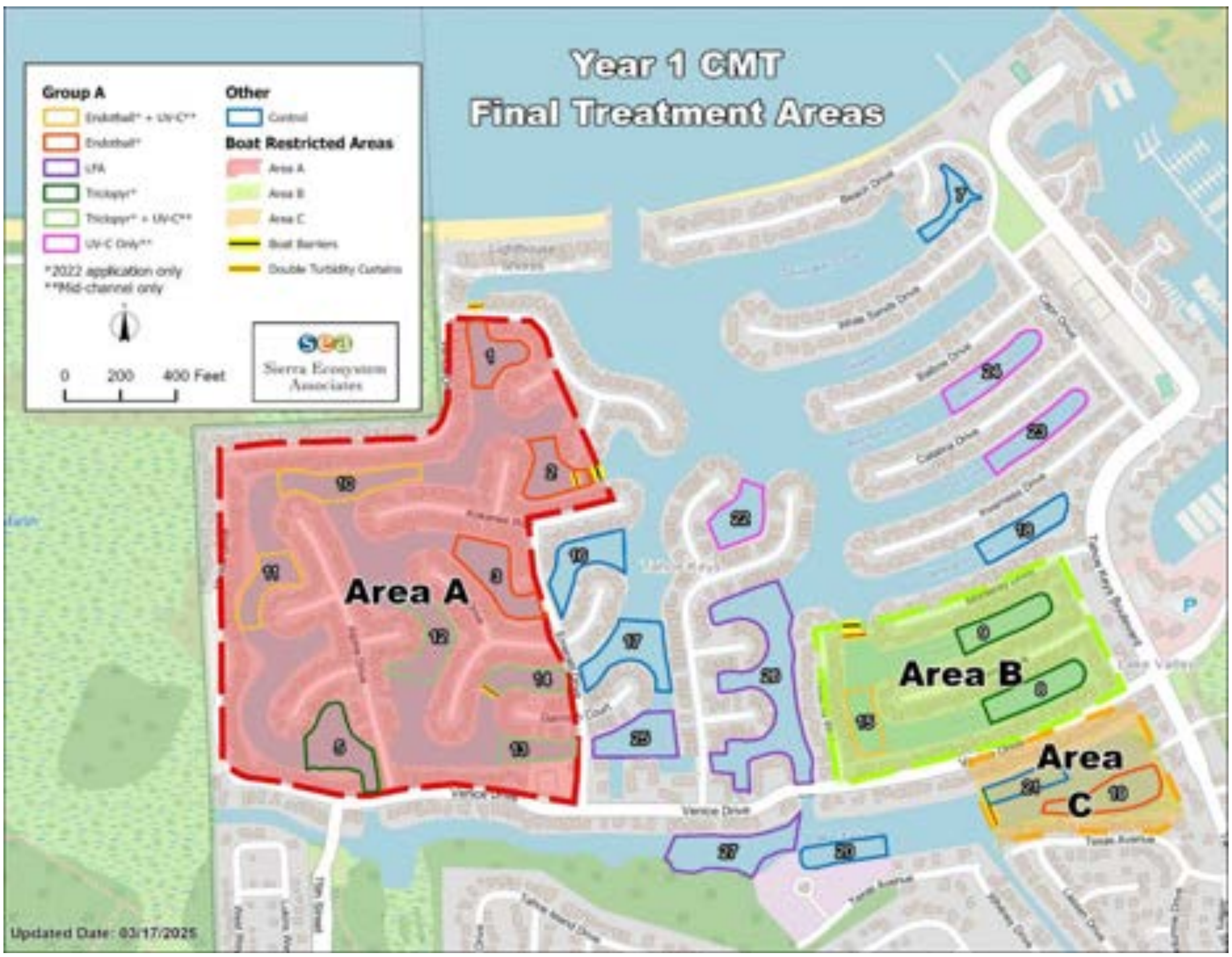


Figure 3-4. Boating restricted areas (A, B, C) during deployment of turbidity curtains. Note: At Sites 1, 3, 13, and 14, culvert plugs were installed to prevent water movement in or out of the Sites into untreated areas or toward Lake Tahoe.

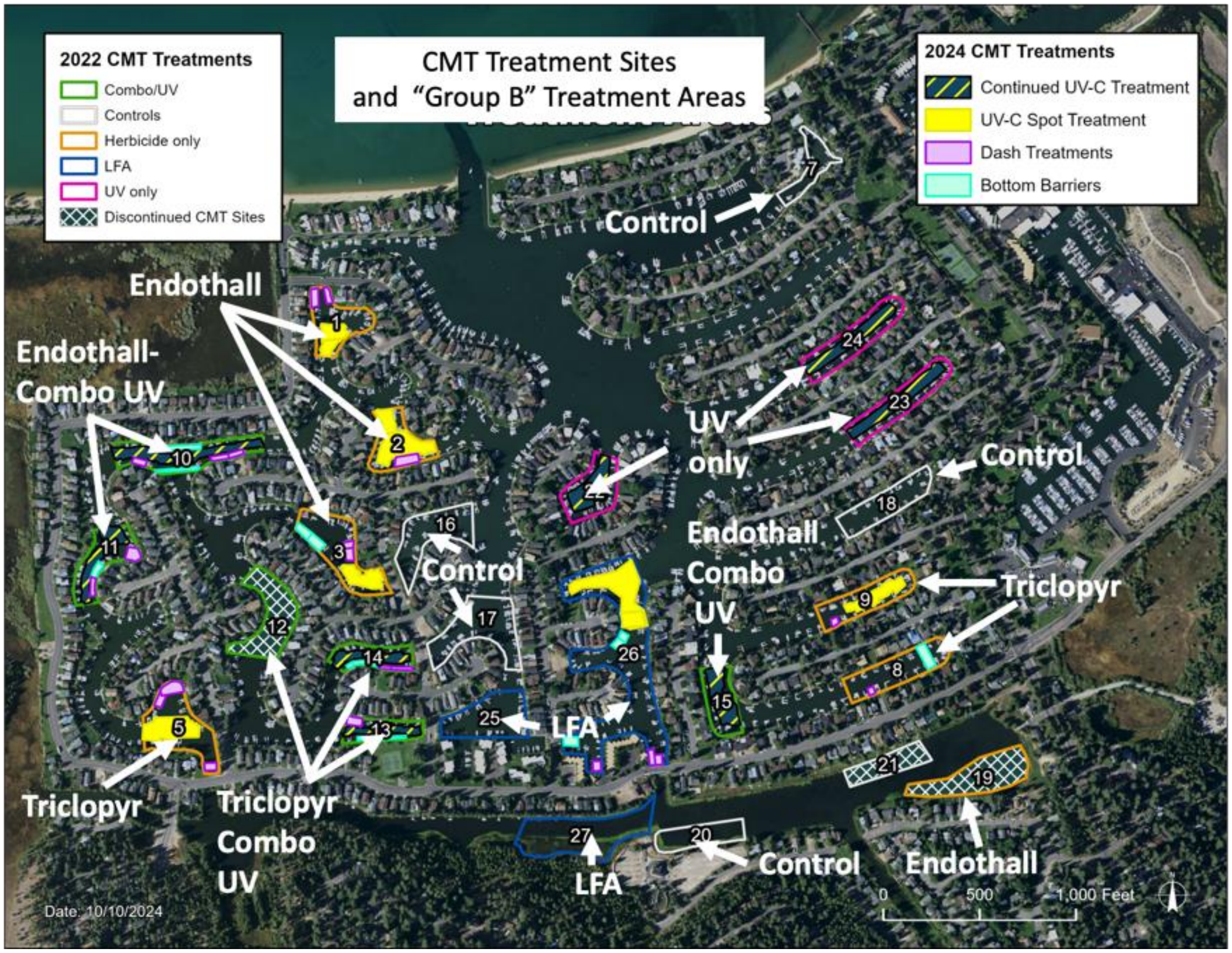


Figure 3-5. Site Locations of Group A Methods: Herbicides, UVC Only, LFA, and untreated reference Control sites.

3.6.2 Group A UVC , LFA, and Group B Spot-UV Treatments

Two vessels, equipped with arrays of UVC LED lamps, were used to expose target AIP with UVC light. One boat was 16 feet wide by 20 feet long and the second was 16 feet wide by 40 feet long. In Year 1, treatments were applied in 15-minute increments. In Year 2, the duration of UV treatments varied from 5 to 10 minutes. Year 3 treatments were refined to improve coverage and treatment efficiencies by increasing the frequency of re-treatments to every 3 to 4 weeks

The lack of access to near-shore zones restricted the UVC treatments to mid-channel areas only (i.e., for UVC Only Sites 22, 23, and 24, and UVC Combination Sites 10, 11, 12, 13, 14 and 15) (Figure 3-5). In Years 2 and 3, the duration and overlap coverage of UVC treatments were improved. For UVC Combination sites and Spot-UV treatments, UVC was used at 3- to 4-week intervals. The detailed polygons showing all UVC treatments are available in Appendix A (IRI UV Report). Examples of UVC Only (Site 22), UVC Combination (Site 13), and Spot-UV (Site 1) treatments are shown in Figure 3-6. The implementation methodologies for UVC treatments varied as operator experience and results informed future treatments to improve efficacy.

LFA systems consisted of shore-mounted compressors used to inject air under pressure through air lines to diffusers anchored to the bottom of the lagoons. The ejected small air bubbles passing from the diffusers have two main effects on the conditions of the water column: increased DO and increased vertical mixing. These changes in conditions are thought to substantially facilitate the degradation of loose, bottom organic material as well as reduce the availability of nutrients in the water column, which in turn may reduce the production of cyanobacteria that can produce HABs. A record of the cyanotoxins and cyanobacteria detected during the CMT can be found in Appendix H. Cyanobacteria and Cyanotoxin Record. There have also been claims that LFA, by affecting nutrient availability, can also lead to the reduction of AIP biomass. LFA systems were installed in two sites in the West Lagoon (Sites 25 and 26) and one site in Lake Tallac (Site 27) to determine if they measurably affected organic bottom materials, nutrients or AIP (Figure 3-5). Monitoring for LFA effects is described in Section 4.3, and in Appendix A (QAPP).

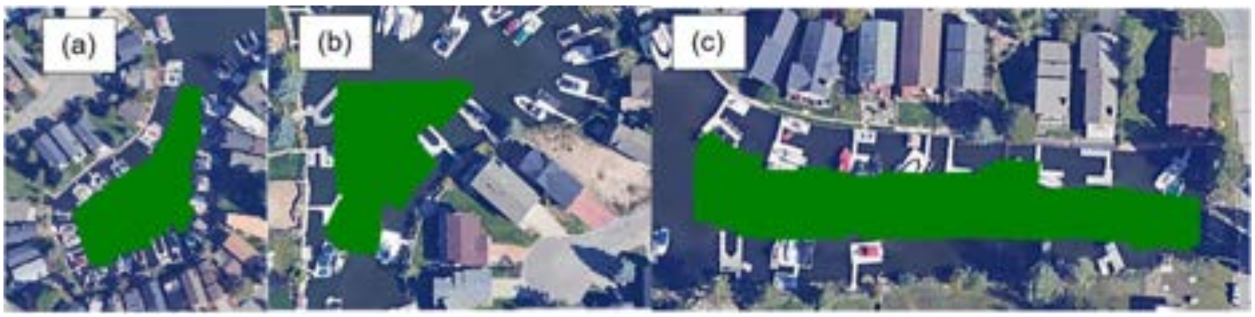


Figure 3-6. Example of UVC Treatment areas; (a) UVC Only (Site 22), (b) Spot-UV treatment (Site1), (c) UVC Combination (Site 13). Note that the near-shore zone areas did not receive UVC treatments.

3.6.3 Group B DASH Implementation

This method relies on divers' ability to identify AIP and dislodge the plants from the bottom materials and guide the removed plants to a suction hose. The hose draws the plants to an on-board or floating mesh (net) bag that retains the intact plants and plant fragments. Periodically the bag is emptied into a large pail and disposed off-site. Since the bottom is disturbed, monitoring of turbidity is required, and DASH stops if turbidity rises higher than 10% of starting levels.

The efficiency and efficacy of DASH is affected by both water clarity (diver visibility) and density of the AIP plants: clear water and sparse plant densities are optimal. However, those ideal conditions are not common in the Tahoe Keys lagoons. For this reason, DASH efficacy may vary considerably by season (with typical changes in turbidity) and may also be affected by the repeat frequency. More frequent DASH should result in progressively more efficient AIP removal since less time is available for plants to re-grow, or for plants from adjacent untreated areas to move into diver-cleared areas. An advantage of DASH is the removal of reproductive structures such as the turion produced in spring by Curlyleaf pondweed. For example, counting the DASH-removed turions in Year 3 showed that Curlyleaf pondweed produces hundreds of thousands of these reproductive propagules per acre. (See Section 11.2).

3.6.4 Bottom Barrier Implementation

Bottom Barriers are used to completely block light, oxygen and rooting habitat for AIP such as Eurasian watermilfoil and Curlyleaf pondweed. Note that Bottom Barriers are not expected to exclude Coontail because this plant does not have roots and can freely grow and move with wind and currents in the water above or next to the bottom. Table 3-4 summarizes the deployments of Bottom Barriers during Years 2 and 3. Details of Bottom Barrier effectiveness are also in prior annual reports and supplemental reports (Appendix A Bottom Barrier Supplement Reports Year 2 and 3).

The locations of 2022 Group A treatment sites are shown in Figures 3-5, 3-7 and 3-8. Locations of Group B sites and treatments are shown below in Figures 3-7 and 3-8 for Years 2 and 3, respectively.

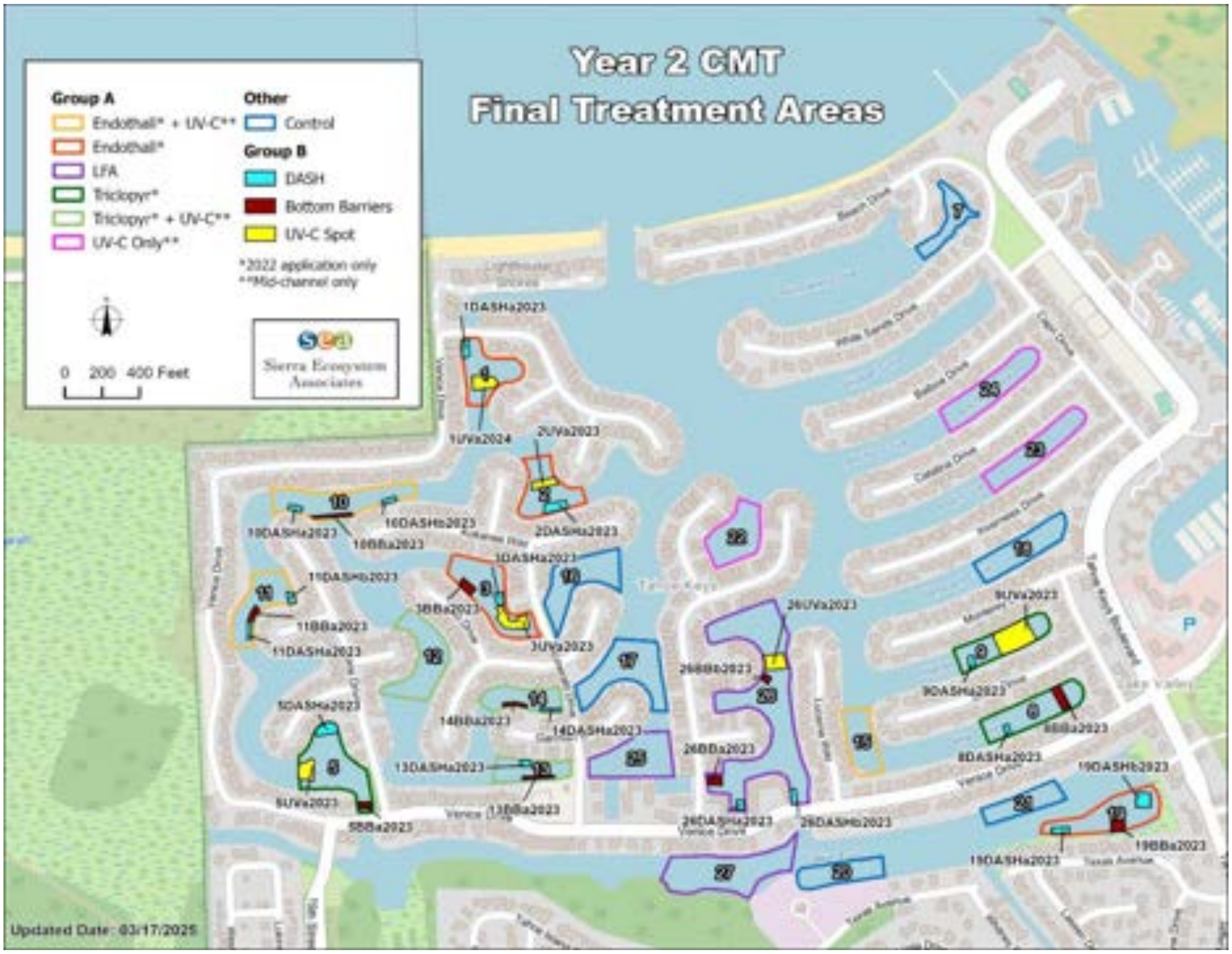


Figure 3-7. CMT Group B areas in Year 2 (2023). Note the map also shows Year 1 (2022) Herbicide applications sites and UVC Only sites

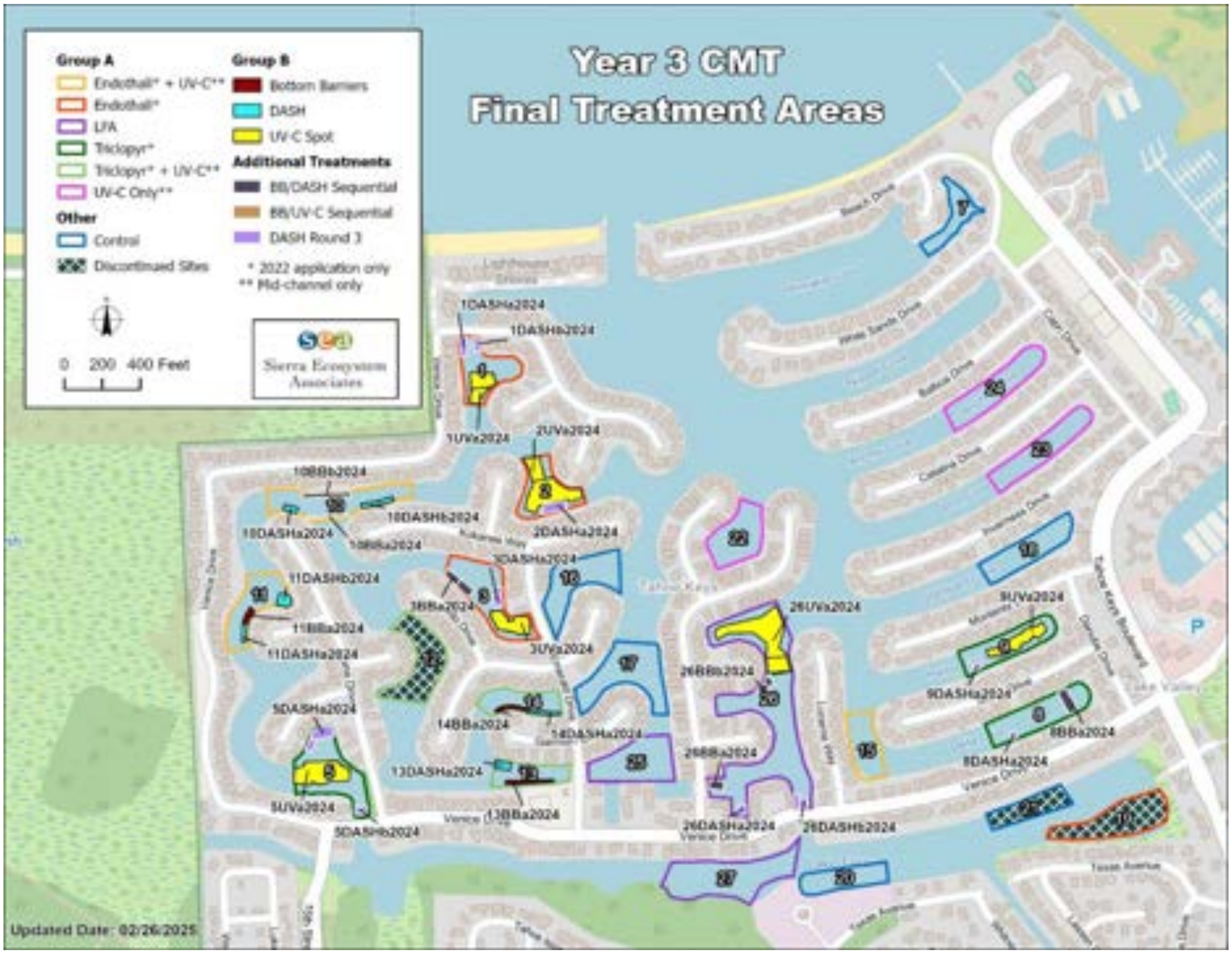


Figure 3-8. CMT Group B areas in Year 3 (2024). Note the map also shows Year 1 (2022) Herbicide applications sites and UVC Only sites

3.7 Summary of CMT Methods Implementation

Group A methods were used in Year 1 followed by Group B methods in Years 2 and 3, and non-herbicide Group A methods (LFA and UVC Only) were continued into Years 2 and 3. Originally, Group A UVC Only treatments (Sites 22, 23 and 24) were limited to the initial year (2022), but were then added as continuing non-herbicide Group A methods in Years 2 and 3. Table 3-3 provides an overall summary of “as treated” Group A and B methods for the CMT project. Table 3-4 provides details of all the Group A sites, methods employed, and size of each treatment. As part of the CMT adaptive approach, in Year 3 additional DASH and Spot-UV treatments were made after the removal of the BBs in some sites (Table 3-3 and Table 3-5). These treatments were intended to stop the AIP re-infestation of areas previously covered by barriers.

Note that herbicide application areas for Combination sites included only the near-shore zones, not the entire site. The Group B methods implementation summary in Table 3-5 shows adjustments to sites and sizes of sites made between Years 2 and 3, and shows that 6 sites were used for the adaptive management sequential (Post BB removal) DASH or UVC treatments.

Table 3-3. Summary of CMT Group A and Group B Methods

Group A and B Methods	**Year 1**	**Year 2***	**Year 3**
Total Group A Acreage	32.97	16.90	18.37
Total Group B Acreage	0.00	3.43	6.05
Total Sequential Treatment Acreage	0.00	0.00	0.70
Total CMT Treatment Acreage	**32.97**	**20.33**	**25.12**

*Note: Reduction of Group A acreage in Years 2 and 3 is because no Group A herbicide methods were used in Year 2 or Year 3.

Table 3-4. Summary of CMT Group A methods (Years 1, 2, and 3)

CMT Treatments	CMT Site	Total CMT Site Sq. ft. (APAP 1)	Year 1 Sq. ft.	Year 2 Sq. ft.	Year 3 Sq. ft.
Group A Treatments					
Control (No treatments)	16	78,408	78,408	78,408	78,408
	17	95,832	95,832	95,832	95,832
	18	65,340	65,340	65,340	65,340
	20	43,560	43,560	43,560	43,560
	21*	43,560	43,560	-	-
Total Control Square Footage		326,700	326,700	283,140	283,140
Total Control Acreage		7.5	7.5	6.5	6.5
Endothall Only	1	65,340	65,340	-	-
	2	65,340	65,340	-	-
	3	91,476	91,476	-	-
	19	87,120	87,120	-	-
Total Endothall Only Square Footage		309,276	309,276	0	0
Total Endothall Only Acreage		7.1	7.1	0	0
Endothall Combination (Shoreline only)	10	87,120	30,492	-	-
	11	69,696	21,780	-	-
	15	52,272	17,424	-	-
Total Endothall Combo Square Footage		209,088	69,696	0	0
Total Endothall Combo Acreage		4.8	1.6	0	0
Total Endothall Treatment Acreage		**11.9**	**8.7**	**0**	**0**
Triclopyr Only	5	95,832	95,832	-	-
	8	69,696	69,696	-	-
	9	65,340	65,340	-	-
Total Triclopyr Only Square Footage		230,868	230,868	0	0
Total Triclopyr Only Acreage		5.3	5.3	0	0
Triclopyr Combination (Shoreline only)	12	82,764	30,492	-	-
	13	43,560	21,780	-	-
	14	43,560	13,068	-	-
Total Triclopyr Combo Square Footage		169,884	65,340	0	0
Total Triclopyr Combo Acreage		3.9	1.5	0	0
Total Triclopyr Treatment Acreage		**9.2**	**6.8**	**0**	**0**
UV-C Combination (Mid-channel only)**	10	87,120	39,204	39,204	40,349
	11	69,696	29,620	29,620	30,259
	13	43,560	-	21,780	17,095
	14	43,560	-	17,424	20,204
	15	52,272	28,255	-	28,255
Total UV-C Combo Square Footage		296,208	97,079	108,028	136,162
Total UV-C Combo Acreage		6.8	2.23	2.48	3.13
UVC Only (Mid-channel Only)***	22	65,340	32,349	32,349	32,349
	23	69,696	35,860	-	35,860
	24	78,408	33,992	33,992	33,992
Total UV-C Only Square Footage		213,444	102,201	66,341	102,201
Total UV-C Only Acreage		4.90	2.35	1.52	2.35
LFA	25	178,596	178,596	178,596	178,596
	26	265,716	265,716	265,716	265,716
	27	117,612	117,612	117,612	117,612
Total LFA Square Footage		561,924	561,924	561,924	561,924
Total LFA Acreage		**12.9**	**12.90**	**12.90**	**12.90**

*Site 21 was eliminated as a Lake Tallac Control Site due to the movement of Endothall into that site.
**Assumed Years 1 and 2 UVC Only square footage based on calculations in Year 3.
***Assumed Year 1 UVC Combination square footage based on calculations in Years 2 and 3.

Table 3-5. Summary of Group B Treatments and Sites (Years 2 and 3).

CMT Treatments	CMT Site	Total CMT Site Sq. ft. (APAP 1)	Year 1 Sq. ft.	Year 2 Sq. ft.	Year 3 Sq. ft.
Group B Treatments					
Bottom Barriers (BB)	3a	91,476	-	4,078	7,439
	5a	95,832	-	2,305	-
	8a	69,696	-	6,305	6,305
	9a	65,340	-	-	-
	10a	87,120	-	3,068	3,067
	10b	See above	-	-	6,006
	11a	69,696	-	2,538	2,538
	13a	43,560	-	2,489	4,022
	14a	43,560	-	2,343	3,018
	19a	87,120	-	4,418	-
	26a	265,716	-	3,614	3,614
	26b	See above	-	1,770	3,975
Total Bottom Barriers Square Footage		919,116	0	32,928	39,984
Total Bottom Barrier Acreage		21.10	0.00	0.76	0.92
DASH	1a	65,340	-	3,566	3,566
	1b	See above	-	-	2,407
	2a	65,340	-	5,770	5,770
	3a	91,476	-	2,897	4,844
	5a	95,832	-	6,205	8,746
	5b	See above	-	-	2,444
	8a	69,696	-	1,775	1,247
	9a	65,340	-	2,327	1,466
	10a	87,120	-	2,259	2,259
	10b	See above	-	1,995	4,146
	11a	69,696	-	2,314	2,314
	11b	See above	-	2,316	4,474
	13a	43,560	-	1,889	3,473
	14a	43,560	-	1,816	2,791
	19a	87,120	-	3,048	-
	19b	See above	-	6,100	-
	26a	265,716	-	2,171	2,171
	26b	See above	-	2,393	4,420
Total DASH Square Footage		1,049,796	0	48,841	56,538
Total DASH Acreage		24.10	0.00	1.12	1.30
Spot-UV	1a	65,340	-	8,874	13,702
	2a	65,340	-	5,426	39,045
	3a	91,476	-	10,829	16,475
	5a	95,832	-	7,707	29,558
	9a	65,340	-	25,560	18,256
	26a	265,716	-	9,028	49,851
Total UV-C Spot Square Footage		649,044	0	67,424	166,887
Total UV-C Spot Acreage		14.90	0.00	1.55	3.83
Sequential Group B Treatments					
BB then Spot-UV	8a	69,696	-	-	6,305
	10a	87,120	-	-	3,067
Total BB then UV Square Footage		156,816	0	0	9,372
Total BB then UV Acreage		3.60	0.00	0.00	0.22
BB then DASH	3a	91,476	-	-	7,439
	10b	87,120	-	-	6,006
	26a	265,716	-	-	3,614
	26b	See above	-	-	3,975
Total BB then DASH Square Footage		444,312	0	0	21,034
Total BB then DASH Acreage		10.20	0.00	0.00	0.48

4.0 MONITORING PROGRAM

The CMT included extensive environmental monitoring consistent with Lahontan Water Board and TRPA permits. Details of the monitoring requirements are in the Aquatic Pesticide Application Plan (APAP), Mitigation Monitoring and Reporting Program (MMRP), and the Monitoring and Reporting Program (MRP). (See Appendix A). Tables 4-1 and 4-2 summarize the monitoring methods, what entity was responsible for each monitoring activity, and the number of data points generated over the CMT project period.

For the CMT, monitoring completeness ranged from 90 to 98% depending on the year. The reasons for most gaps in monitoring were loss (e.g., boat encounter or dislodging and destructive bear behavior) or malfunction of the loggers that recorded hourly DO and temperature. In some instances, gaps in data could be filled by the data from weekly mid-depth water quality monitoring using a hand-held sonde device. The locations of monitoring stations and types of monitoring are summarized in Figure 4-1. The following sections briefly describe key monitoring methods.

Figure 4-1. CMT monitoring station locations for Year 1 Group A Sites (Herbicides, UVC Only and LFA). Yellow dots indicate water quality monitoring stations. Red dots are nutrient sampling stations. The double yellow/red line indicates double turbidity curtains.

4.1 Herbicide and Herbicide Degradants (Endothall and Triclopyr)

High frequency replicated sampling of water inside and adjacent to herbicide applications was conducted by independent contractors (Table 4-2). Rhodamine Water Tracer (RWT) Dye was applied with each herbicide application and the dye movement and concentrations could be monitored in real-time using hand-held meters. Water samples were taken before and after herbicide applications within each herbicide site (see Table 4-1). In addition, If RWT was detected outside of an application site, or if RWT was detected outside a containment curtain, then water samples were taken for laboratory herbicide analysis.

Monitoring for RWT continued for extended time periods when RWT was detected, and further water samples were then taken for herbicide analysis. Water samples were taken and herbicide concentrations were analyzed until a “non-detect” level resulted from two consecutive samples taken 24 hours apart. A complete report of Year 1 herbicide monitoring is available in Appendix A (Sediment Monitoring Report).

4.2 Water Quality Monitoring

Standard, calibrated hand-held data sonde equipment was used to obtain mid-depth water turbidity, temperature, DO, specific conductivity, pH, and oxidation reduction potential (ORP). (See Table 4-1 for frequency of sampling). In addition to the sonde equipment, TKPOA deployed anchored, recording DO and temperature loggers near the surface and bottom of each CMT site. Loggers were downloaded weekly by a TRPA contractor, and, from that data, weekly average DO and temperatures were generated, stored as Excel files, and used to develop graphical summaries (Table 4-1).

TKPOA crew conducting water quality measurements

4.3 LFA/Bottom Organic Materials

Twice annually, the effects of LFA on bottom organic sediment were assessed. Methods to assess changes in organic sediment were expanded in Year 1 to include mesh bags containing a blended, measured volume of organic sediment that was then analyzed in Years 2 and 3 for changes in volume and nutrients based on laboratory analyses. The final sampling of mesh bags will be in spring, 2025 and a supplemental report will summarize results. The monitoring methods were as follows:

(a) The depth of organic sediment that accumulated on metal plates fixed to the bottom of the lagoons was measured by a diver.
(b) Staff gauges attached to dock pylons provided a fixed baseline for divers to measure changes in the depth of bottom sediments.
(c) Replicated mesh bags filled with uniformly composited and weighed bottom materials were placed on anchors near the bottom. Replicate bags from each site were removed in spring and fall of 2023 and 2024 and spring of 2025. Contents of the bags were sent to a laboratory for analysis of percent organic matter, TN and TP. The intent of this method was to determine if exposure to LFA conditions affected organic content or nutrient levels.

4.4 Macrophyte (AIP) Abundance and Species Occurrence Monitoring

Determining the effectiveness of the Group A and Group B methods was one of the most important monitoring components of the CMT. How these methods affected each AIP species and desirable native species - and under what conditions - provides critically important information to support the development of successful lagoon-wide management. Two well-established methods were used to derive metrics that accounted for both the abundance of AIP and how each species responded to the Group A and Group B methods: rake sampling and hydroacoustic scanning.

4.4.1 Rake Sampling

Rake sampling requires a plant survey crew to 1) conduct the sampling, 2) identify and record the species found and their relative abundance on the rake, 3) note the condition of plants (plant "health"), and 4) rank the overall number of plants on the rake, called "Rake Fullness" (See Appendix I. Macrophyte Sampling Metrics). Each rake sample location was georeferenced and the water depth at the sampling point was recorded (Figure 4-2). When present, in Year 3, the number of Curlyleaf pondweed turions were counted and the length of shoots from sprouted turions were also measured and recorded. Typically, 30 rake samples were taken in each CMT site every two weeks (about 30 samples per acre).

Approximately 10-12 samples were taken in near-shore zones, and 16 to 20 samples were taken in mid-channel CMT areas. For each year of the CMT, over 7,000 rake samples were taken and each sample produced five data points (Table 4-2). The high frequency and intensity of AIP rake surveys provided a critically important basis for evaluating effects of Group A and Group B methods and assisted with selecting locations for the Group B target areas. The rake sampling and counts of Curlyleaf pondweed turions were critically important because turion production and turion dispersal drive the reinfestation of CMT treatment areas and continuing expansion of Curlyleaf pondweed both in the Tahoe Keys lagoons, and in Lake Tahoe. (See Section 10.0)

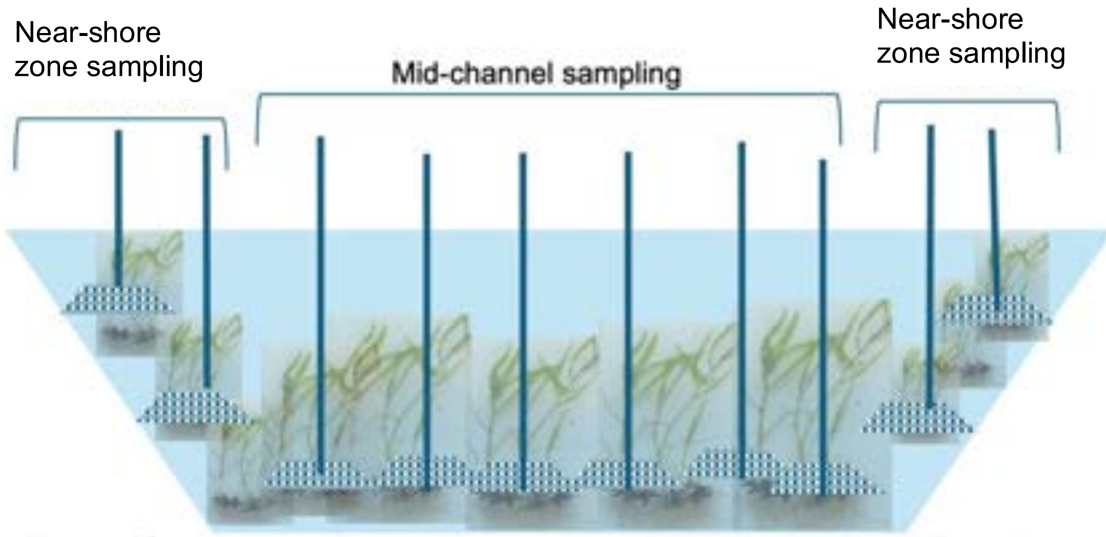


Figure 4-2. Depiction of macrophyte survey rake sampling in near-shore zone and mid-channel areas.

4.4.2 Hydroacoustic Scanning

This method relies on the use of a specialized "sonar" device (a "transponder") that sends high frequency sound impulses downward through the water from a boat-mounted "transducer." The returning (reflected) sound is then used to detect the presence of plants and determine, through software applications, how much space (volume) the plants occupy in the water, termed plant "Biovolume." Sparse and low-height AIP populations have low biovolumes; dense and taller AIP populations have high biovolumes. The system works like a typical "fish finder" except that the data generated are more detailed and can be used to create very useful "heat maps" that graphically depict the relative amount (biovolume) of aquatic plants beneath or near the transponder signals (Sobol et al. 2009).

This method can efficiently survey large areas for aquatic plants. However, these scans cannot distinguish separate species, nor provide information on reproductive structures, such as the turions produced by Curlyleaf pondweed, or flowers/seeds produced by both Curlyleaf pondweed and Eurasian watermilfoil. TKPOA has used this system to track aquatic plants in the Tahoe Keys for 10 years and scanned the entire West Lagoon and Lake Tallac every two weeks during the CMT Project. An example of a "heat map" generated in the late summer of Year 1 is shown in Figure 4-3. The high biovolume areas (red) are easily distinguished from low biovolume areas (green), and the gradations between these extremes are evident (yellow).

4.4.3 Combining Rake Sampling and Hydroacoustic Scans

When the timing of hydroacoustic scans align with rake sampling events, their overlap can be used to calculate an estimated "species biovolume." By using the species occurrences obtained from the rake data, and the biovolume from scans in the same area and within a few days of rake sampling, the individual species percent composition of, and volume contribution to, the overall biovolume can be determined. (See Appendix J. Biovolume Metrics and Calculations).

This metric is useful in estimating how each species affects the total impact (abundance) of AIP on native plants, native fish habitat, recreational and aesthetic values, and where to focus management resources. For a more detailed report on this approach and also to review an evaluation comparing pre-CMT to post-CMT aquatic plant conditions, see the Biological Restoration Report located in Appendix A.

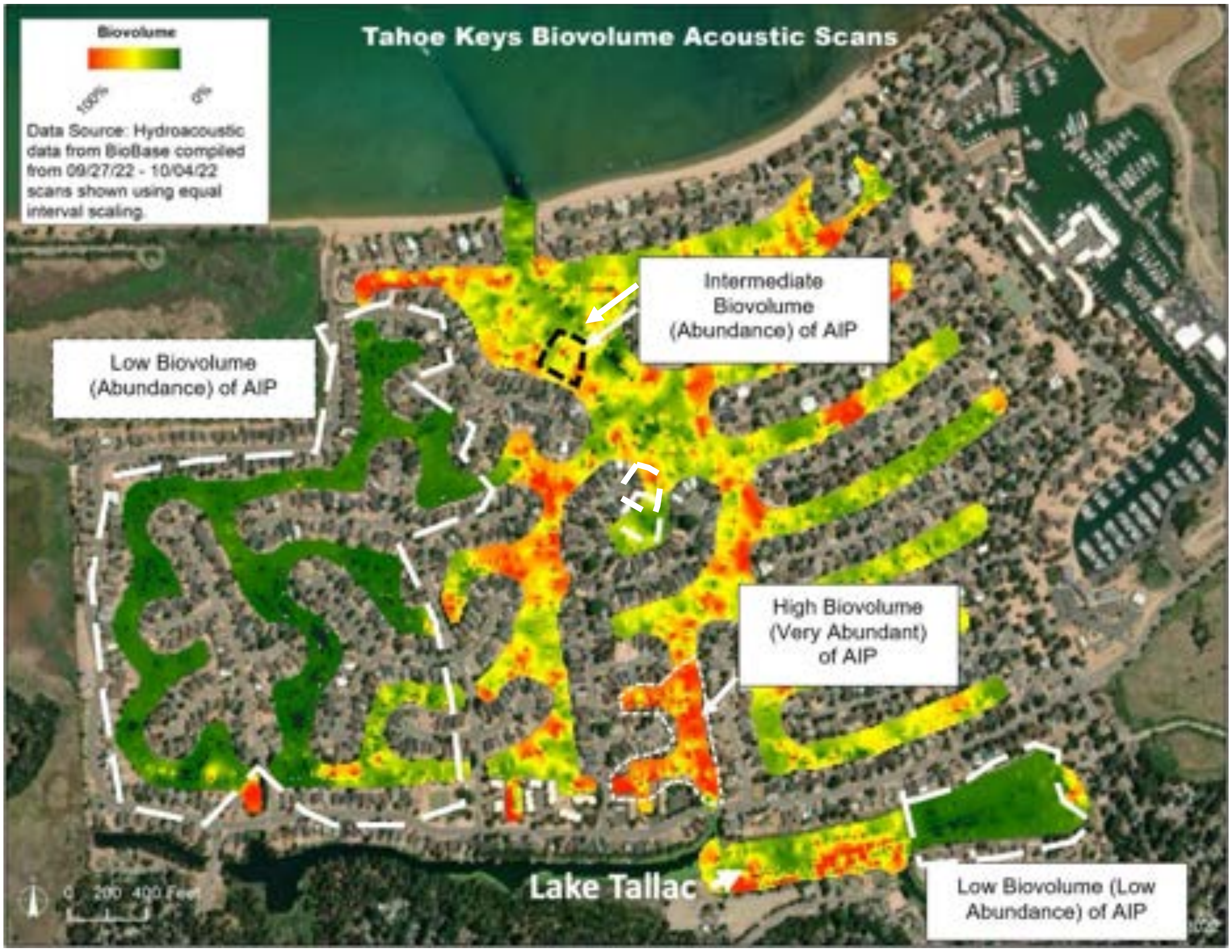


Figure 4-3. Example of heat map generated from hydroacoustic scan in September 2022. Areas green (large white dashed boundaries) = very low AIP abundance. Areas in Red (small white dashed boundaries=very high AIP abundance). Yellow areas (black dashed boundary) have intermediate AIP abundance.

Table 4-1. CMT Monitoring Activity Frequencies

Monitoring Activity	Year 1 Frequency	Year 2 Frequency	Year 3 Frequency
Herbicide Residue and Degradant Sampling (water column)/ Sediment sampling	Water Column: Pre, 7 DAT, 1x/week until 2 ND Sediment: Pre, Post at 90-120DAT	N/A	Sediment: 2 years post application
RWT Dye Monitoring inside curtains and at receiving water stations/ Contingency Sampling	Inside Curtains: 3x/week Receiving Water: 2DAT, every 48 hours until 14DAT or until ND Contingency: If detected at RWT stations, 48-hour measurements until 2 ND	N/A	N/A
Spill Prevention and Response	Standby with response equipment during herbicide application	N/A	N/A
West Channel Hydrologic Monitoring	Every 30 minutes during herbicide application	N/A	N/A
Standard WQ (inside test areas)	Herbicide, UVC Only, Combination, Control: Pre, 3 DAT, 3x/week until fall LFA: 2x/month	All sites: Pre, 1x/week until fall	All sites: Pre, 1x/week until fall
Standard WQ (outside test areas)	Herbicide, UVC Only, Combination, Control: Pre, 3 DAT, 3x/week until fall LFA: 2x/month	N/A	N/A
Continuous WQ (miniDOTs)	Hourly measurements/ Downloaded weekly until fall	Hourly measurements/ Downloaded weekly until fall	Hourly measurements/ Downloaded weekly until fall
Turbidity Monitoring	Curtains: Pre, hourly during install/removal, 24-hours post if elevated	BB and DASH: 3x/workday; one 24-hour post measurement	BB and DASH: 3x/workday; one 24-hour post measurement
Culvert Bladder and Turbidity Inspections	1x/day inspections	N/A	N/A
DASH Turion Counts	N/A	Collected during every DASH treatment/ counted in the fall	Collected during every DASH treatment/ counted in the fall
Nutrient Grab WQ Sampling	Herbicide, Controls: 7-30 DAT, 1x/week UVC Only, Combination: 12DAT, 1x/week, until 60DAT LFA: 2x/year	Combination, Control, Spot-UV: Pre, 14DAT, 1x/week until 60DAT UVC Only: Pre, 14DAT, 1x/month, until 60 DAT LFA: 2x/year	Combination, Control, Spot-UV: Pre, 14DAT, 1x/week until 60DAT UVC Only: Pre, 14DAT, 1x/month, until 60 DAT LFA: 2x/year

Monitoring Activity	Year 1 Frequency	Year 2 Frequency	Year 3 Frequency
Cyanobacteria Sampling	Daily Obs./If confirmed 2x/month until fall	Daily Obs./If confirmed 2x/month	Daily Obs./If confirmed 2x/month
Macrophyte Sampling	Herbicide, UVC Only, Combination, Control: Pre, 14DAT, 2x/month, until 120DAT LFA: 2x/year	Herbicide, UVC Only, Control, Spot-UV, DASH: Pre, 14DAT, 2x/month until fall BB: Pre, 1-6DAR, 2x/month until fall Combination: Pre, 14 DAT, 1x/month until fall LFA: 2x/year	Herbicide, UVC Only, Control, Spot-UV, DASH: Pre, 14DAT, 2x/month until fall BB: Pre, 1-6DAR, 2x/month until fall Combination: Pre, 14 DAT, 1x/month until fall LFA: 2x/year
Hydroacoustic Scans	Pre, 2x/month until fall	Pre, 2x/month until fall	Pre, 2x/month until fall
BMI Sampling	1x/year; Sites 7, 25, 27 sampled in the fall; all other in the spring	1x/year; Sites 7, 25, 27 sampled in the spring and fall; all other in the spring only	1x/year; Sites 7, 25, 26 sampled in the fall only; all other in the spring
Well Water Sampling	Pre, 2 DAT, 48-hour sampling until 14DAT	N/A	N/A
Light level Monitoring	N/A	mid-June to mid-October; 1x/month	N/A
PAR Profiling	N/A	mid-June to mid-October; 1x/month	mid-June to mid-October; 1x/month
Muck Depth (Steel Plates, Staff Gages, Mesh Bags)	N/A	Steel Plates: 1x/year Staff Gages: 1x/year Mesh Bags: 1x/year	Steel Plates: 1x/year Staff Gages: 1x/year Mesh Bags: 2x/year
Percent Organic Sampling	1x/year	2x/year	NA

Table 4-2. Summary of CMT Monitoring Data Points Collected

Monitoring Activities (Responsible Entities)	Year 1 Data Points	Year 2 Data Points	Year 3 Data Points	Total Data Points/ Monitoring Activity
BMI **(ESA)**	168	168*	156*	492
Continuous WQ (miniDOTs) **(Stratus)**	14,586	18,748	21,807	55,141
Cyanobacteria **(TKPOA)**	271	135	105	511
DASH Weight and Turions **(TKPOA)**	-	68*	66	134
Herbicide Residue and Degradants and RWT Dye **(Blankinship)**	3,600	-	13**	3,613
Hydroacoustic Scans **(TKPOA)**	14	13*	13	40
Inspection of Turbidity Curtains/Culvert Plugs **(TKPOA)**	132	-	-	132
Light Level **(TKPOA)**	-	990	-	990
Macrophytes **(ESA)**	34,068	41,590*	44,615	120,273
Muck Depth **(TKPOA)**	-	96	101	197
Nutrients **(ESA)**	1,088	1,168	1,128	3,384
PAR Profiling **(TKPOA)**	-	126	1,119	1,245
Percent Organic Matter **(TKPOA)**	8*	16	-	24
Standard WQ- Inside Test Areas **(TKPOA)**	17,460	10,169	11,622	39,251
Standard WQ- Outside Test Areas **(ESA)**	3,321	-	-	3,321
Spill Prevention and Response **(Stratus)**	13	-	-	13
Turbidity- Curtains **(TKPOA)**	227	-	-	227
Turbidity- BB **(TKPOA)**	-	100	122	222
Turbidity- DASH **(TKPOA)**	-	155	313	468
Well Water **(Stratus)**	138	-	-	138
West Channel Flow **(TKPOA)**	90	-	-	90
Year-end Completeness Percentage:	90%	98%	98%	95%
Total CMT Data Points:	75,184	73,542*	81,180	229,906

*Indicates data point calculation/total was adjusted for comparison across years.
**Herbicide sediment sampling only.

5.0 RESULTS OF PERMIT COMPLIANCE MONITORING

The Lahontan Water Board National Pollutant Discharge Elimination System Permit (NPDES)-required monitoring data for all CMT years are included in each annual report (Appendix A). A summary of those results is provided in the following sections.

5.1 Year 1 Herbicide Levels and Movement

Endothall and Triclopyr applications occurred in late May 2022, and all required follow up water sampling and laboratory analyses for active ingredients and degradants (decomposition products) completed. The 2022 annual report, which includes results from herbicide monitoring, water quality monitoring and efficacy assessment results, was submitted in March 2023 and is accessible in Appendix A (Year 1 CMT Annual Report). The key results from that report include the following:

(a) Except for two transient storm events in June that partially dislodged some curtains, the use of double turbidity curtains contained applied herbicides to the treatment areas. The brief disruption of some curtains by storm events was quickly remedied within 24 hours, and containment was sustained.
(b) Triclopyr degradation to “non-detect” levels (1 ppb) took longer than expected (months, not 1 to 2 weeks). This degradation timeline required that the turbidity curtains stay installed until September per the NPDES Permit. Because Triclopyr degradation is primarily light dependent, elevated turbidity and resulting in very low light levels likely contributed to the slower degradation. The low light condition was probably prolonged by the continued use of the curtains, which likely created “stagnant” areas that encouraged algae growth.
(c) Endothall degraded to non-detect levels (5 ppb) within 45 days after applications.
(d) Aeration was deployed in herbicide sites to increase DO levels and to help accelerate herbicide degradation.
(e) The use of both herbicides provided a 75% reduction in AIP abundance during Year 1 (See Section 6.0, and Appendix A (Efficacy Report for Year 1)).
(f) Monitoring of TKPOA drinking water wells (at 48-hour intervals from May 26, 2022 to June 14, 2022 showed no detection of the RWT Dye or herbicides.
(g) The use of RWT Dye was effective for real-time detection of potential herbicide presence and movement, although dye concentrations did not always correlate with actual herbicide concentrations.
(h) Bottom sediment sampling in Endothall sites detected Endothall in 2022 but follow-up sampling in 2024 showed no detectable Endothall. Triclopyr was non-detect in the sediment samples collected in 2022.

5.2 Water Quality Response to Herbicide Applications

The main effects of herbicide applications on water quality are summarized below. For a complete record of all mid-depth sonde and miniDOT logger graphs generated for the project, refer to Appendix K. Mid-depth Sonde Data Graphs and Appendix L. miniDOT Data Graphs.

(a) Turbidity. In Year 1, Endothall Only sites and Triclopyr Only sites had highly elevated turbidity by mid-summer. Combination sites also had elevated turbidity, less than the increases in the Endothall Only sites, but with a greater increase in the Triclopyr-Combination sites (Figures 5-1 and 5-2). However, three-year synoptic data shows that untreated Control sites also showed elevated turbidity in subsequent years, and that turbidity in sites previously treated with herbicides were similar to the untreated Control sites in Years 2 and 3 (Figures 5-3 to 5-5). The increased turbidity in herbicide sites may be attributed to the efficacy of Endothall and Triclopyr and resultant decomposition of AIP, which releases nutrients and plant contents that drive the growth of algae. The transient increases in turbidity in all sites, including Control sites in 2023 and 2024, may have resulted from much higher spring inflows from the lake into the West Lagoon and stormwater into the Lake Tallac Lagoon.

(b) Conductivity. Increased conductivity is associated with decomposition of submersed aquatic plants and can reflect the seasonal release of cell contents during senescence. Similarly, efficacious applications of aquatic herbicide may also elevate conductivity, which occurred mainly in the Endothall Only sites and Triclopyr Combination sites (Figures 5-6, 5-7). However, these sites also had higher conductivity before herbicides were applied. Note that Year 2 and Year 3 increases in conductivity reflected typical late season AIP decomposition in all sites. The very low water volume in 2022 likely resulted in overall increased conductivity due to higher concentrations of released plant tissue constituents compared with the following high-volume (elevated lagoon water level) conditions in 2023 and 2024).

(c) DO. DO was depressed near the bottom of both the untreated Control sites and herbicide treated sites (Figures 5-8 to 5-10). The decline in DO is somewhat a transient condition since the targeted AIP produces oxygen during the day and, with AIP reduced abundance, would be expected to decrease DO. The DO levels in untreated Control sites by mid-late summer are a typical pattern when abundant aquatic plants begin to senesce naturally. The low water volume in Year 1 probably further lowered DO, since the microbial activity of decomposing of AIP biomass in the smaller volume would reduce DO. Notably, in Years 2 and 3, reduced DO was not observed in sites where herbicides had been applied in Year 1 (Figure 5-9, surface water). The three-month use of turbidity curtains likely exacerbated and prolonged the degraded water quality conditions in general since normal water mixing and transport were limited by the curtains (See Appendix G).

(d) Temperature. Besides seasonal day-length, the most consistent pattern in water quality over the CMT period and between all CMT sites was water temperature. The temperatures in Control sites are shown in Figure 5-11. By early to mid-May, temperatures are typically above 15 degrees Celsius, which is sufficient to drive AIP growth, coupled with lengthening daylight hours (Figure 5-11). However, even though spring temperatures were nearly the same in all years, the very low water in Year 1 appears to have resulted in surface water temperatures above 20 degrees Celsius during August compared with Years 2 and 3 which had late summer temperatures below 20 degrees Celsius beginning in early August. This pattern was consistent in all West Lagoon CMT sites and may have also contributed to increased algae-generated turbidity (See Figure 5-3). None of the CMT treatments affected water temperature except LFA, which reduced lagoon water thermoclines (See Section 5.6).

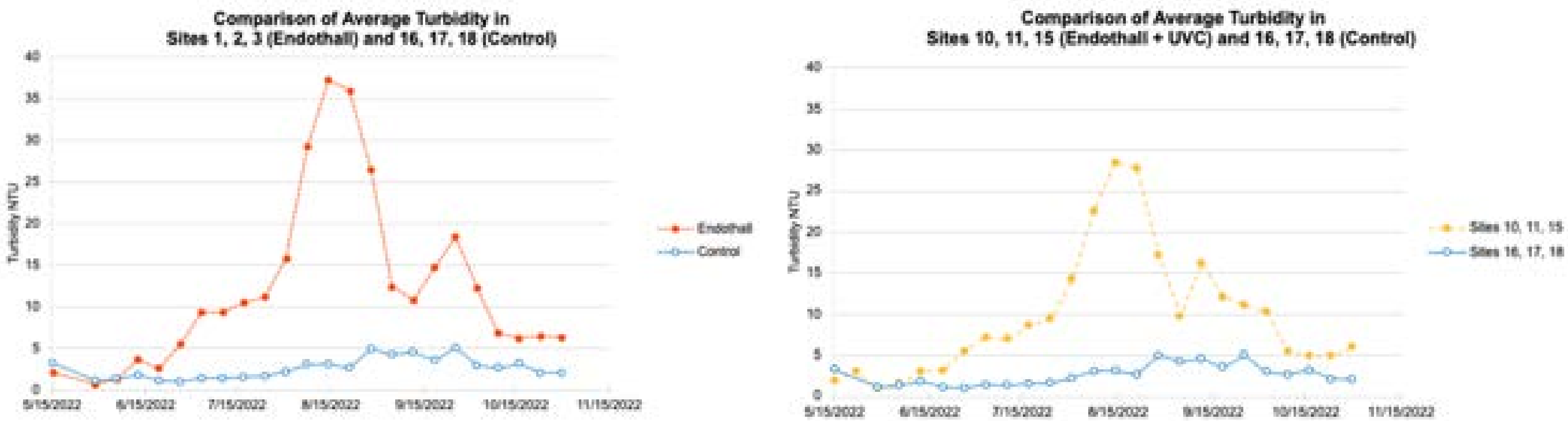


Figure 5-1. Year 1 turbidity in Endothall Only (left) and Endothall/UVC Combination sites (right). Blue open circles are untreated Control sites.

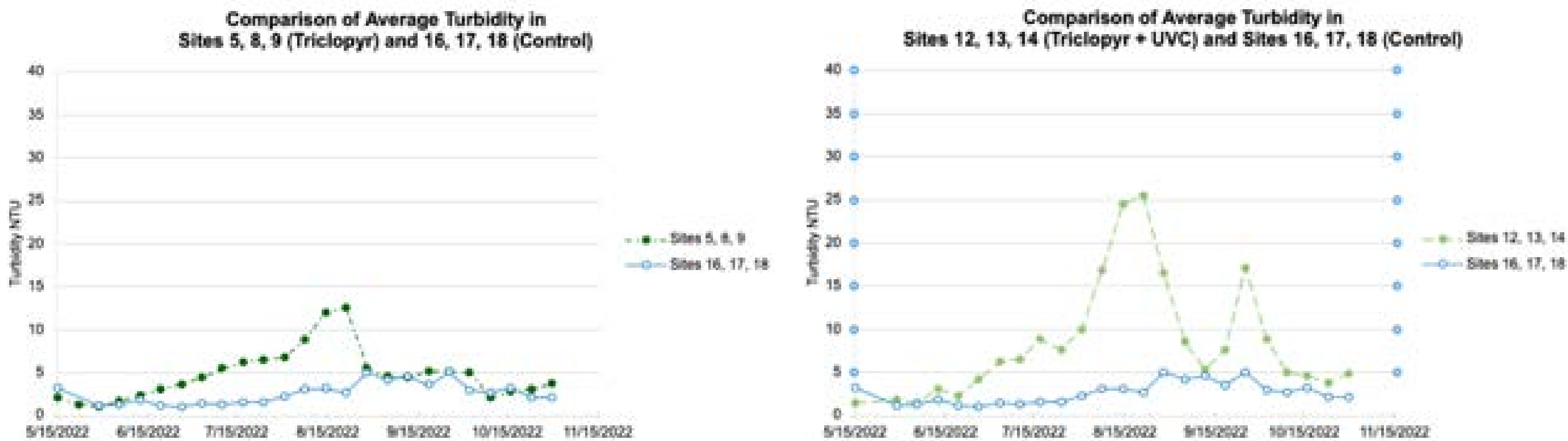


Figure 5-2. Year 1 turbidity in Triclopyr Only (left) and Triclopyr/UVC Combination sites (right). Blue open circles are untreated Control sites.

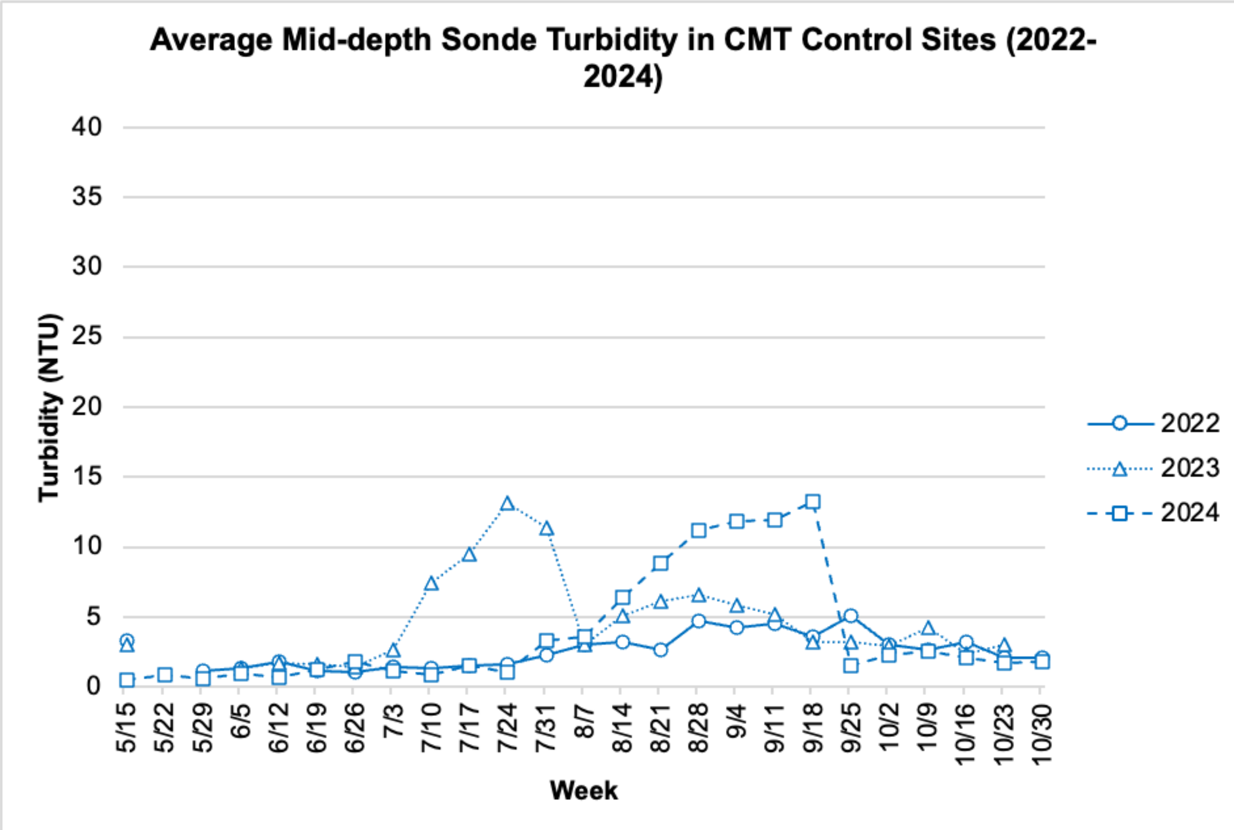


Figure 5-3. Turbidity in untreated Control sites during the CMT.

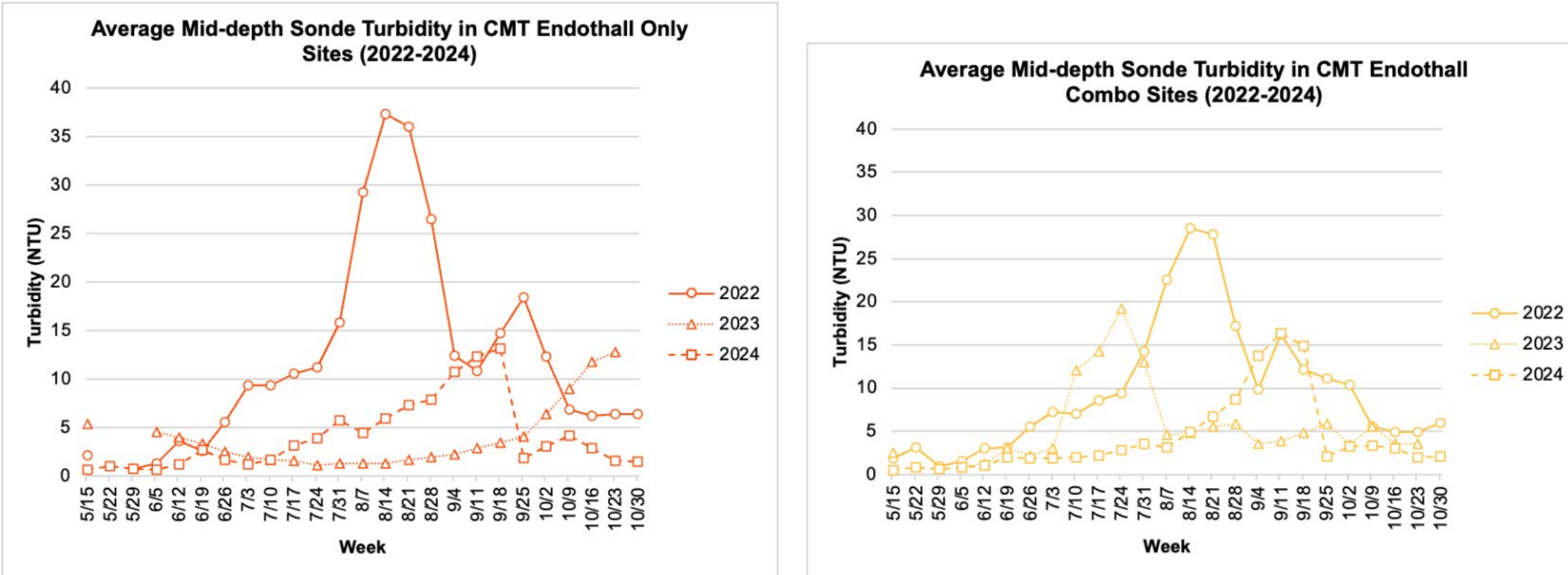
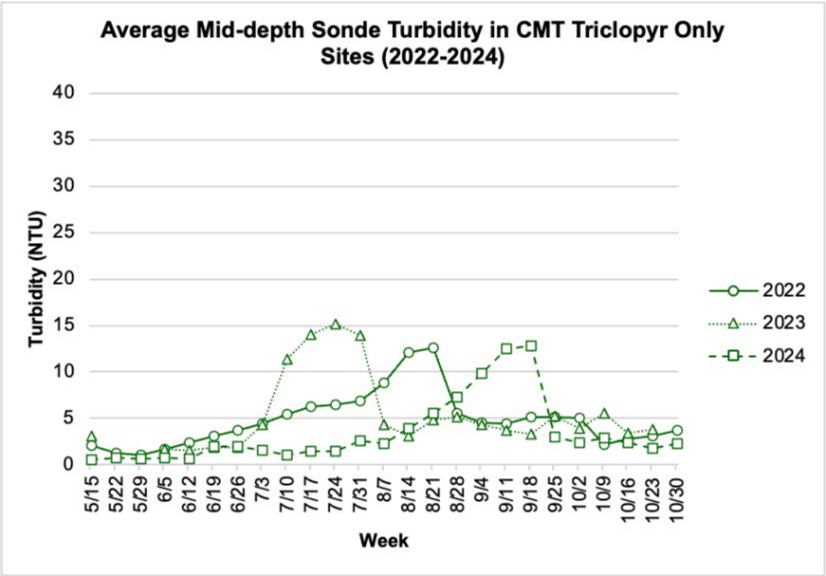


Figure 5-4. Turbidity in Endothall Only sites (left) and Endothall Combination sites (right) during the CMT.



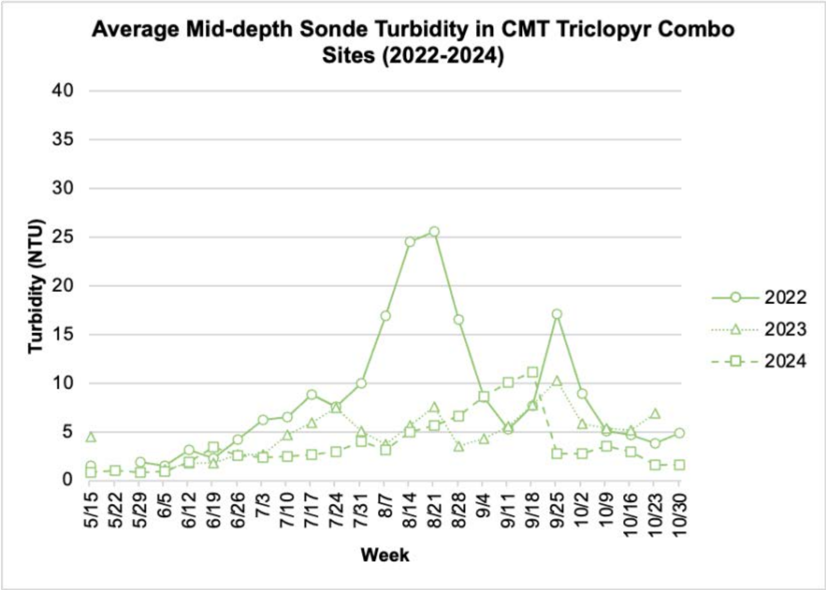


Figure 5-5. Turbidity in Triclopyr Only sies (left) and Triclopyr Combination sites (right) during the CMT.

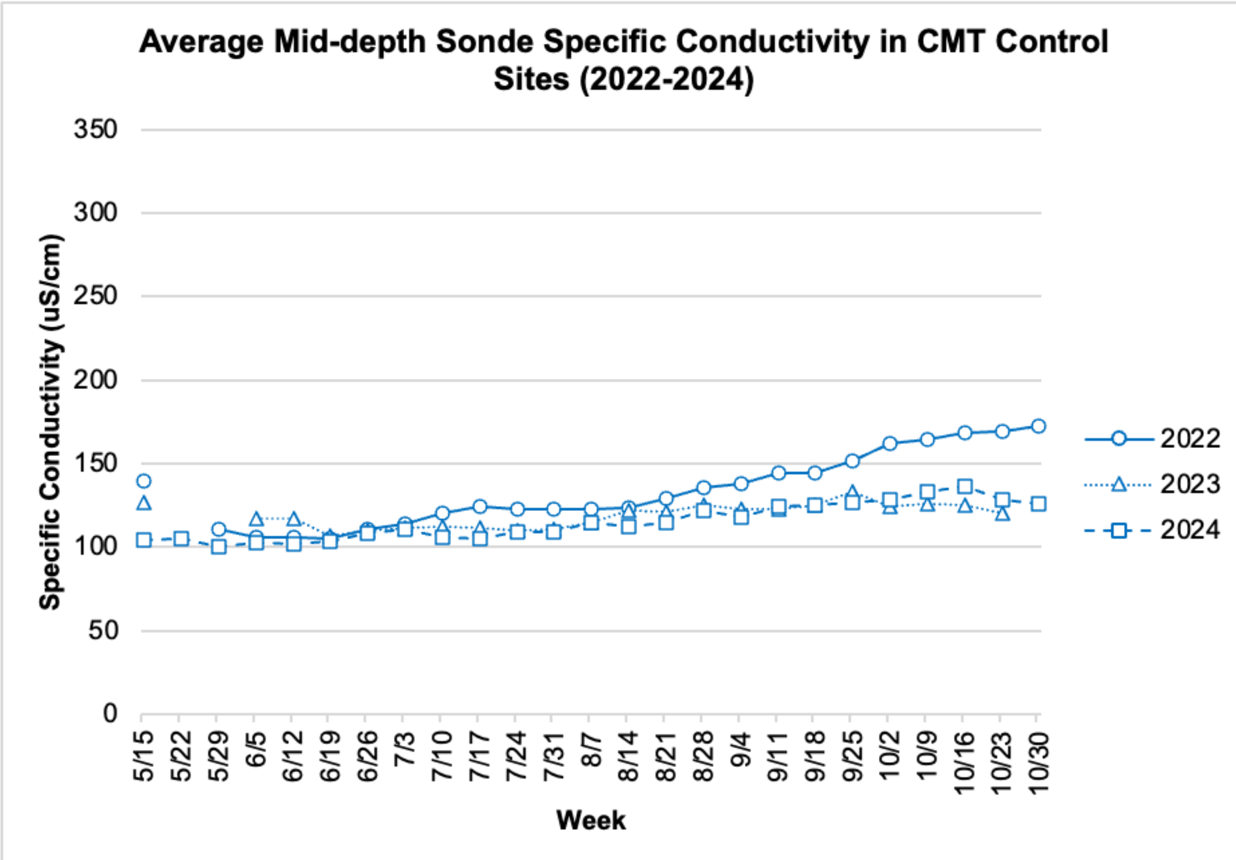


Figure 5-6. Conductivity in untreated Control sites during the CMT.

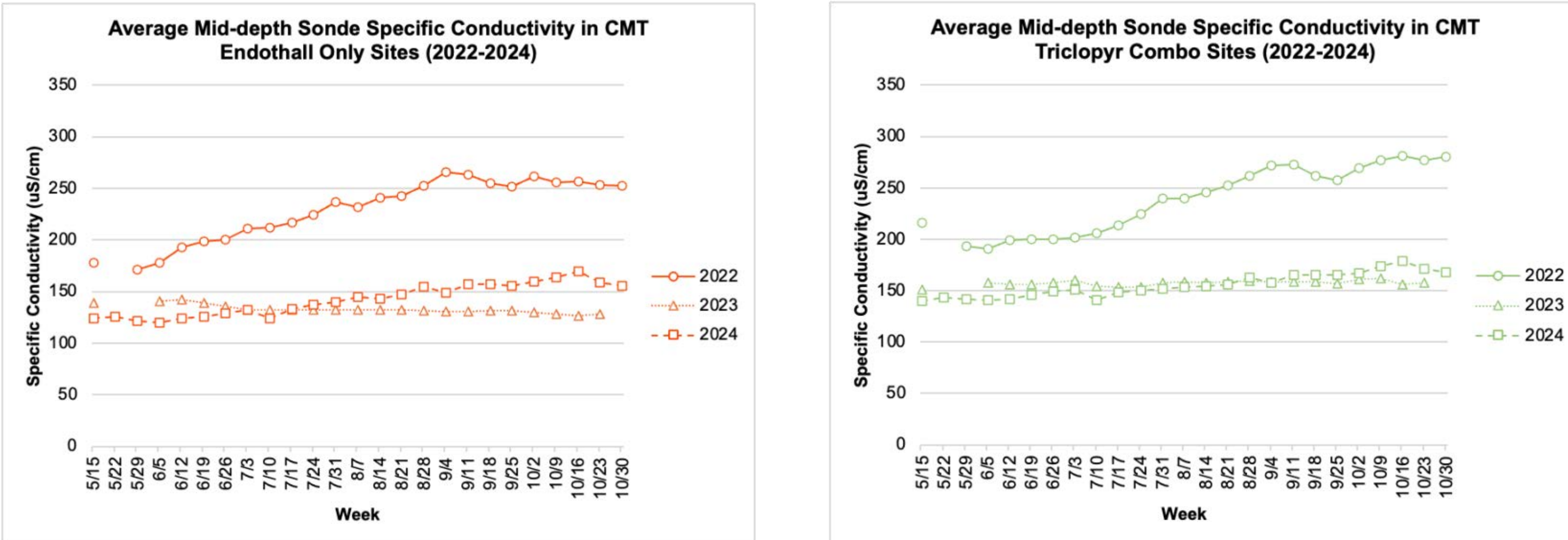


Figure 5-7. Conductivity in Endothall Only (left) and Triclopyr Combination sites (right) during the CMT.

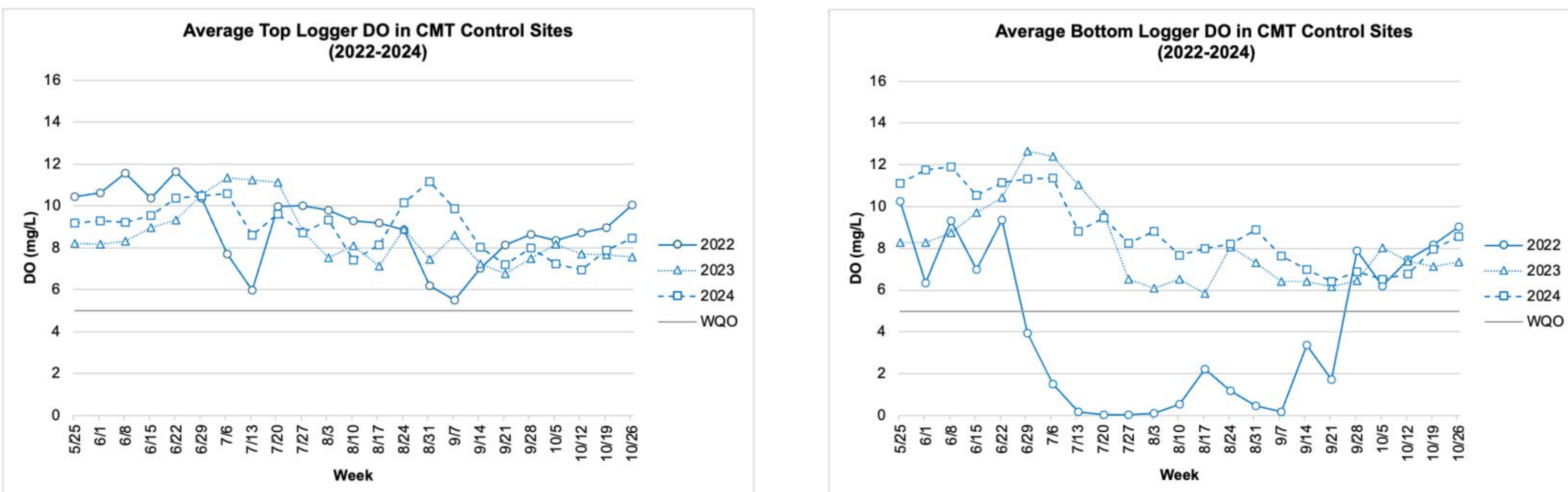
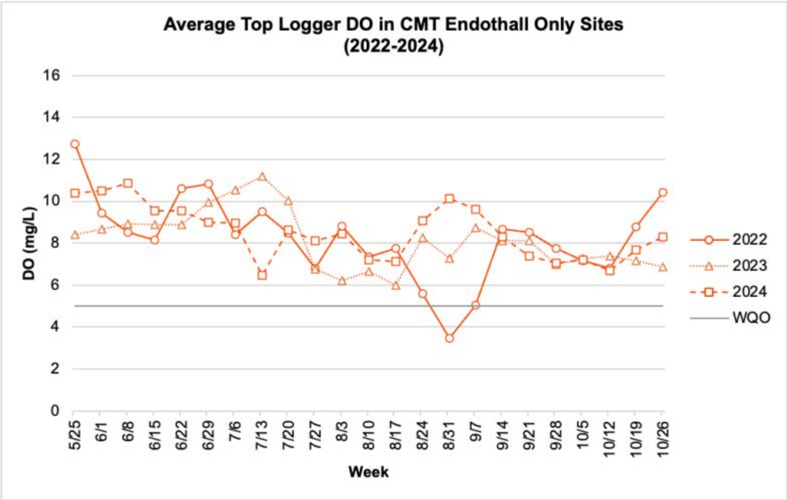


Figure 5-8. DO during the CMT in untreated Control sites: Left= near surface; Right=near bottom. Horizontal black line shows 5 mg/L level.



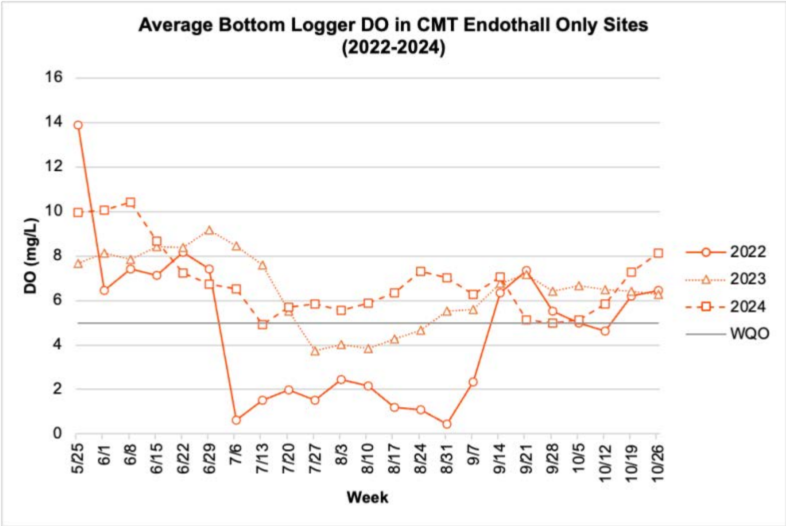
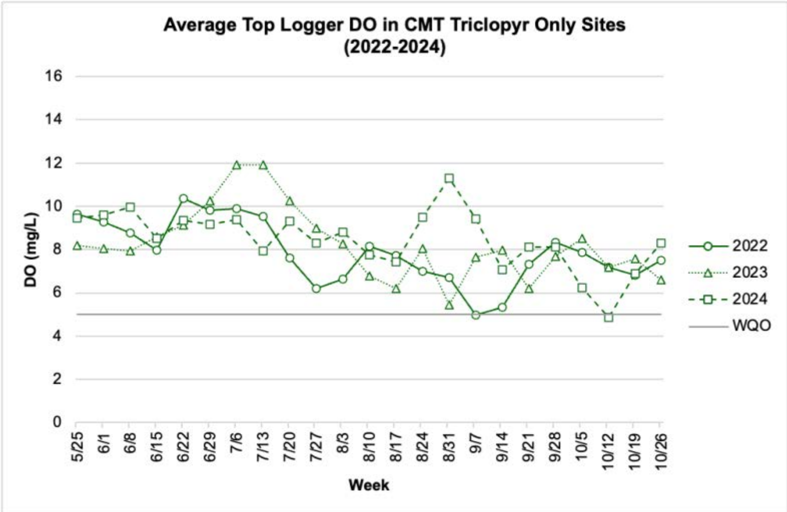


Figure 5-9. DO during the CMT in Endothall Only sites: Left=near surface; Right= near bottom. Horizontal black line shows 5 mg/L level.



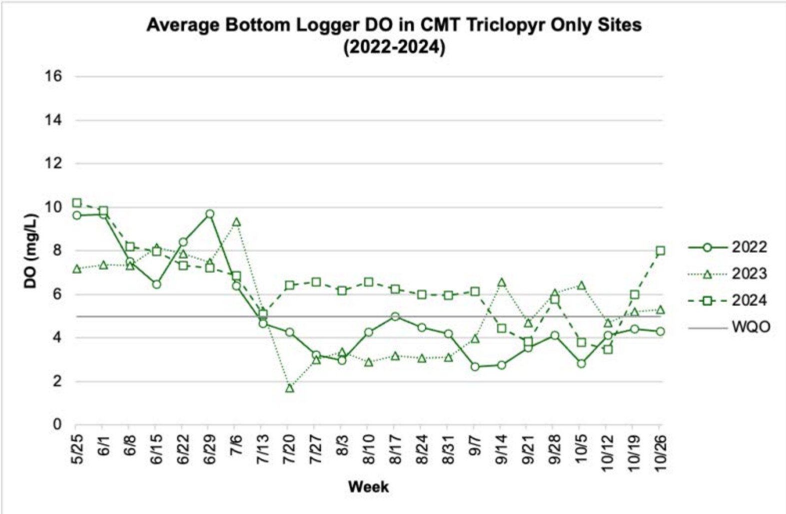


Figure 5-10. DO during the CMT in Triclopyr Only sites: Left = near surface; Right= near bottom. Horizontal black line shows 5 mg/L level.

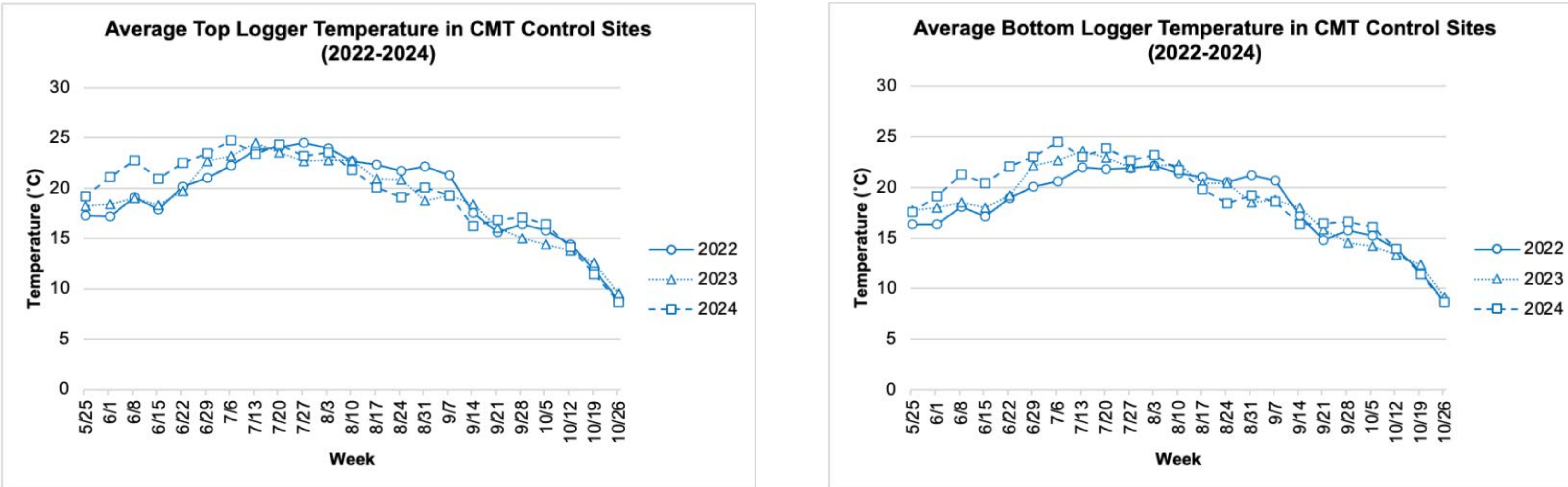


Figure 5-11. Water temperature in untreated Control sites during the CMT: Left= near surface; Right= near bottom. Note sustain temperatures above 20 C in August in Year 1.

5.3 Nutrient Responses to Herbicide Applications

In Year 1, the Herbicide-treated sites, especially Endothall Only sites, had elevated TP, TN and phosphate OP (Figure 5-12). These increases were likely due to decomposition of target plants during the weeks following herbicide applications. These conditions did not persist in Year 2 and 3 (See Appendix M. Nutrients Data Graphs). UVC treatments also resulted in elevated nutrient levels in some sites for short periods (weeks) following the treatments. Triclopyr Only sites had a similar pattern of increased nutrients, but the changes were less pronounced than in Endothall sites (Figure 5-13). The smaller increases of nutrients in the Triclopyr sites may have been due to the selectivity of this herbicide, which does not affect Coontail and thus would result in less AIP biomass decomposing during 2022.

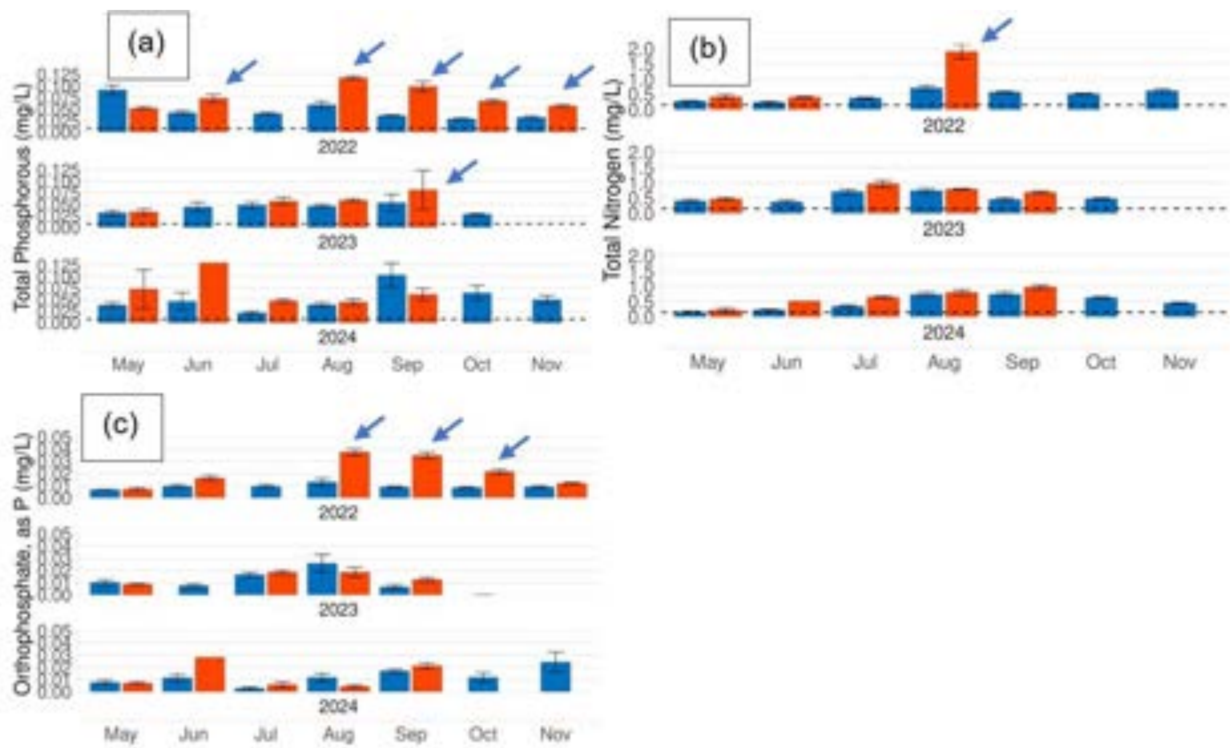


Figure 5-12. Nutrient Levels during the CMT in Endothall Only sites (red bars) Compared to Untreated Control sites (blue bars): (a) TP;(b) TN; (c) OP. Arrows show incidences of elevated nutrient levels.

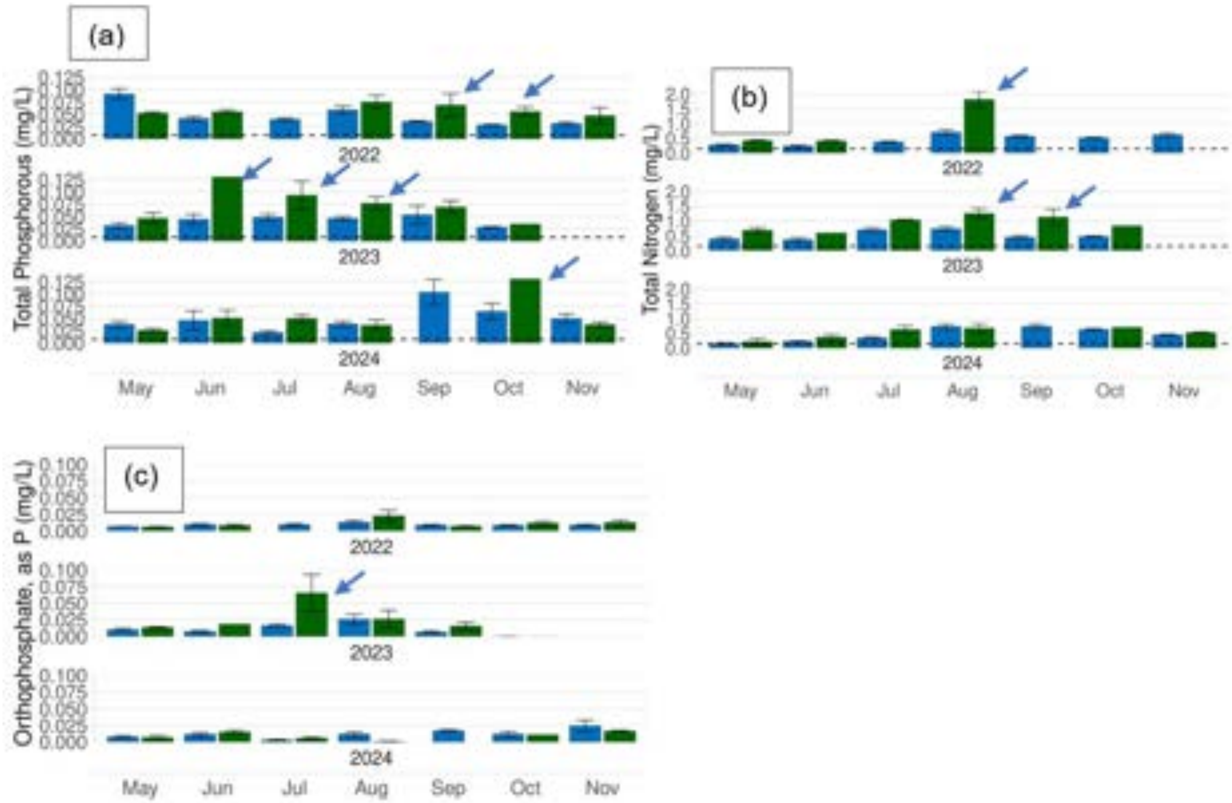


Figure 5-13. Nutrient levels during the CMT in Triclopyr Only sites (green bars) Compared to Untreated Control sites (blue bars): (a) TP;(b) TN; (c) OP. Arrows show incidences of elevated nutrients levels.

5.4 Water Quality Responses to UVC Treatments

Sites 22 and 24 represent the longest UVC Only treated sites in the CMT (Years 1, 2, and 3). Site 23 received UVC treatments in Years 1 and 3 only and was not treated in Year 2 due to limited resources for UVC treatments.

(a) Turbidity. There were no effects from the UVC treatment on turbidity when compared with untreated Control sites (Figure 5-14 and Figure 5-3).

(b) Conductivity. UVC treatments did not affect conductivity, but these sites showed typical late summer to fall increases in conductivity similar to untreated Control sites. The increased conductivity was likely due to seasonal senescence of AIP (See Figure 5-6 for Control site conductivity).

(c) DO. There were no effects from UVC on DO at the surface or near the bottom of the three UVC Only sites when compared with untreated Control sites (Figure 5-15).

(d) Temperature. The arrays of UVC lamps have the potential for transferring heat to the water when operating. However, continuous (hourly) measurements of near surface and near bottom water temperatures in UVC treatment sites revealed no changes in temperature compared to untreated Control sites (Figures 5-16 and see Control sites in Figure 5-11)

Figure 5-14. Turbidity (left graph) and conductivity (right graph) during the CMT in UVC Only sites.

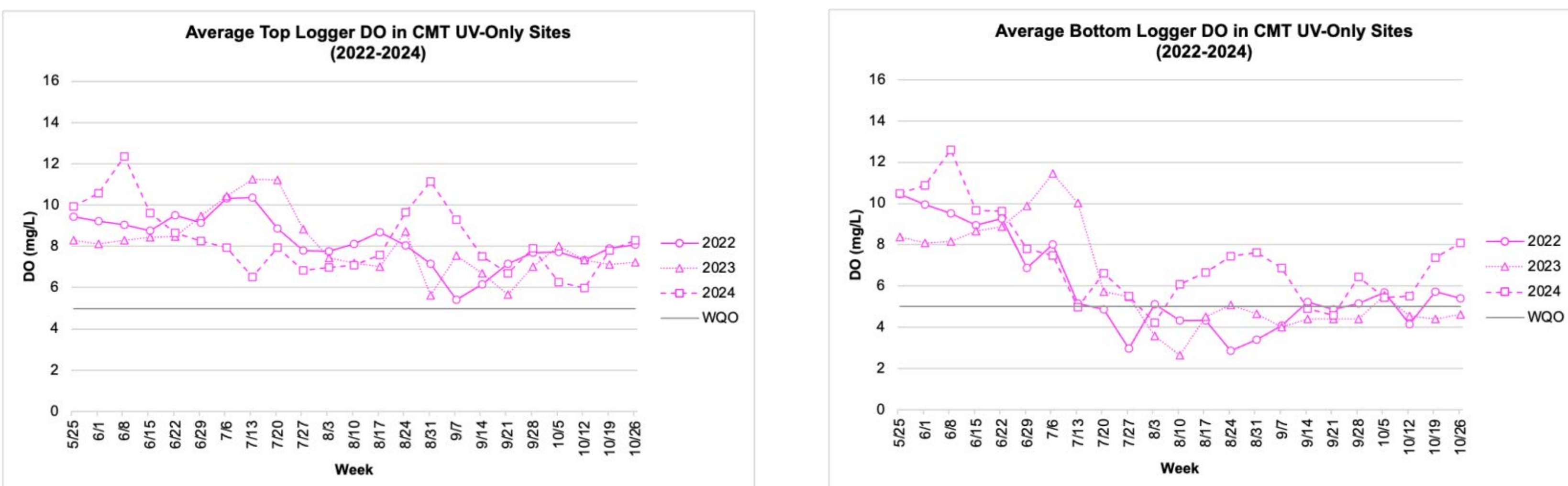
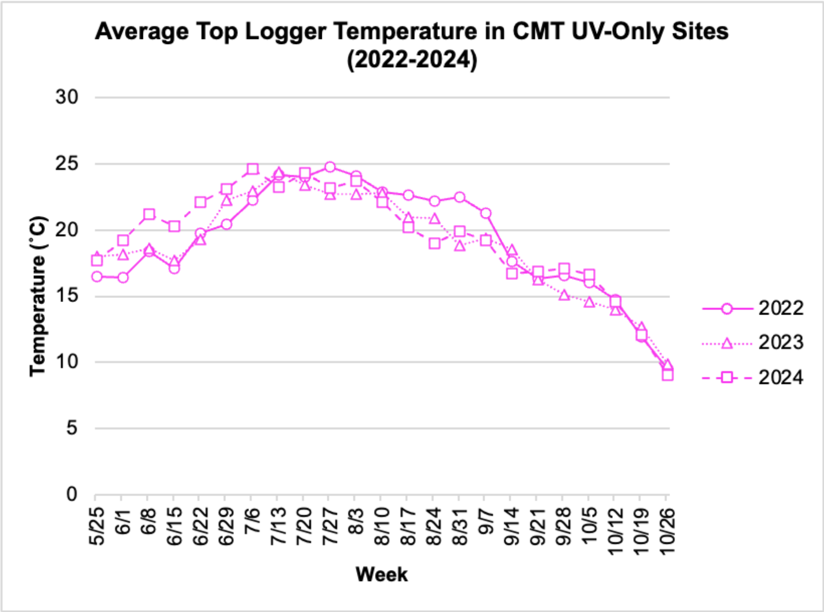


Figure 5-15. DO during the CMT in UVC Only sites: bottom of the water column (left) top of the water column (right).



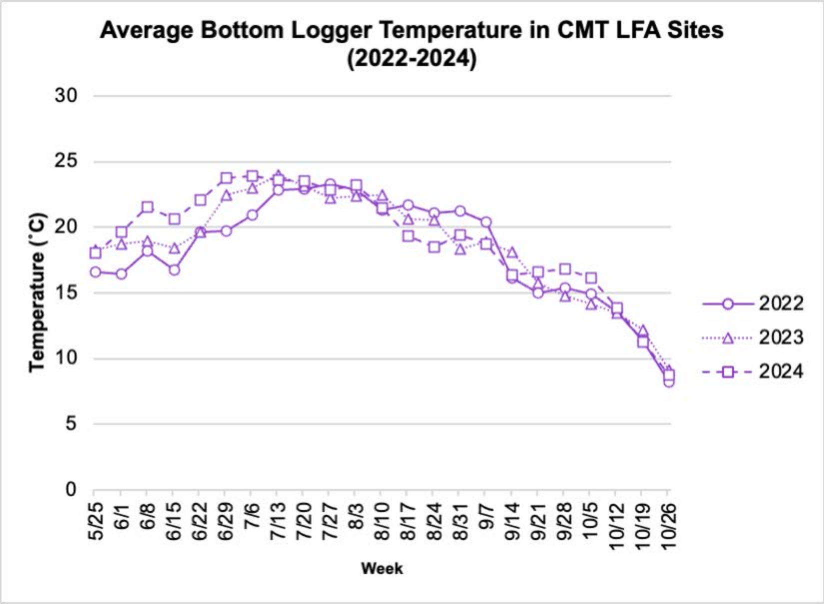


Figure 5-16. Water temperatures during the CMT in UVC Only sites: bottom of the water column (left) and top of the water column (right).

5.5 Nutrient Responses to UVC Treatments

The main effects of UVC treatments in Site 24 were slightly and transiently elevated for TP and OP in July, Years 2 and 3. No effects were seen on nutrient levels from the UVC treatments in Site 22 in all three years. Interestingly, Site 23, which was not treated in 2023 and received its second UVC treatment in 2024, exhibited the most increase in TP and OP. These increases occurred in July 2022 during the first treatments. Subsequently, no notable differences were seen for nutrients compared with Control sites during 2023 when not treated, nor in 2024 during UVC treatments. When the nutrient levels are averaged for Sites 22 and 24, no substantial differences in nutrient levels are observed between treated sites and untreated Control sites (Figures 5-17 to 5-18).

Figure 5-17. OP in UVC Only sites 22 and 24 CMT Years 1,2,3.

Figure 5-18. TN in UVC Only sites 22 and 24 CMT Years 1,2,3.

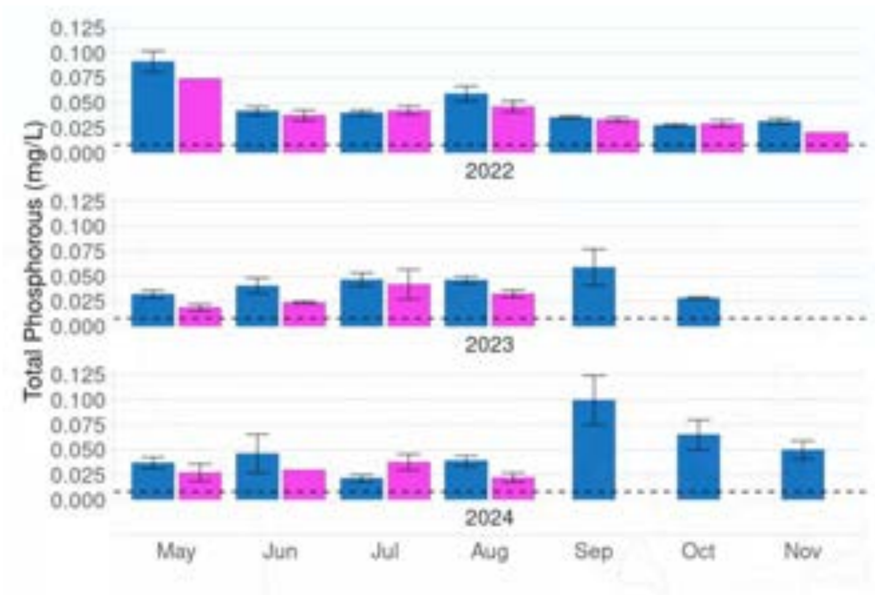


Figure 5-19. TP in UVC Only sites 22 and 24 in CMT Years 1, 2, 3.

The Group B Spot-UV treatments were used in Years 2 and 3 to sustain AIP reductions in CMT sites with Year 1 herbicide applications. These treatments were usually in small areas within the larger CMT Sites (See Table 3-5). However, some Spot-UV treatments were large (for example Sites 5 and 26, Table 3-5). The main effects of Spot-UV treatments on water quality were transient, elevated levels of TP. (Figure 5-20). Similar to the UVC Only site treatments, Spot-UV treatments had no effect on near surface or near bottom water temperatures or DO.

The Sequential (Post BB removal) sites treated with UVC (as an adaptive management method to control Curlyleaf pondweed turions that sprouted after removal of BBs) had no effect on nutrients or other water quality variables. This was not surprising since the sites were small, and the single treatments were in the fall when biomass from plants was very low.

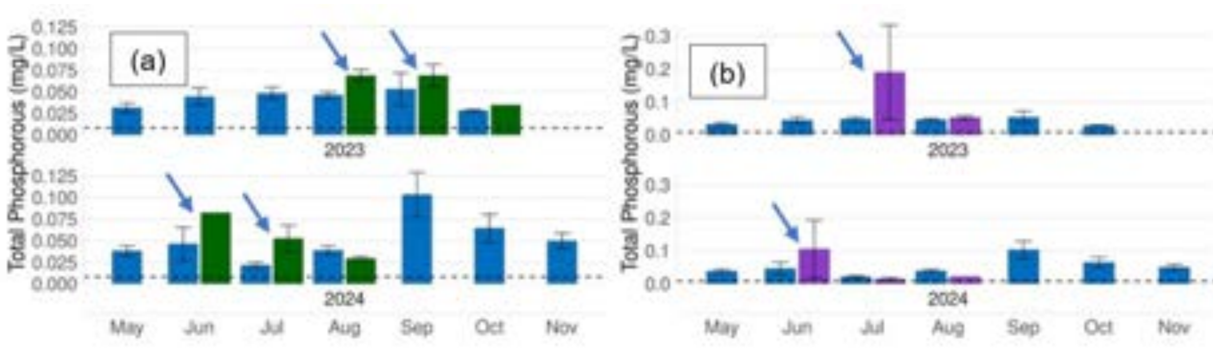


Figure 5-20. TP in Spot-UV treatments Year 2 (2023) and Year 3 (2024) at Site 5 (a) and Site 26 (b). Arrows show sampling dates with elevated TP.

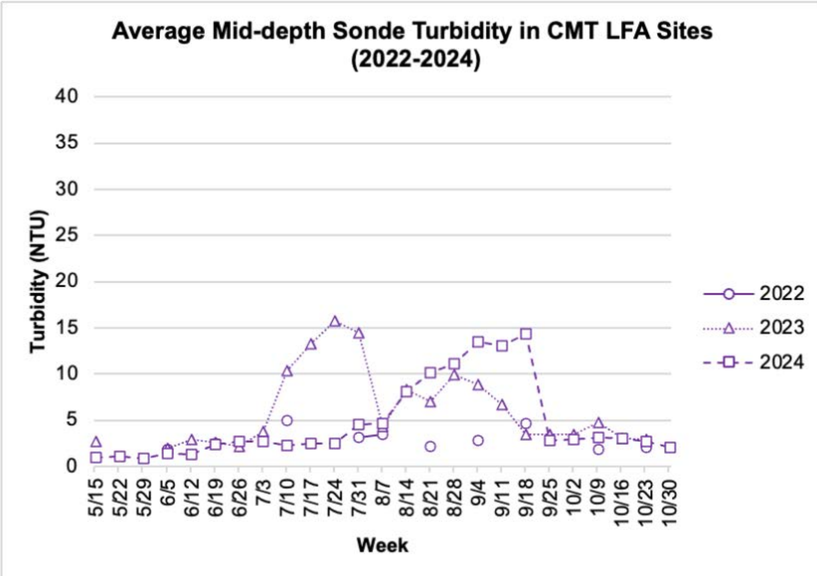
5.6 Water Quality Responses to LFA Treatments

The LFA air-bubbler systems were installed in 2019 (Site 26) and 2022 (Sites 25 and 27). The systems induced water column mixing and generally created more uniform water quality conditions throughout the water column as documented in the CMT Annual Reports (Appendix A). Some anomalies seen in Year 1 data were most likely due to the very shallow water conditions. For example, low DO near the bottoms was observed in several other sites, including controls sites.

(a) Turbidity. LFA did not affect turbidity compared with Control sites, although Year 1 had much more variable turbidity levels in Site 26 (Figure 5-21).

(b) Conductivity. LFA did not affect conductivity, but the LFA sites exhibited a typical increase in late summer in Year 1 due to AIP seasonal senescence and shallow water conditions (Figure 5-21).

(c) DO. With the exception of Year 1, LFA Site 26, the longest running LFA system, produced fairly uniform distribution of DO in both the upper surface and bottom water levels (Figure 5-22).



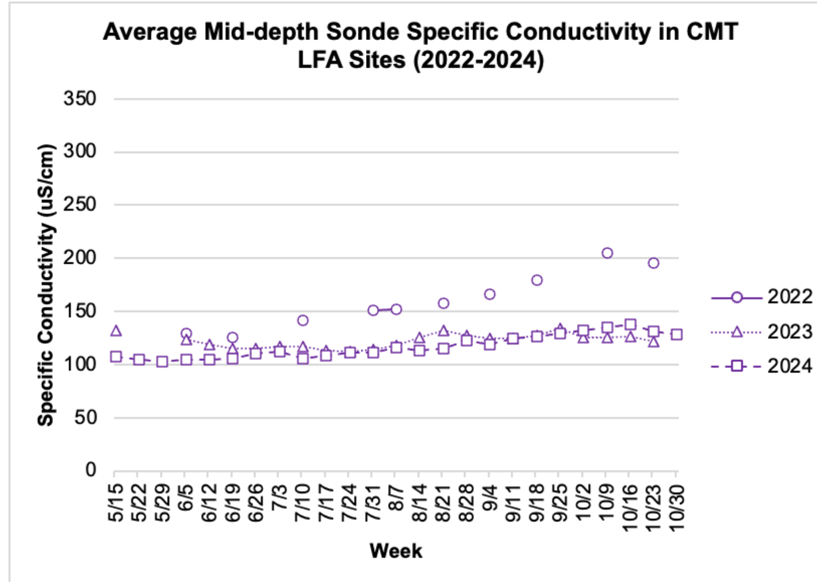


Figure 5-21. Turbidity (left graph) and conductivity (right graph) in LFA Sites during the CMT.

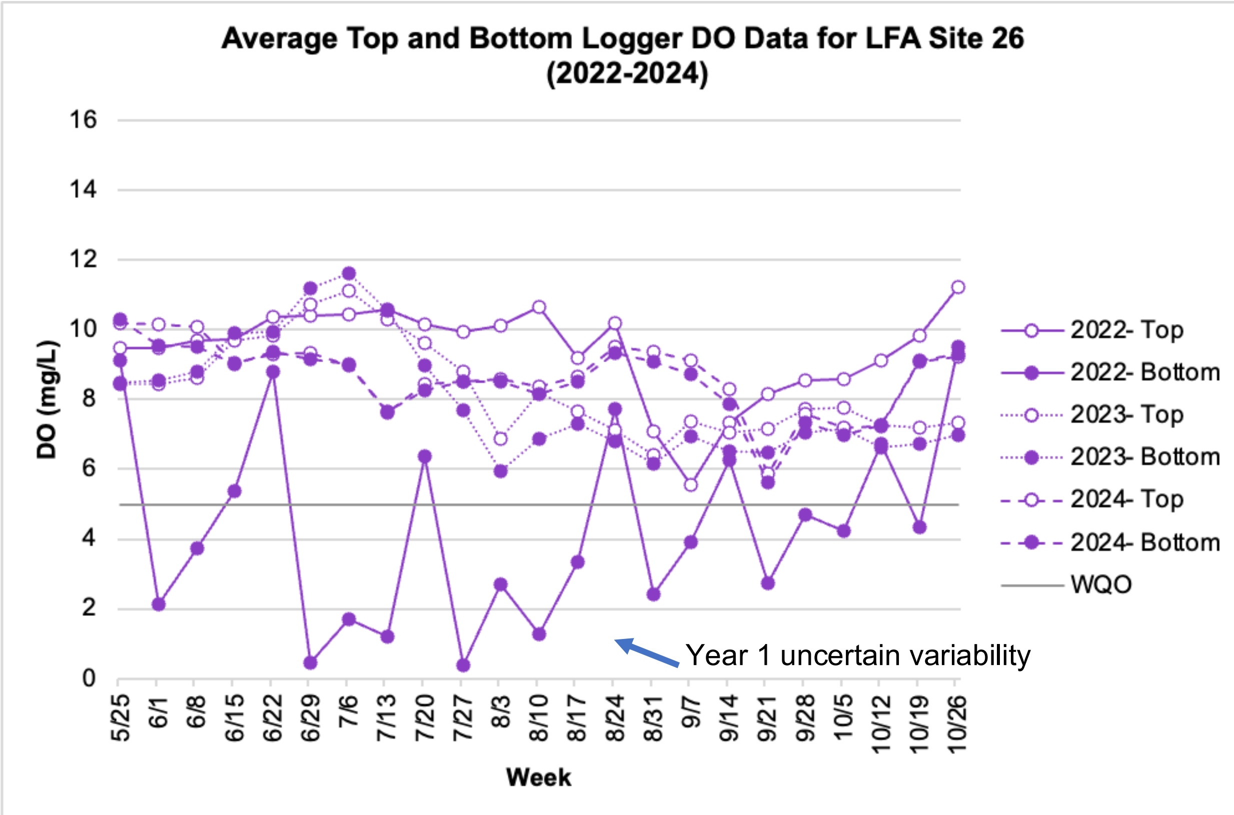


Figure 5-22. Average DO during the CMT in LFA Site 26 . Note anomalies in DO during Year 1. These highly variable DO values in bottom areas were observed in most of the Year 1 CMT sites including the Control sites.

5.7 Biological Restoration Status

The Biological Restoration Report, located in Appendix A, evaluated native plant species (excluding Coontail), water quality, and BMI as indicators for post-CMT Project restoration in the Tahoe Keys lagoons. Fish were eliminated as an indicator of restoration due to the abundance of invasive, warm water fish in the lagoons. "Fully restored" for each of the indicators means that the conditions in the lagoons reflect pre-project conditions or better (Appendix A; Lahontan 2022). Summary conclusions for each of the indicators analyzed in the report are detailed below.

5.7.1 Plants (Native)

Aquatic plants or macrophytes are one of the selected indicators of habitat restoration and/or improvement following implementation of the CMT, specifically, the recovery of native plants (excluding Coontail). The metrics used to evaluate the macrophyte data are frequency of occurrence and biovolume percent. The 2024 post-treatment data for the aquatic plants shows that native plant species have increased, and AIP species have decreased in both occurrence and biovolume for the West and Lake Tallac lagoons when compared to 2020 and CMT 2024 Control site conditions. This indicates not only that the CMT was effective in increasing natives and decreasing AIP, but that restoration has been achieved for both the West and Lake Tallac lagoons.

5.7.2 Water Quality

The parameters selected for evaluating water quality in the lagoons were temperature, pH, turbidity, and DO. These parameters were required to be monitored during the CMT Project as they may impact other aquatic life through complex interrelationships. While the temperature in 2019 varied from 2024 temperatures, both contained similar ranges, and the 2024 Control site data remained consistent with the application/treatment sites data both in the West and Lake Tallac lagoons. A similar pattern occurred for all the water quality parameters when comparing the 2019 and 2024 datasets. In every case, the 2024 application/treatment site datasets were similar to the 2024 Control site datasets, indicating restoration for water quality in the West and Lake Tallac lagoons.

5.7.3 Benthic Macroinvertebrates (BMI)

The metrics used to analyze BMI in the lagoons are overall richness, EPT richness, diversity, tolerance, and function. These metrics, used in combination with the Index of Biological Integrity, resulted in a detailed evaluation of BMI data, which can be reviewed in the BMI Summary Report (Appendix A). Data collected from the 2024 sampling event showed all the metrics as either being statistically equivalent to the pre-treatment values (2022) or showing improvement from pre-treatment values in both the West and Lake Tallac lagoons. Overall richness has increased in some cases, and tolerance has decreased, suggesting that water quality may have improved in treatment sites post-treatment. As a result, restoration for BMI in the West and Lake Tallac lagoons has been achieved.

6.0 RESULTS OF CMT METHODS ON AIP CONTROL

The assessments of CMT methods effectiveness were completed using rake sampling and hydroacoustic scanning methods described in Section 4.0 (monitoring). Based on surveys of aquatic plants over the past 10 years, greater than 95 percent of the aquatic plant biovolume in the lagoons currently consists of the AIP species, which are the non-native Eurasian watermilfoil and Curlyleaf pondweed, and the native nuisance Coontail.

The CMT goals and objectives included AIP reduction, water quality maintenance or improvement, and other criteria as described in Section 3 of this report. The criteria for successful outcome of the Group A and Group B methods on the AIP target species were: (1) reduce and maintain by 75% the total biomass ("biovolume") of the target AIP (Eurasian watermilfoil, Curlyleaf pondweed and Coontail); (2) increase the occurrence and percent composition of desirable native plants (primarily *Elodea canadensis*) relative to invasive and nuisance plants, and (3) achieve and maintain a minimum 3-foot VHC in test sites. At the close of each CMT season, an Efficacy Report regarding progress on these criteria was prepared by Environmental Science Associates (ESA). ESA data was obtained using extensive rake sampling and analysis of data collected. These reports are accessible in Appendix A (Efficacy Reports).

In addition to the rake data, TKPOA staff performed biweekly hydroacoustic scans during the CMT project. The scan data, transformed into "heat maps", provided lagoons-wide surveys of the abundance (biovolume) of AIP (See Figures 6-9 to 6-11). The scan data was also used to determine VHC by calculating the distance from the top of plants to the water surface. As described in Section 4.4, the data from rake sampling and scan data were used to calculate "species-specific biovolumes". (See Appendix H for Biovolume Metrics and Calculations).

6.1 Rake Sampling Data

Due to the voluminous data, graphs and tables provided in each annual report, the key results of CMT treatments for Years 1, 2, and 3 are summarized and presented below graphically by a series of gradient/shaded "arrows". These results are based on rake fullness and species relative abundance data are derived from rake sampling (Detailed data graphs are accessible in Appendix A). An example is provided in Figure 6-1. Solid black represents fully successful results (75% reduction in AIP abundance); gray represents 50 to 65% reduction in AIP abundance, and white represents less than 40% reduction in AIP abundance. Gradients show intermediate ranges of successful results. In the example below (Figure 6-1), the top arrow (a) represents an excellent outcome in Years 1 and 2, but less success in Year 3. The bottom arrow (b) represents a successful outcome in Year 1 but limited to no success in Years 2 and 3. The arrows (a, b) represent different monitoring locations for AIP (near-shore zone and mid-channel) (see Figure 4-2).

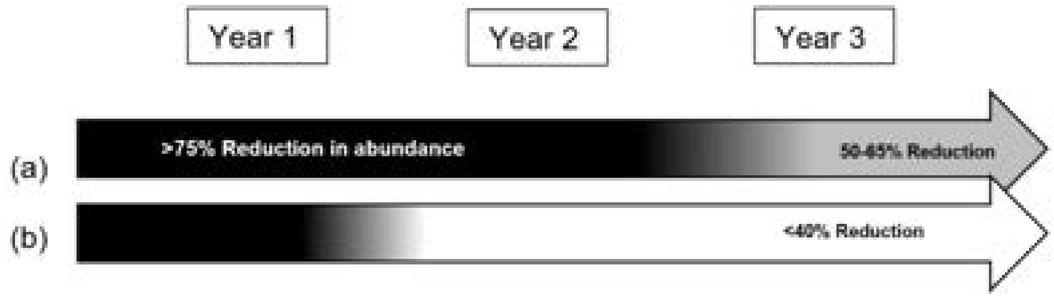


Figure 6-1. Example of Arrow Gradient Summaries representing CMT method effectiveness in years 1, 2, 3.

6.2 Results of CMT Group A Methods: West Lagoon Sites

The CMT Project evaluated three Group A methods identified as having the potential to reduce, or “knock-back” AIP biovolume by 75%. These consisted of two herbicides (Endothall and Triclopyr), UVC light, and LFA, all of which were implemented in 2022. While herbicides were only applied in Year 1 (2022) of the CMT, UVC and LFA method tests were conducted in 2022 and then continued as non-herbicide Group A treatments in 2023 and 2024. UVC treatments were also tested as a Group A combination method whereby UVC treatments were applied in 2023 and 2024 to mid-channel areas where herbicides had been applied to near-shore zones in 2022. Section 3.6 of this report further describes the stand-alone and combination Group A methods tested. It is important to note that Triclopyr is selective and does not control Coontail.

6.2.1 AIP Reduction in Herbicide Only, UVC Only, Herbicide/UVC Combination, and LFA Methods

In 2022, Endothall and Triclopyr herbicides were applied only once to 13 CMT sites over a period of 6 days, including three alternating days when no herbicides were applied. Seven of these sites were Herbicide Only sites and six sites were Herbicide/UVC Combination sites. Only herbicides were used in these sites during 2022. In subsequent Years 2 and 3, UVC treatments were made only in the mid-channel areas of the six “Combination sites” where herbicides had been applied only to near-shore zones in 2022. The results are summarized in Figure 6-2.

The Figure 6-2 gradient arrows represent the level of success in achieving and maintaining 75% reduction in abundance. The gradient arrows show that the one-time Endothall applications resulted in successful control of AIP in mid-channel areas for two years and partial control in Year 3. Near-shore zone control with Endothall was only effective in Year 1. The lack of effectiveness in the near-shore zones was probably due to the almost four-foot increase of water level in Year 2, and a one to two-foot increase in Year 3, which created previously untreated (in 2022) habitat into which AIP spread.

Triclopyr, which selectively controls Eurasian watermilfoil and does not control Coontail, had only moderate effectiveness on total AIP in mid-channel areas, but poor effectiveness in near-shore zones. The lack of overall AIP reduction in Triclopyr sites is mainly due to the unimpaired growth of Coontail, which is not controlled by Triclopyr.

The effectiveness of UVC was limited to mid-channel areas, where AIP abundance was reduced primarily in Years 2 and 3 when UVC methodologies were improved. These improvements included increases in UVC-exposure time, and reducing physical gaps between the placements of the UVC lamp arrays. Importantly, the UVC treatments were more effective when the lamp arrays were lowered directly onto the top of the aquatic plant canopy, primarily because the characteristically high turbidity of the lagoon waters degrades light transmissivity (and UVC effectiveness) rapidly with distance.

The Herbicide/UVC Combination methods had variable results (Figure 6-2 (b)). Endothall /UVC treatments resulted in good control in Year 1 mid-channel areas but were only very effective in near-shore zones in Year 1, not in Years 2 or 3 (similar and likely for the same reasons as the Endothall Only sites). Triclopyr did not produce acceptable results in reducing overall AIP in the near-shore zone where it was applied. Rake sampling showed that this was due to sustained Coontail populations, which were not controlled by either Triclopyr, or UVC treatment: UVC treatments in mid-channel slightly improved in Year 3, but did not meet the 75% level of reduction in overall AIP. In general, UVC is least effective on Coontail compared with the other target AIP (See Section 6.2.5), which can be expected because Coontail is not rooted and moves freely in the water based on wind, currents, and boat traffic.

6.2.2 Laminar Flow Aeration (LFA).

Figure 6-2 (a) shows that LFA did not reduce AIP throughout the three-year CMT project. In fact, AIP abundance increased in LFA Site 25 in Years 2 and 3, compared with untreated Control sites as documented in the Annual Efficacy Reports (See Appendix A).

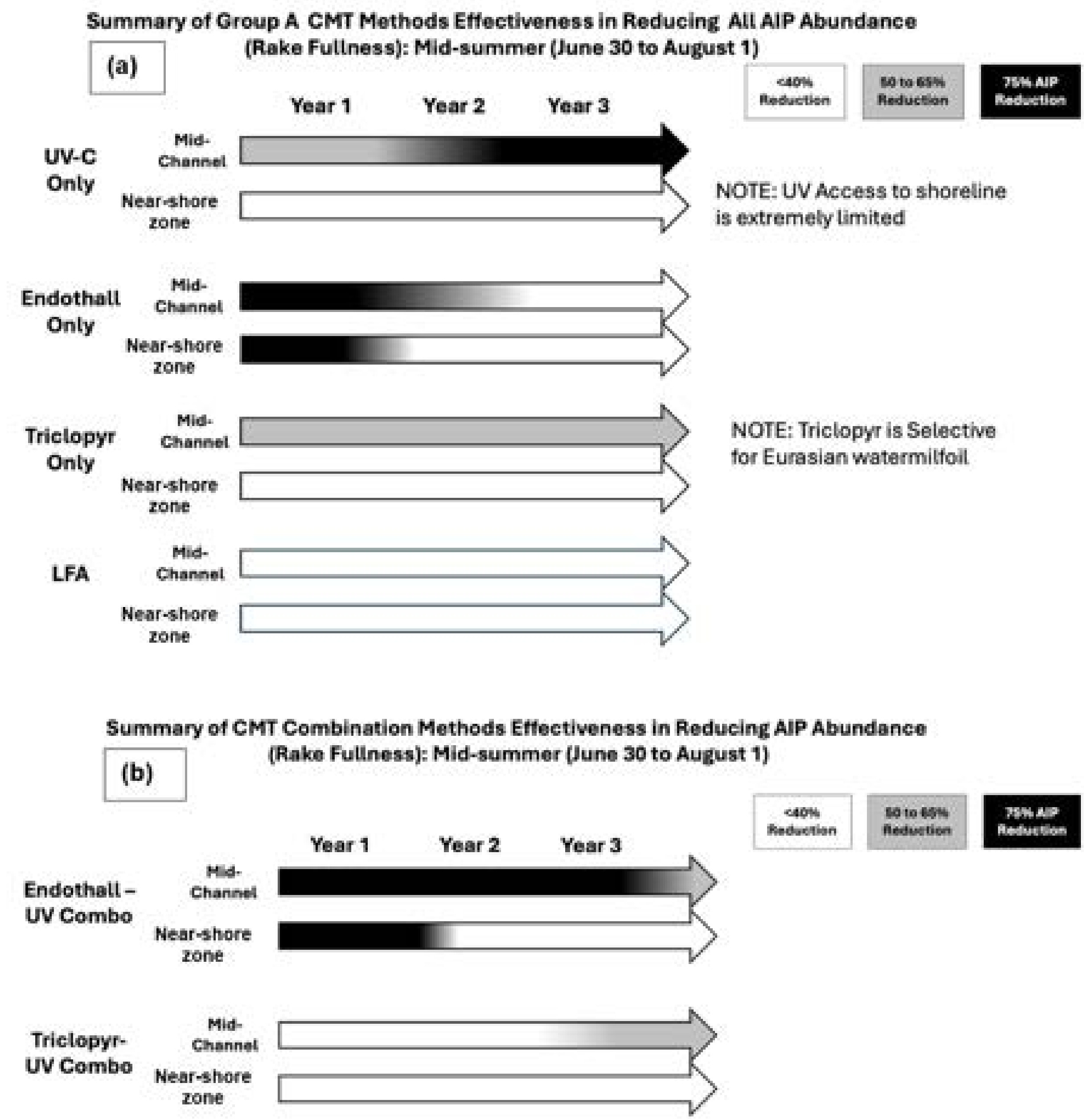


Figure 6-2. (a) Effectiveness of CMT Group A methods on all AIP: Herbicide (entire site), UVC only (mid-channel only), and LFA (mid-channels); (b) Effectiveness of Combination sites with near-shore zone application of herbicides (Year 1 only), and UVC treatments in mid-channel areas in Years 2 and 3. Note that Triclopyr does not control Coontail, a major component of AIP.

6.2.3 Species-Specific Responses to Group A Methods - Herbicides Only

Using rake sample data, the percent contribution to overall abundance for each species can be calculated in both mid-channel and near-shore zones. This metric provides valuable information on how CMT methods affected each type of AIP. These data are also instructive in understanding how AIP species responded to the increased water depth from 2022, when herbicides were applied, to 2024 when water depths had increased by about 5 feet. Since herbicides were applied during very low water levels in 2022, near-shore zones had not been submerged in 2022 and thus did not receive any treatments. However, as water levels increased after Year 1, untreated near-shore zones became submerged and provided more AIP habitat in Years 2 and 3 for growth and expansion of AIP. This may account for the reduced effectiveness of Year 1 herbicide applications in the near-shore zones in Year 2 and greatly reduced efficacy by Year 3. The effects of these conditions are also reflected in the species-level responses in mid-channel and near-shore zone habitats (Figures 6-3 to 6-6).

Eurasian watermilfoil
Figure 6-3 shows that Endothall or Triclopyr used alone provide nearly 3 years of successful Eurasian watermilfoil control in both mid-channel and near-shore zones. Triclopyr sustained control better than Endothall in Year 3, most likely due to its (systemic) movement into the roots and rhizomes of this plant during Year 1 (compared to Endothall, a “contact” herbicide). The data that shows this information is presented in the CMT Annual Reports (See Appendix A).

Curlyleaf pondweed
Endothall used alone was effective in controlling Curlyleaf pondweed in both mid-channel and near-shore zones in Year 1. In Year 2, it was partially effective in mid-channel areas, but not in near-shore zones, nor did it successfully control Curlyleaf pondweed in Year 3 in any areas. Triclopyr-only applications resulted in 75% reduction of Curlyleaf pondweed in mid-channel areas for the entire three years. However, after Year 2, Triclopyr did not control Curlyleaf pondweed in near-shore zones (Figure 6-3). The effectiveness of herbicides on Curlyleaf pondweed was reduced by the large ‘bank’ of turions present throughout the lagoons, which did not appear to be affected by the herbicides prior to sprouting. These turions represent one of the primary challenges for future AIP management in the lagoons as discussed later in Section 11.2 of this report.

Coontail
Endothall alone successfully controlled Coontail in mid-channel areas in Years 1 and 2. However, control in the near-shore zones was only in Year 1. By Year 3, Coontail was not controlled in either mid-channel or near-shore zones. (Figure 6-3).

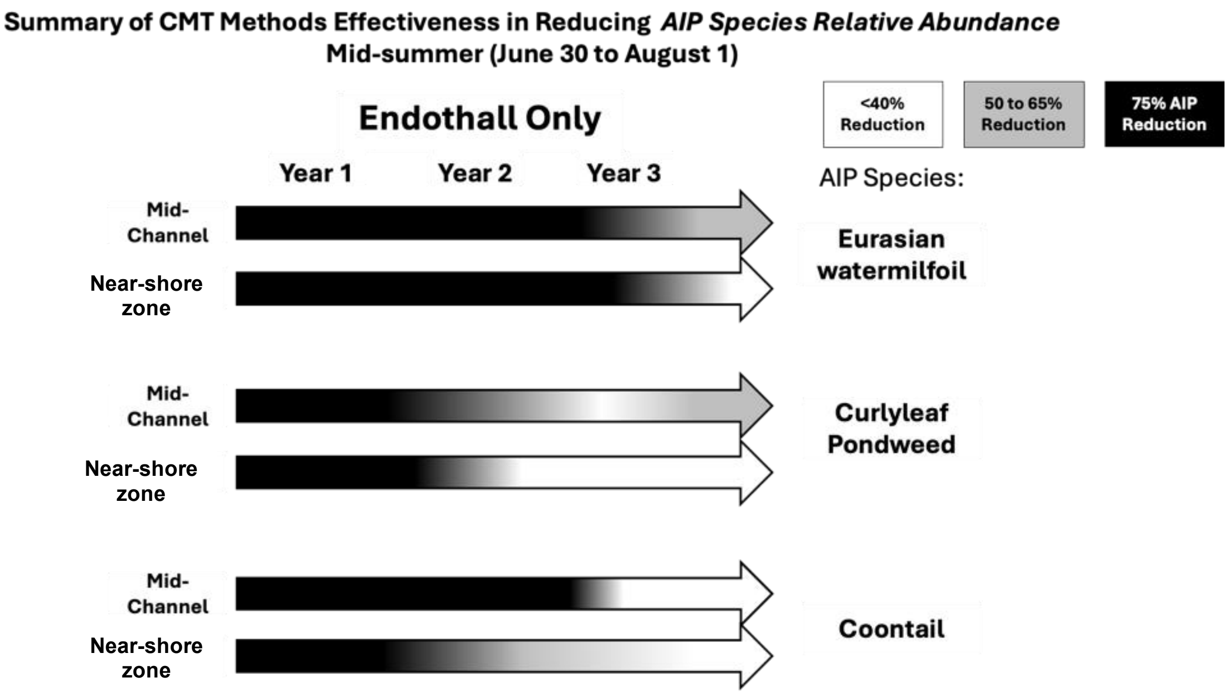


Figure 6-3. Effectiveness of Group A entire-site Endothall applications on AIP species.

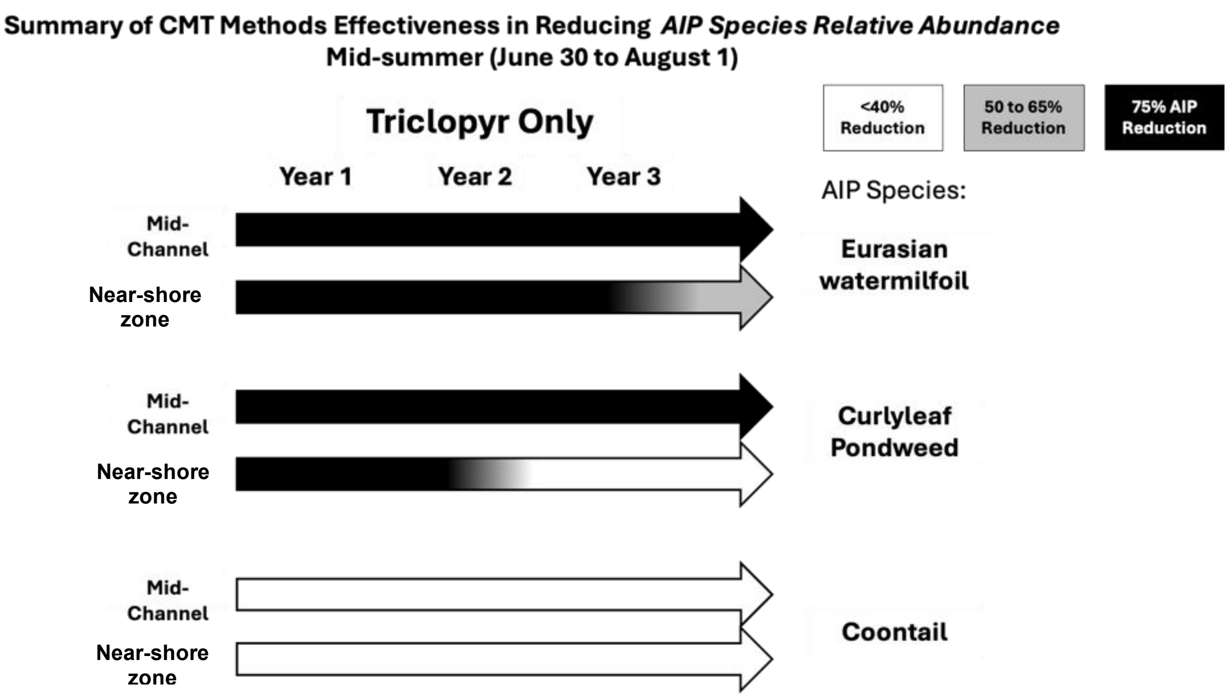


Figure 6-4. Effectiveness of Group A entire-site Triclopyr applications on AIP species.

6.2.4 Species-Specific Responses to Group A UVC Only Methods

The UVC treatments were made only in the mid-channel areas of the CMT sites, although regular bi-weekly rake sampling of both mid-channel and near-shore zones were conducted throughout the CMT project years. The summary results (Figure 6-5) show that Eurasian watermilfoil was well controlled in the mid-channel areas in Years 2 and 3 but not in Year 1. Curlyleaf pondweed was controlled only partially in Year 2 and successfully in Year 3. Coontail was better controlled in mid-channel areas in Year 3, but did not meet 75% reduction levels in any of the CMT project years with UVC.

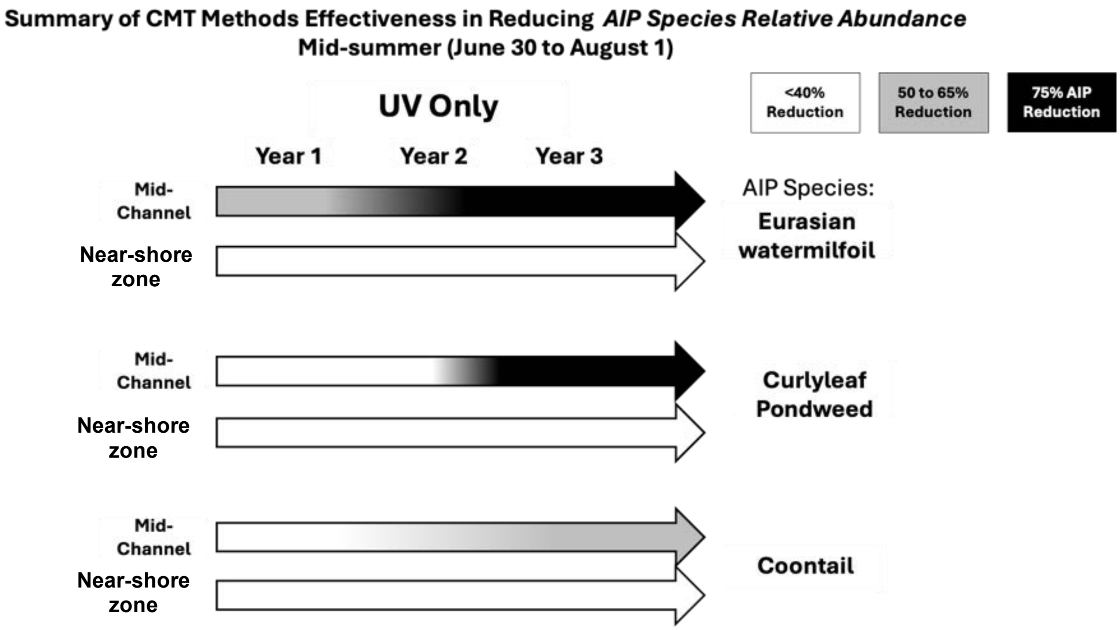


Figure 6-5. Effectiveness of UVC Only treatments. (near-shore zones were not treated)

6.2.5 Species-Specific Responses to Group A Endothall/UVC Combination

In this Combination method, Triclopyr or Endothall was applied only to near-shore zones in Year 1 (2022). In Year 2, the mid-channel areas were treated with UVC three or four times (depending on Year and Site). Therefore, summary results for Year 1 only reflect the effectiveness of herbicide applied to the near-shore zones. Summary results for Years 2 and 3 reflect the AIP responses to UVC in the mid-channel areas (Figures 6-6 to 6-8).

Eurasian watermilfoil
Figure 6-6 shows that Endothall and UVC together resulted in good control of Eurasian watermilfoil in mid-channel and nearly all the near-shore zones in all three years.

Curlyleaf pondweed
Combination treatments successfully controlled Curlyleaf pondweed in Years 1 and 2 in mid-channel areas, but only in Year 1 in near-shore zones. The near-shore zone populations of Curlyleaf pondweed were not controlled in Years 2 or 3. This is not surprising since these areas were not treated by UVC, nor had they been exposed fully to Endothall in 2022.

Coontail

Combination Endothall and UVC provided moderate control in Year 2, but poor control in Year 3 regardless of habitat (near-shore zone or mid-channel). The lack of differences in habitat control effectiveness probably reflects the lack of rooting in Coontail, which allows it to move easily to both near-shore habitats and deeper, mid-channel habitats.

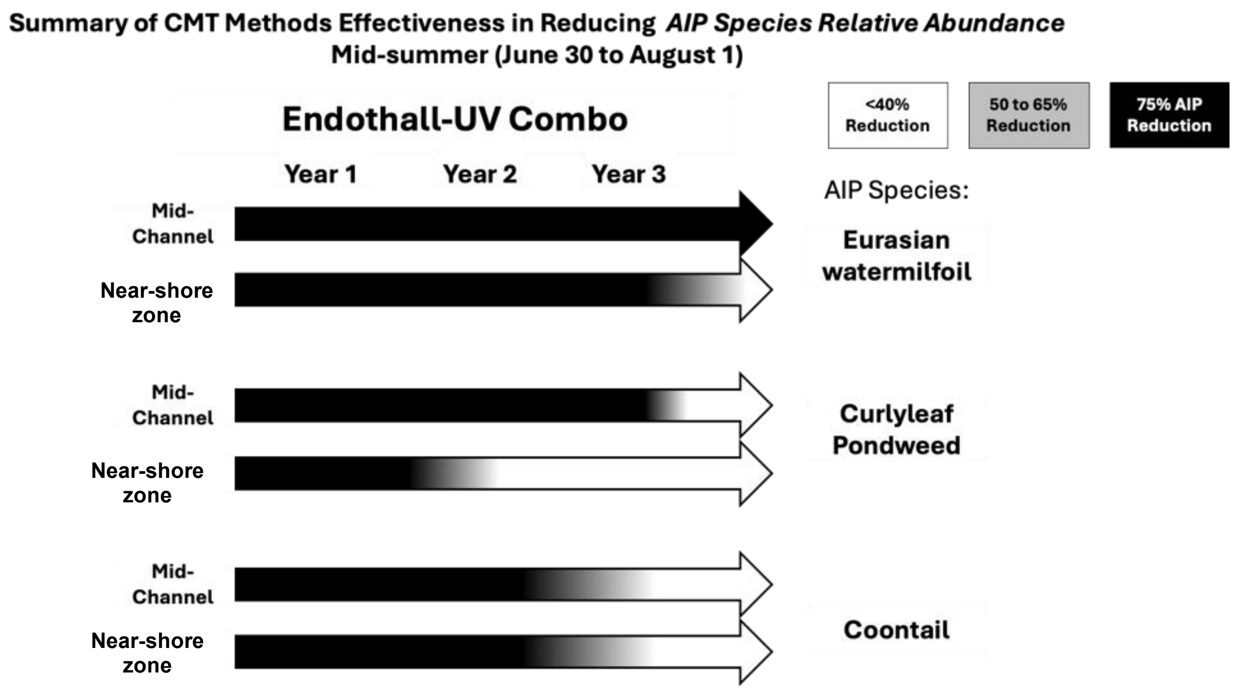


Figure 6-6. Efficacy of Combination Endothall (Year 1, near-shore zone only) and UVC (Years 2, 3).

6.2.6 Species-Specific Responses to Group A Triclopyr/UVC Combination

Triclopyr selectively controls Eurasian watermilfoil, but not Coontail. The CMT data also shows that Triclopyr can reduce the abundance of Curlyleaf pondweed, a finding not anticipated by the CMT Project design. The effectiveness of the Triclopyr/UVC Combination method for each AIP species is summarized in Figure 6-7.

Eurasian watermilfoil

The Triclopyr/UVC Combination methods provided three years of control in mid-channel areas and good control in near-shore zones in Years 1 and 2. The selectivity and ability of Triclopyr to affect roots and rhizomes of this plant enabled this successful, multi-year efficacy.

Curlyleaf pondweed

Even though Curlyleaf pondweed is not listed on the Triclopyr labels as a “target” weed, the CMT Triclopyr applications in both the entire-site applications and the near-shore zone Combination applications, with UVC treatments in Years 2 and 3, resulted in better than expected control of this species in all three years in the mid-channel areas (Figure 6-7). However, control was not sustained in the near-shore zones in Year 2 and Year 3. This reflects the ability of Curlyleaf pondweed to move easily into newly submerged near-shore zone habitats either by spread from fragments or turion in these habitats that had not been exposed to Triclopyr in 2022.

Coontail
The lack of reduction in Coontail was expected because Triclopyr was known to not affect this species. However, the lack of Coontail control in mid-channels, which received UVC treatments in Years 2 and 3, suggests that this UVC method may not be very effective either for Coontail control. The problem is compounded by Coontail's ability to move easily into areas - and water volumes - not exposed to herbicides in Year 1.

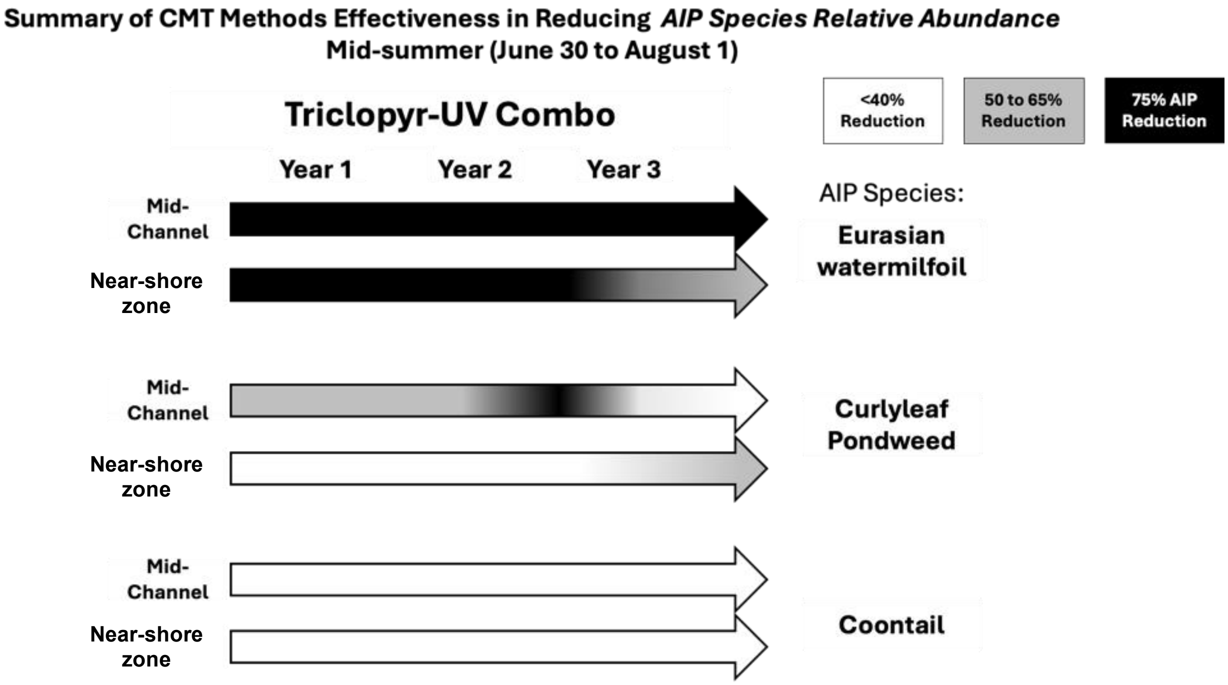


Figure 6-7. Efficacy of Combination Triclopyr (Year 1, near-shore zone only) and UVC (Years 2, 3).

6.2.7 Hydroacoustic Monitoring Results

The biweekly hydroacoustic scans provided lagoon-wide assessments of AIP biovolume (abundance). The scan data was transformed into color-contoured heat maps that show high biovolume in red (large abundance of AIP), intermediate levels of biovolume in yellow, and low biovolume (least abundant AIP) in green and blue.

The heat maps below (Figure 6-8) are grouped horizontally by season (late spring, early summer and summer), and vertically by year. The early summer "window" is important because rapid growth of AIP occurs then, and Curlyleaf pondweed produces most of its turions by early July. Therefore, preventing growth of Curlyleaf pondweed between May and July is critical to successful control of this species. As noted previously, however, the panels of maps reflect total aquatic plant biovolumes and do not distinguish between plant species, but do provide a large-area summary view of efficacy.

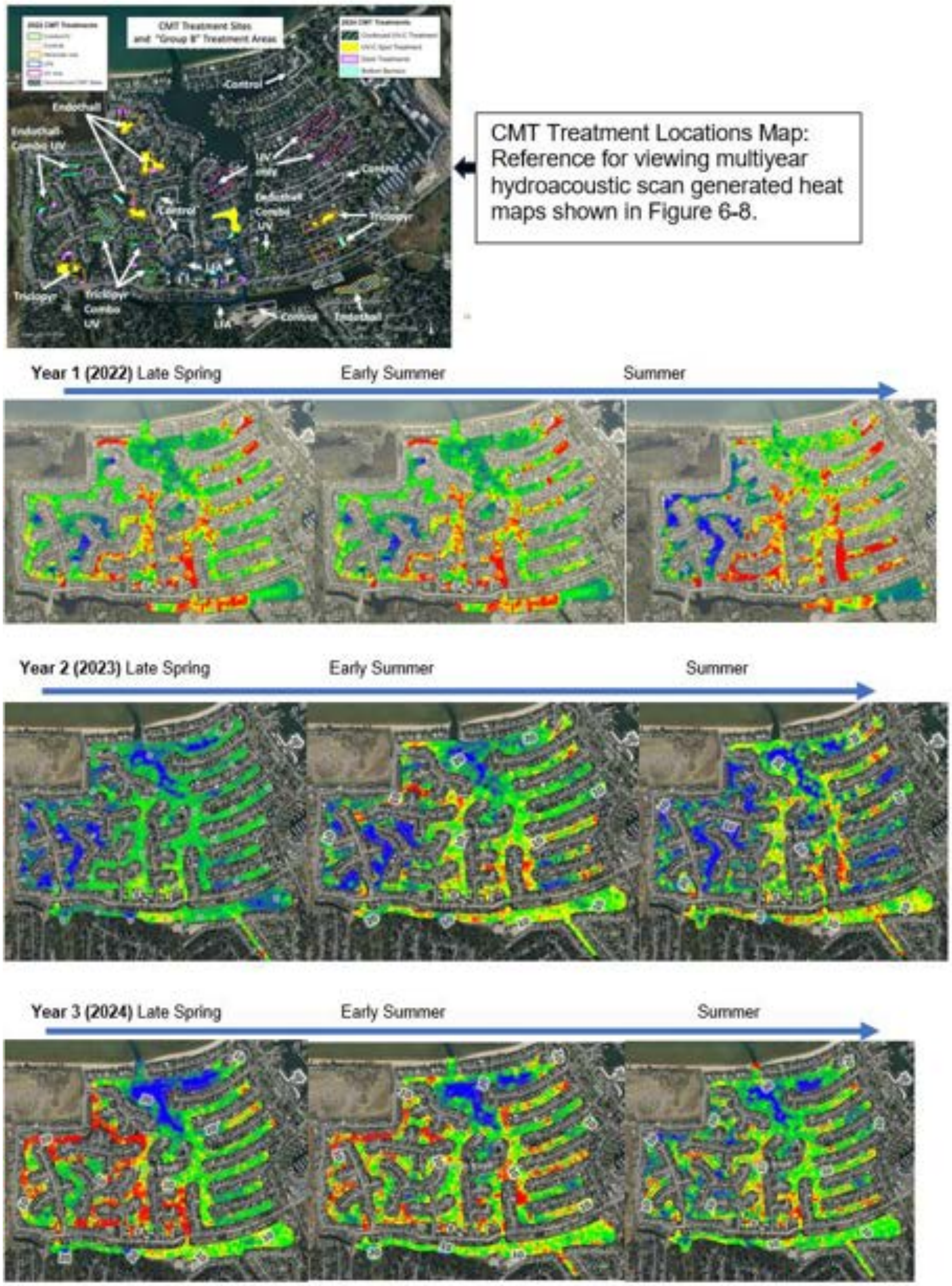


Figure 6-8. Heat maps showing abundance (Biovolume) of AIP in Years 1, 2 and 3: Late Spring, Early Summer, and Summer.

The heat maps show that, between late spring and early summer, AIP biovolume was kept low in Year 2, mainly where Endothall was applied in Year 1, and where Combination treatments (UVC mid-channel treatments) were used in Years 2 and 3. By Year 3, AIP reduction was more variable. The heat maps for 2023 also show how much deeper water reduced overall biovolume by summer even in the Control sites. This is also clearly seen in the large blues area just south of (below) the West Channel in Years 2 and 3 compared with Year 1. Although the heat maps are extremely useful in monitoring biovolume of all AIP combined, they do not provide the detail needed to determine what species were best controlled by the CMT methods. This detail is provided above in Figures 6-1 to 6-7 and is based on data from more than 20,000 rake samples taken during the CMT (See Appendix A for access to annual CMT Reports).

6.2.8 Species Biovolume

The species-specific data from rake sampling and hydroacoustic scans were used together to calculate estimates of biovolumes among the Group A methods in early July in each CMT year (Section 4.4.3). This approach provides a metric that helps quantify the biovolume occupied by each AIP species and its contribution to the overall AIP biovolume. Figure 6-9 shows that Triclopyr was successful in reducing biovolume of Eurasian watermilfoil and Curlyleaf pondweed by 75% in all CMT years compared to untreated Control sites. However, the data show that Coontail increased in biovolume compared to Control sites. This most likely resulted from the selectivity of Triclopyr, which may have enabled Coontail to occupy more habitat that no longer was occupied by Eurasian watermilfoil or Curlyleaf pondweed.

Endothall also reduced the biovolume of Eurasian watermilfoil and Coontail by over 75% in Years 1 and 2 of the CMT (Figure 6-10). Curlyleaf pondweed was only controlled well in Year 1, and none of the target plants were reduced by 75% in Year 3. Increases in lagoon water levels and the associated increases in untreated near-shore zone habitats likely explain the reduced effectiveness.

For comparisons of the biovolumes shown in Figures 6-9 and 6-11 to the efficacy “gradient arrows,” and for species-specific effects from Triclopyr and Endothall based on rake samples alone, see Figures 6-3 and 6-4. For UVC effects, compare the summary arrows in Figure 6-5.

Note that the rake sampling locally differentiated the AIP growing in near-shore zones from mid-channel areas, which may explain some differences in the biovolume and rake fullness metrics. Although the hydroacoustic scan- generated biovolumes focus on a similar seasonal period (early to mid-summer), the software that generates heat maps from the hydroacoustic scan data interpolates biovolumes at varying distances from the direct sonar acoustic signal. This distance factor, which affects the accuracy of calculated biomass, also may be the source of some variations between species biovolume calculated from both scan and rake data, and data only from rake samples. However, the species biovolume metric data is generally consistent with the rake-generated “relative abundance” data and “rake fullness” data used to generate the summary arrows in Figures 6-1 to 6-7. For example, both metrics show that Triclopyr provided long-term (three year) control of Eurasian watermilfoil and Curlyleaf pondweed but insufficient control of Coontail (Figure 6-9). However, the biovolume (hydroacoustic scan) method appears to have undervalued the UVC effects on Eurasian watermilfoil and Curlyleaf pondweed since the rake sampling indicated better results (Figure 6-5). In contrast to this, the biovolume metric indicated better control of Coontail in Year 3 than was determined by rake samples (Figure 6-5).

Taken together, the monitoring methods for the CMT methods effectiveness succeeded in producing extremely informative data.

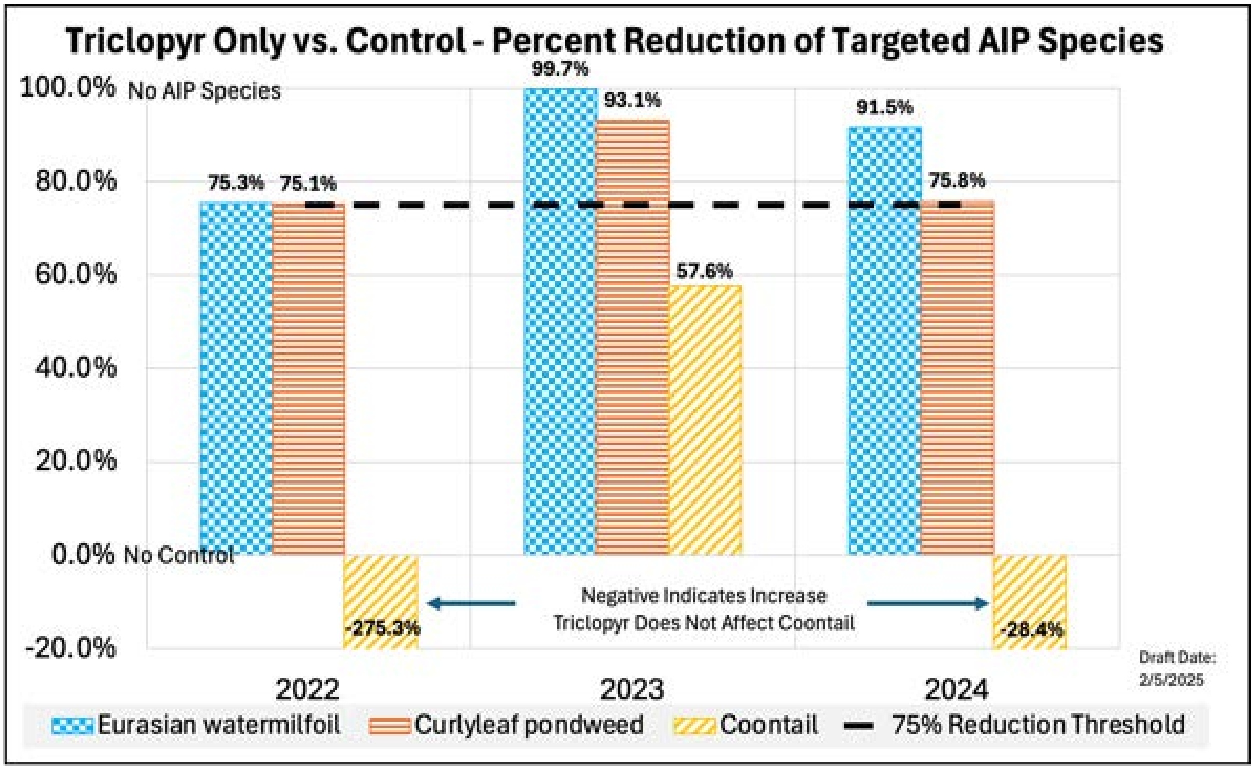


Figure 6-9. Effects of one-time application Triclopyr on AIP species biovolume. Dashed line shows 75% reduction compared with Control sites.

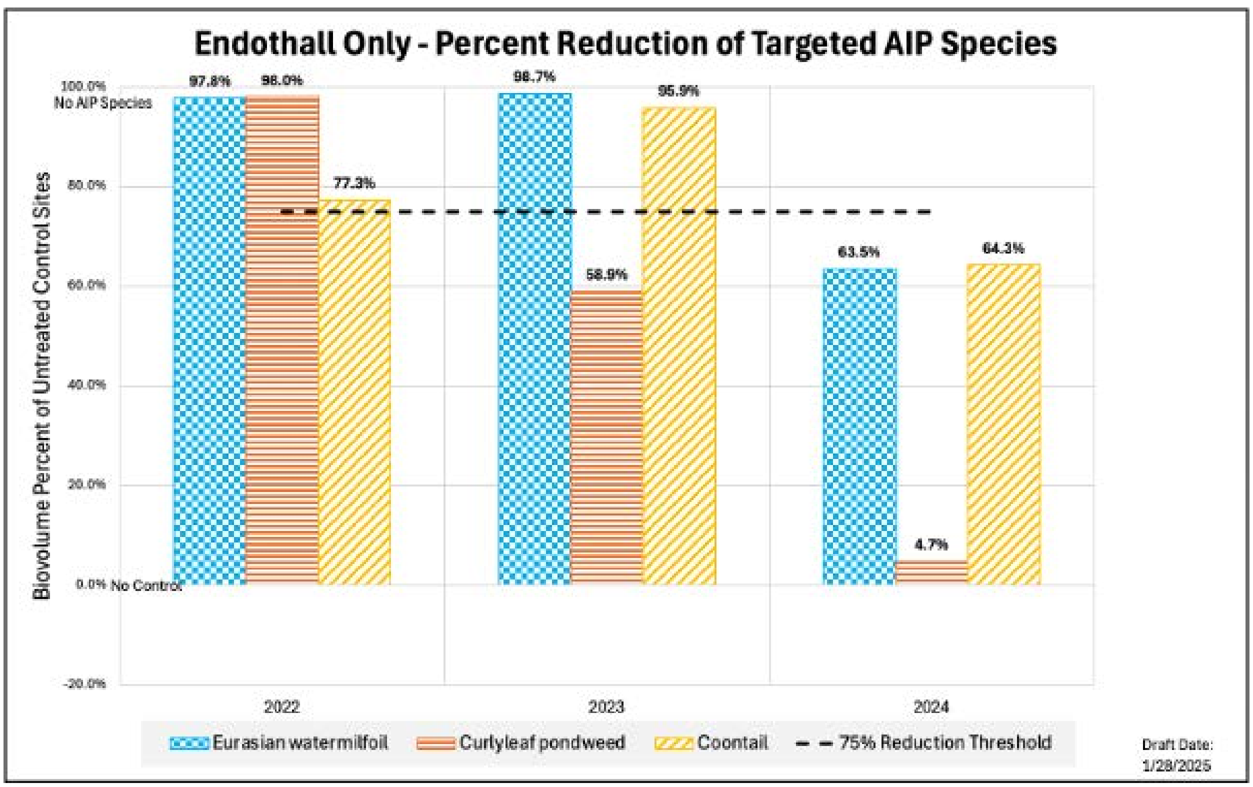


Figure 6-10. Effects of one-time application Endothall on AIP species biovolume. Dashed line shows 75% reduction compared with Control sites.

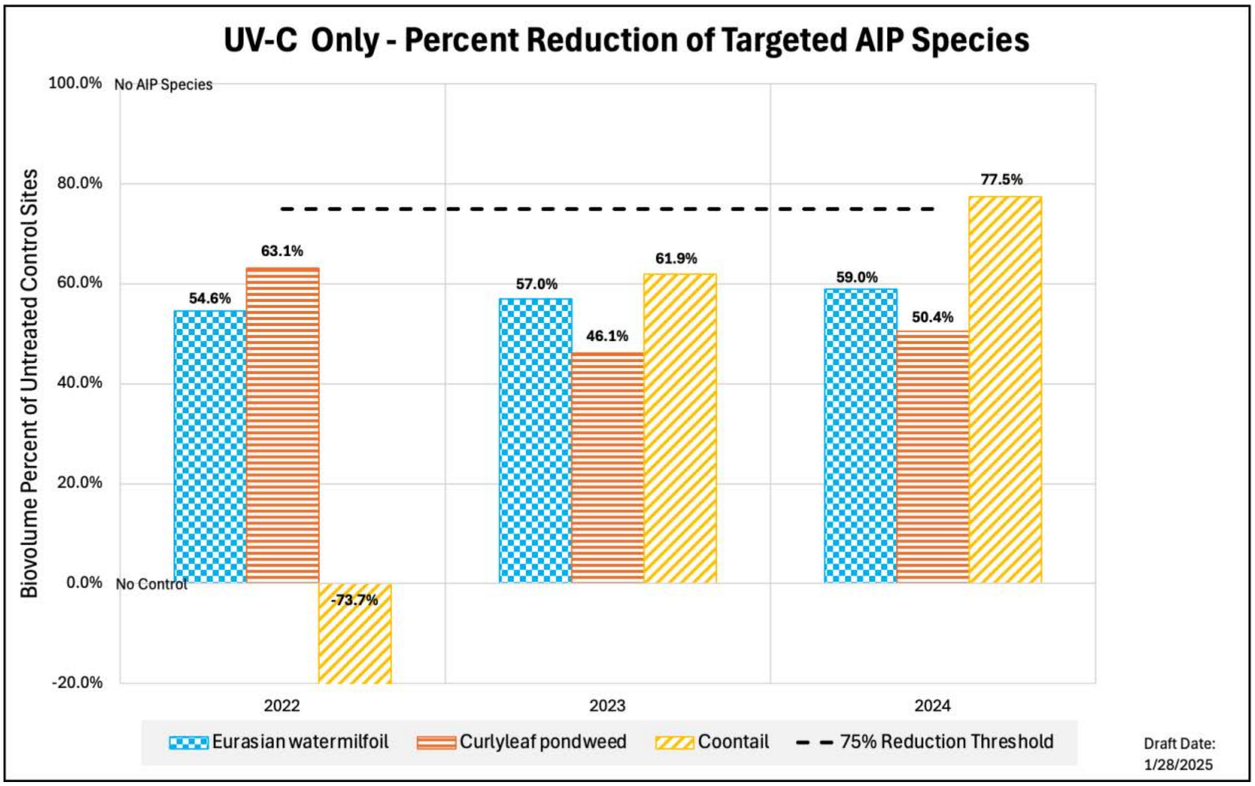


Figure 6-11. Reduction in biovolume of AIP species following UVC Only Treatments. Dashed line shows 75% reduction compared with Control sites.

6.2.9 Vessel Hull Clearance

VHC was assessed by TKPOA using hydroacoustic scan data collected pre-treatment (April/May), August, and fall (October/November). The scans provide data on the distance from the top of the AIP canopy to the water surface. The target clearance for the CMT is 3 feet between the surface of the water and the top of the plant canopy.

In all years, VHC was greater than 3 feet during the spring, April/May assessment period, including Control sites (Figures 6-12 to 6-20). However, not all Control sites maintained VHC during the peak of summer and only Control Site 18 had VHC greater than 3 feet by end of season. In Years 2 and 3, VHC in Control sites was maintained during all months assessed, but it should be noted that water levels were about 5 feet deeper mid-channel compared to Year 1. The increase in water depth by about five feet from 2022 to 2024 resulted in acceptable VHC in all CMT sites.

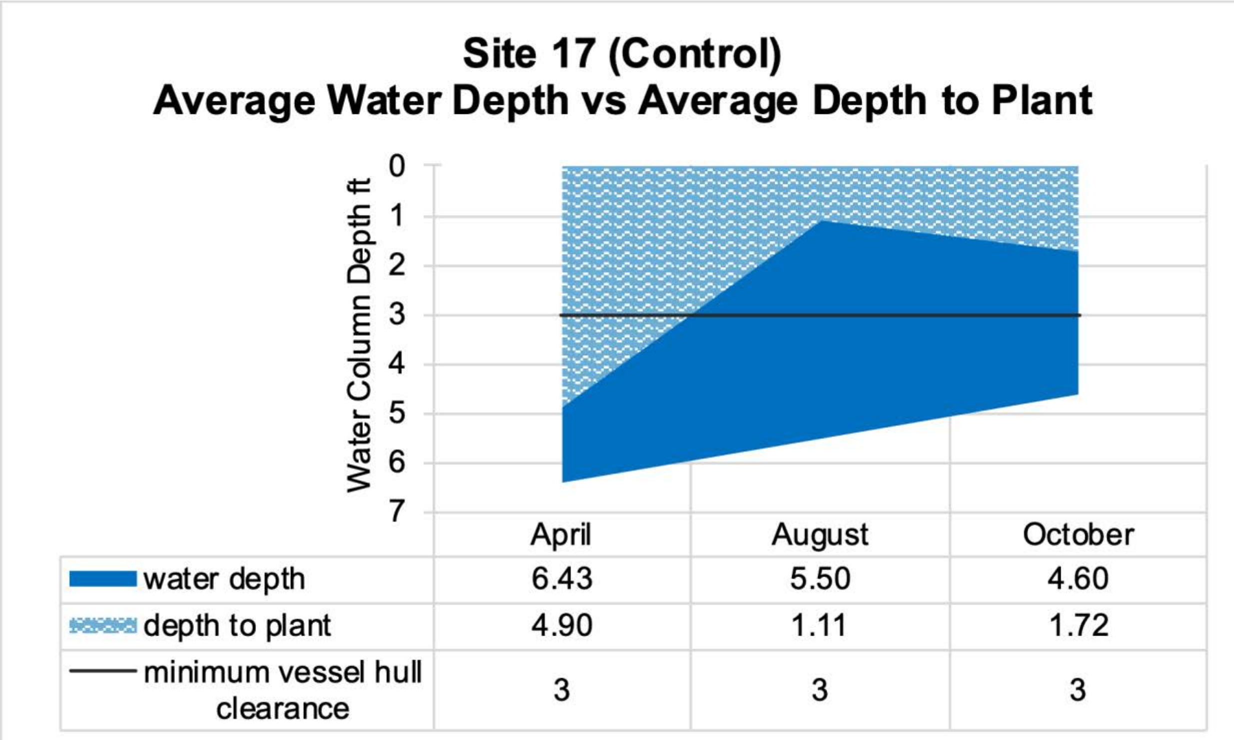


Figure 6-12. VHC in Control Site 17 in Year 1. The solid dark area represents the AIP profile

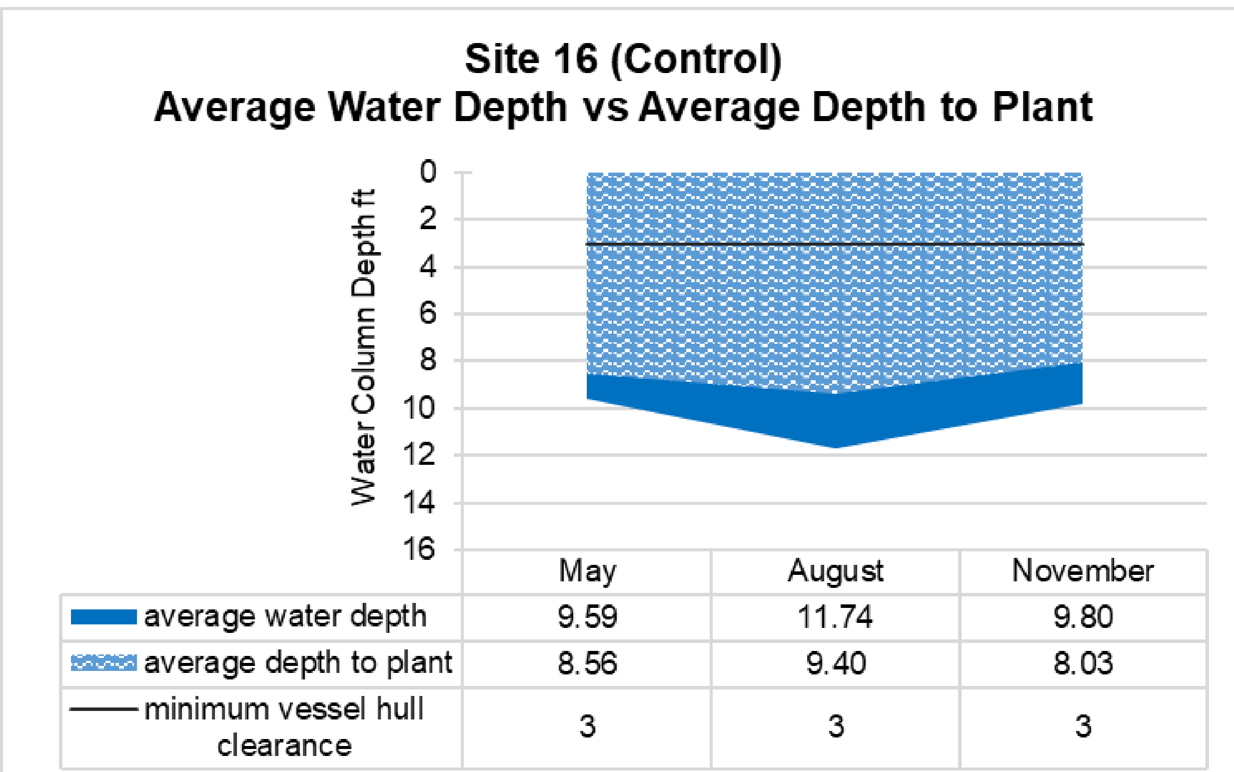


Figure 6-13. VHC in Control Site 16 in Year 2.

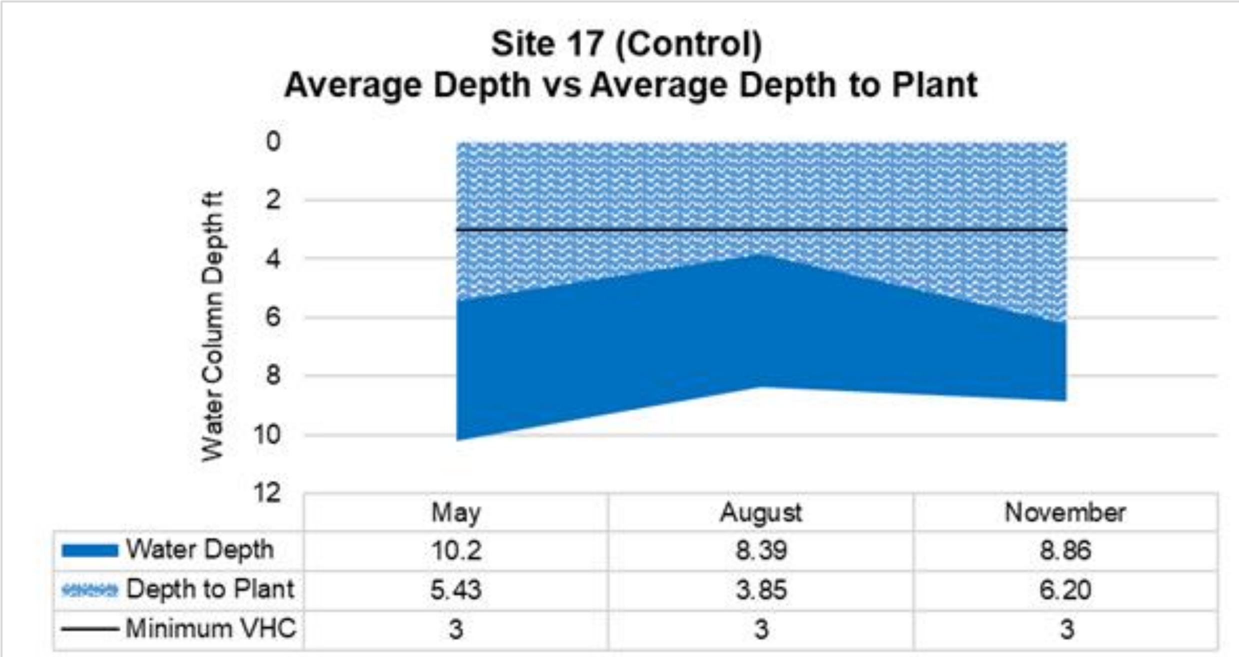


Figure 6-14. VHC in Control Site 17 in Year 3.

VHC resulting from CMT treatments in Year 1 was somewhat variable. All Endothall Only sites maintained VHC greater than 3 feet to end of season (Figure 6-15), including Site 19 in Lake Tallac. Of the Triclopyr Only sites, Site 5 maintained VHC to end of season while Sites 8 and 9 were 2 to 2.5 feet mid-season and at or near 3 feet by end of season (Figure 6-16) in Year 1. All UVC Only sites maintained VHC to end of season (Figure 6-17). Of the Combination sites, only Site 15 (Endothall + UVC) and Site 13 (Triclopyr + UVC) did not achieve VHC mid-season. VHC was greater than 3 feet in LFA Site 25 in the early season, but plants were “topped” out (at the water surface) mid-season (Figure 6-18). Note the Endothall sites sustained VHC in Years 2 and 3, partially due to high water in both those years (Figure 6-19, 6-20).

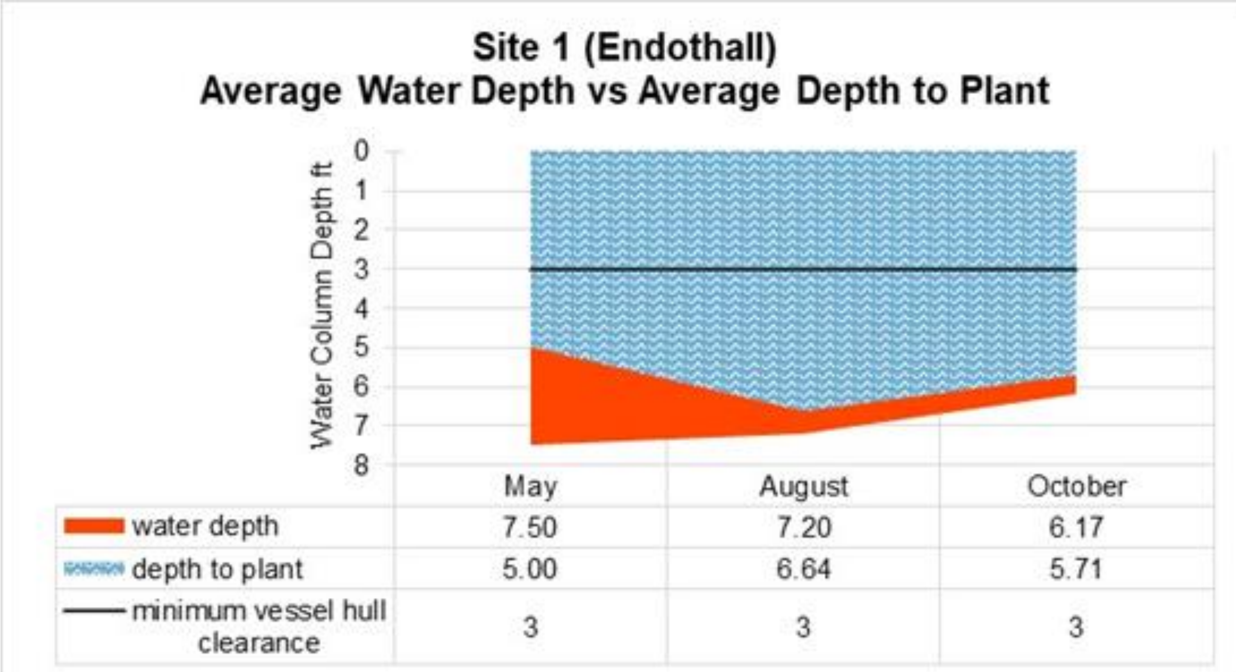


Figure 6-15. VHC in Endothall Only Site 1 in Year 1.

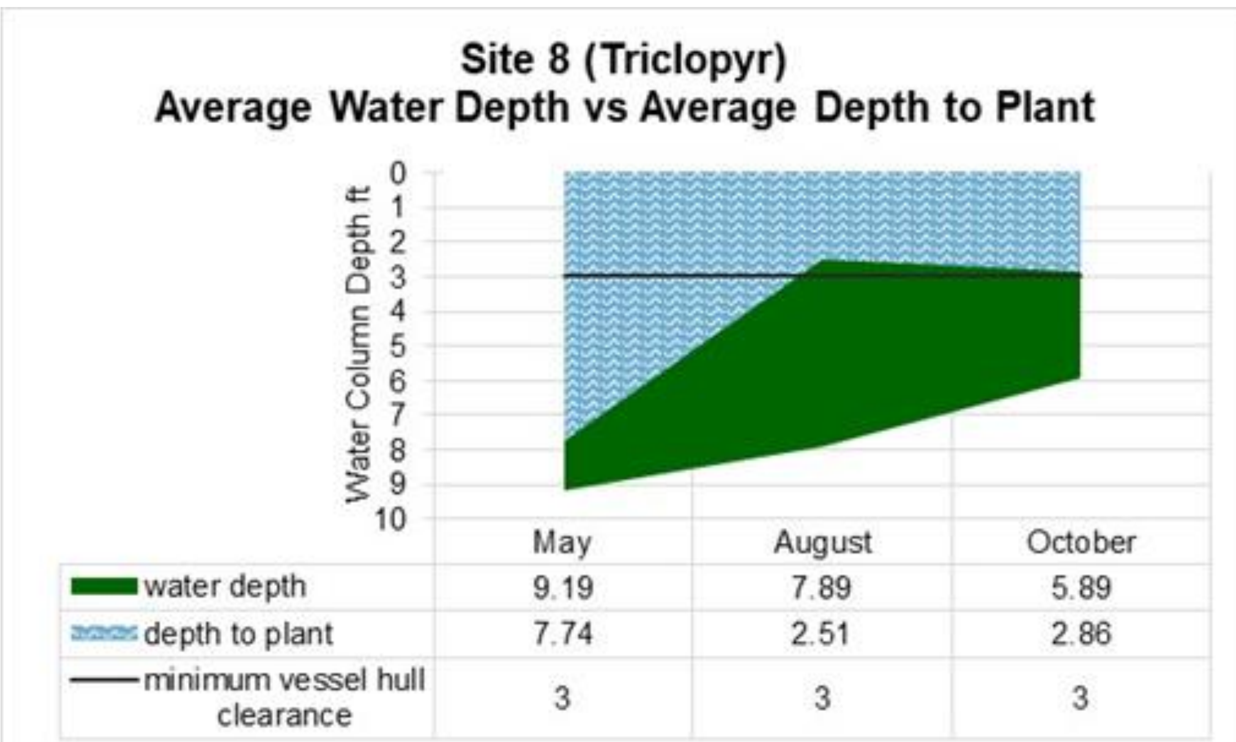


Figure 6-16. VHC in Triclopyr Only Site 8 in Year 1.

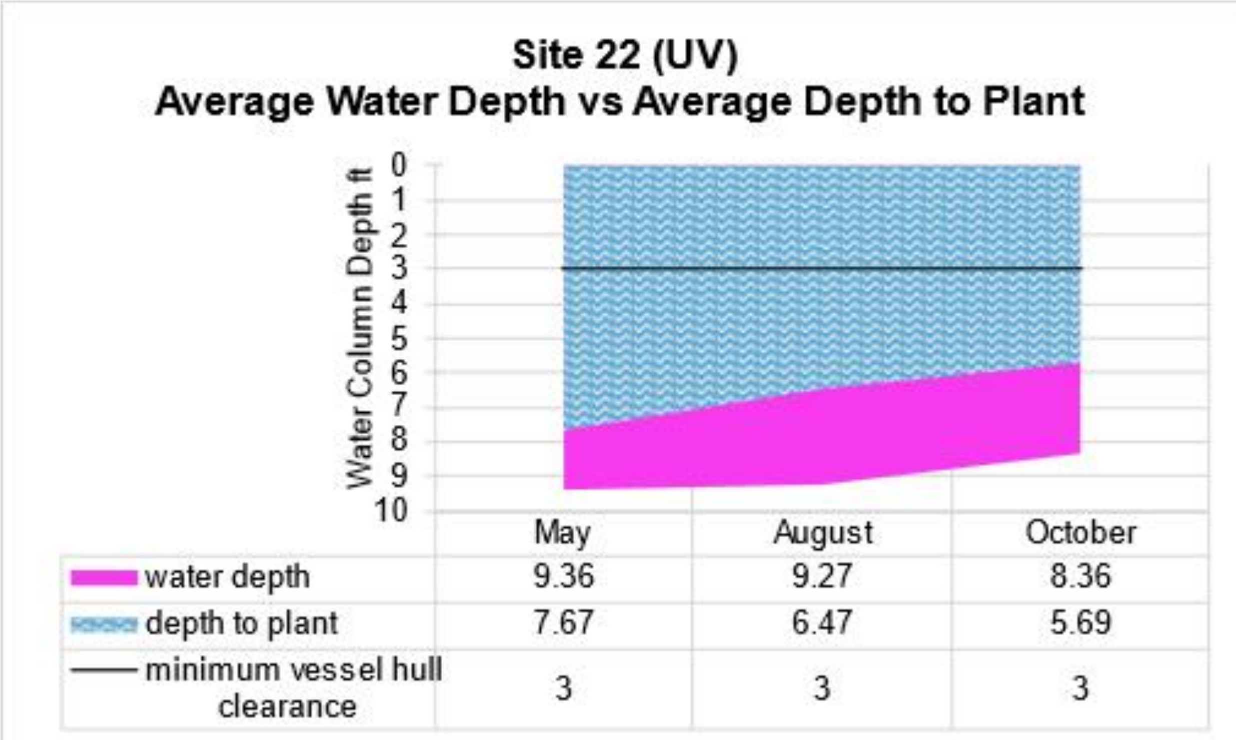


Figure 6-17. VHC in UVC Only Site 22 in Year 1.

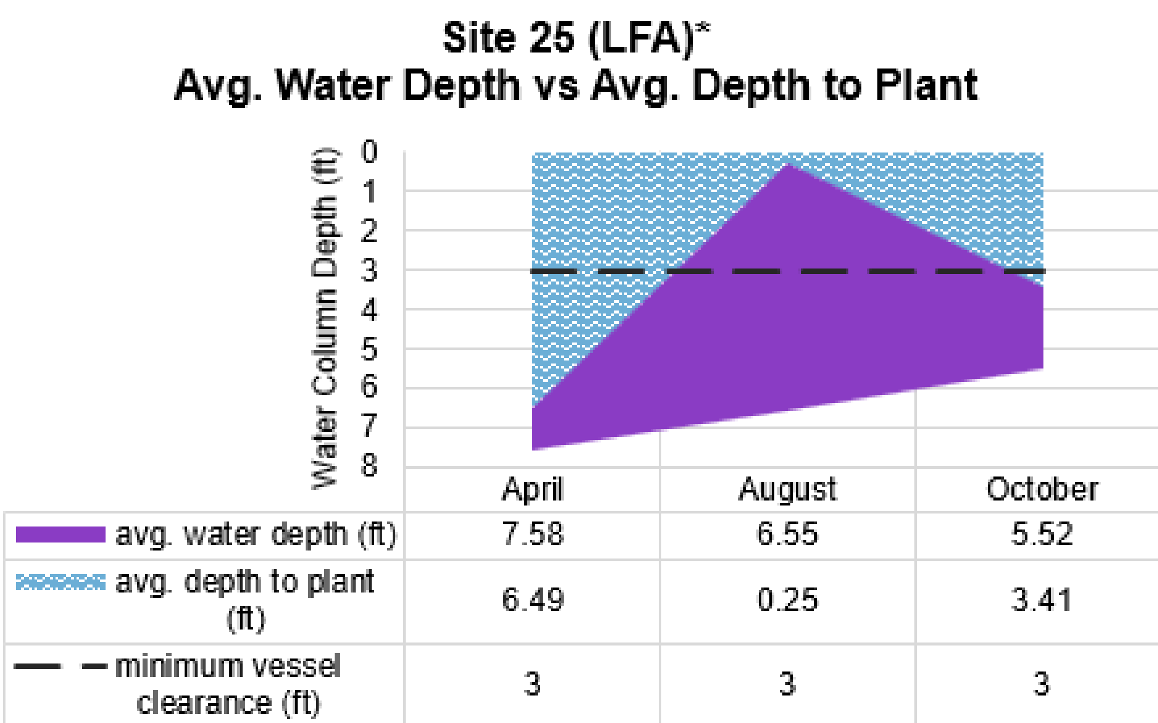
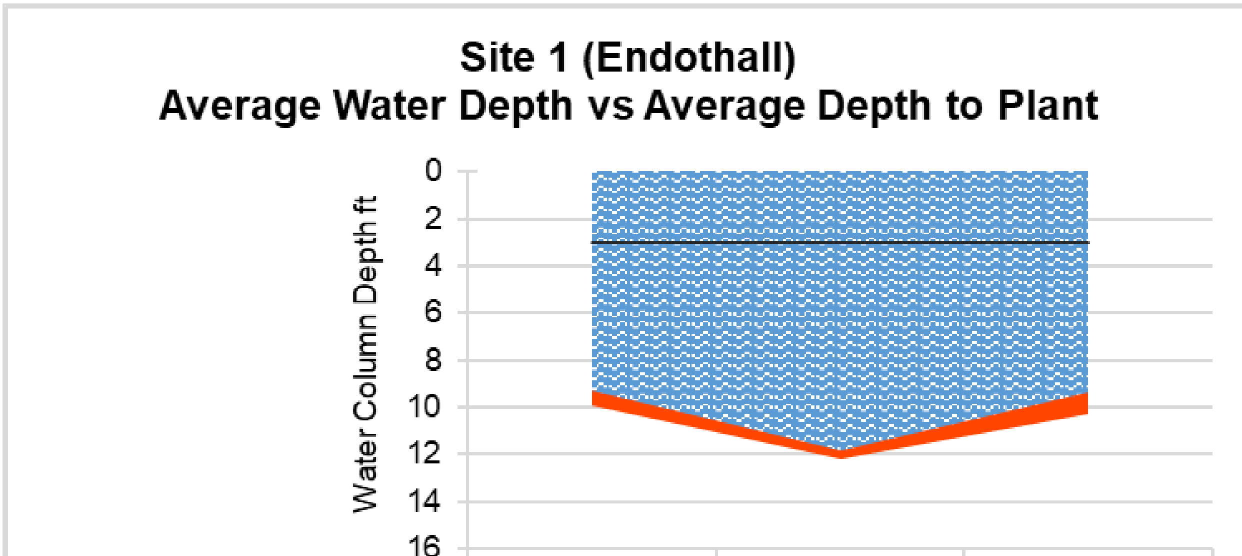


Figure 6-18. VHC in LFA Site 25 in Year 1.

Sustained VHC was observed in Years 2 and 3 for all CMT sites, including LFA. As previously mentioned, lake and lagoon water levels were substantially higher in Years 2 and 3. VHC was generally much greater in Year 2 compared to Year 3 (See Figure 12-1) , presumably due to very high water in Year 2 that limited light penetration for plant growth but subsequently allowed for plant recovery in Year 3.



	May	August	November
average water depth	9.94	12.21	10.27
average depth to plant	9.32	11.83	9.39
minimum vessel hull clearance	3	3	3

Figure 6-19. VHC in Endothall Only Site 1 in Year 2.

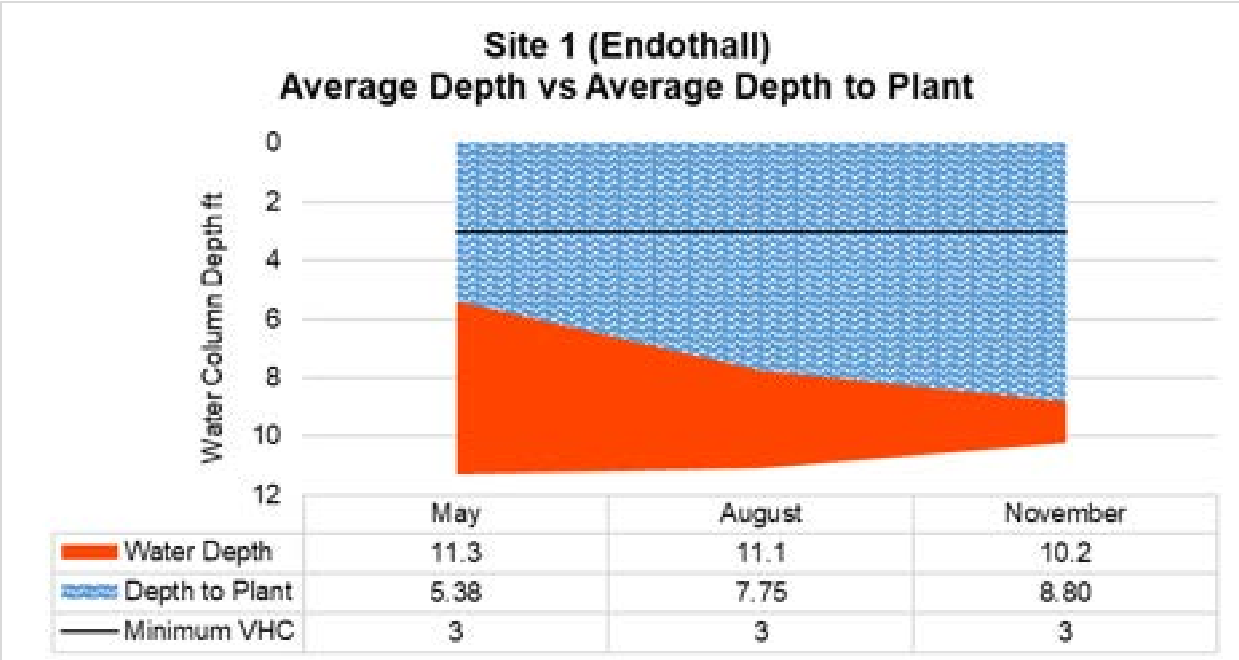


Figure 6-20. VHC in Endothall Only Site 1 in Year 3.

7.0 LAKE TALLAC: CMT GROUP A METHODS

The only two Group A methods used in Lake Tallac Lagoon were LFA and a one-time application of Endothall at 2 ppm. Before the Endothall application was made, a double turbidity curtain was installed at the east end of the lake to isolate the application site from the rest of Lake Tallac (See Figures 3-4, and 3-5). Endothall was applied to the mid-channel area, not along the near-shore zone. Water sampling for herbicide levels, and monitoring for water quality variables were the same for the Endothall treated site in the Lake Tallac Lagoon as in the West Lagoon (Appendix A Annual report CMT Year 1). Similarly, monitoring of water quality for the LFA and Control sites in the Lake Tallac Lagoon was the same as in the West Lagoon.

7.1 Effect of Endothall on Water Quality

During the weeks following the Endothall application, changes in water quality were similar to those observed in the West Lagoon Endothall sites:

(a) Some decline in DO in bottom areas.
(b) Some decrease in pH bringing levels within WQO range (7.5-8.4). This was likely due to a reduction in AIP biomass and corresponding reduction in photosynthesis-driven elevation in pH and reduced DO.
(c) Nutrients were released from decomposing AIP elevating TN, TP, and OP to 2 to 3 times the levels in the untreated Control sites.
(d) Turbidity was elevated to about twice the Control site levels (This was less of an increase than was observed in West Lagoon Endothall treated sites.)
(e) Conductivity was elevated by about 25% compared with the Lake Tallac Control Site.

7.2 Efficacy of Endothall Application in Lake Tallac

Endothall Only Site 19 and untreated Control Site 20 in Lake Tallac were dominated by Coontail. Hydroacoustic scans and rake sampling showed that Endothall reduced AIP abundance in Year 1 by over 75% (Figure 7-1.) However, this level of efficacy did not persist in Year 3. (Figure 7-1). To see the heat maps representing Lake Tallac, see Figure 6-8 and note the difference between Year 1 and Years 2 and 3. Once the turbidity curtains were removed from the Endothall application area in fall 2022, Coontail was free to move into the Endothall site in the following two years. Note that Figure 7-1 was from derived from rake-sampling data shown in Figure 7-2.

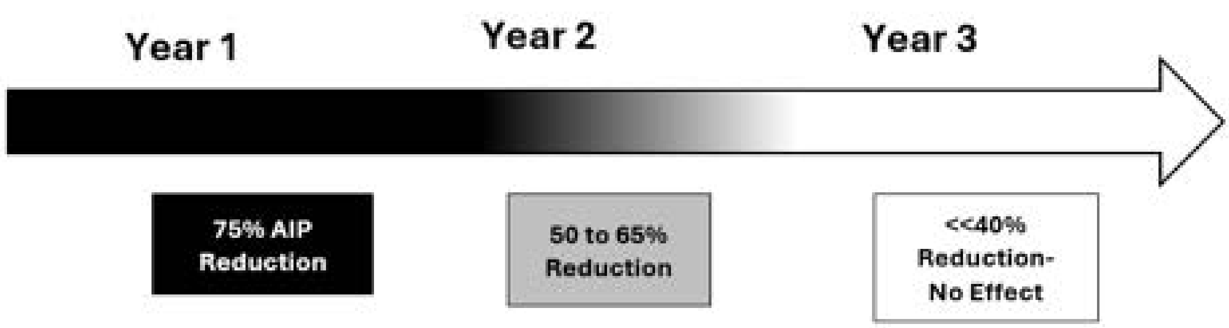


Figure 7-1. Relative abundance of Eurasian watermilfoil in Lake Tallac following one-time application of 2 ppm Endothall in 2022.

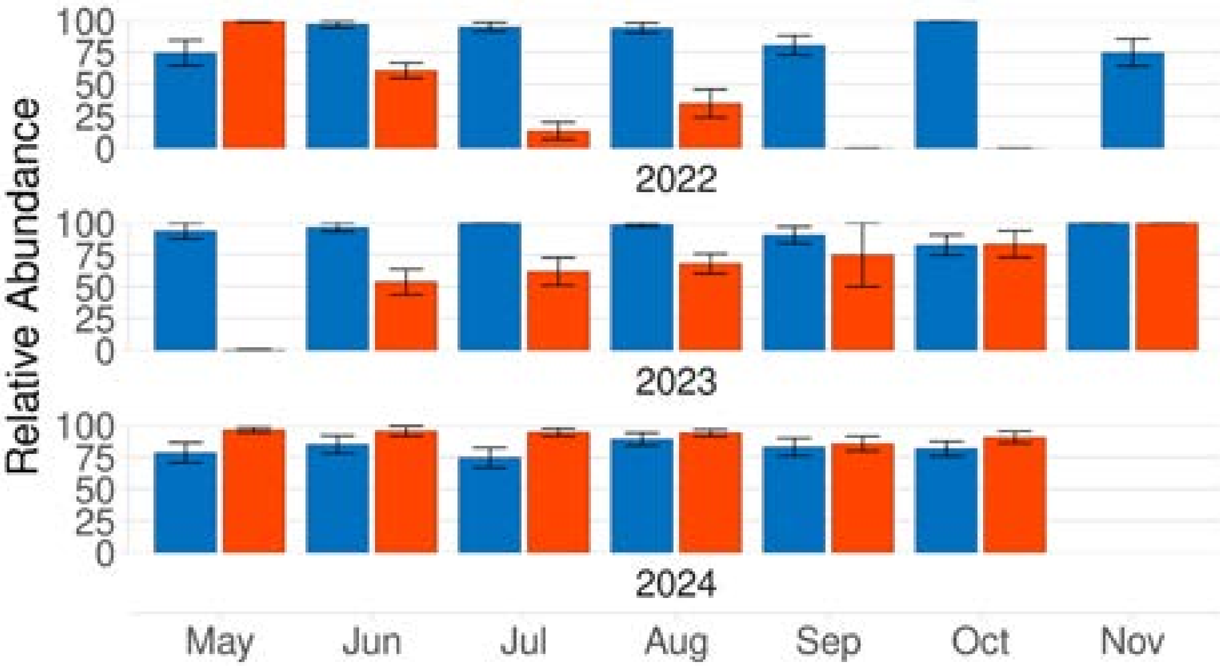


Figure 7-2. Relative abundance of Eurasian watermilfoil after one-time application of Endothall in Lake Tallac in 2022. Blue bars show relative abundance in untreated Control site; red bars show relative abundance in the Endothall treated site.

8.0 LAMINAR FLOW AERATION (LFA)

8.1 Effects of LFA on AIP

LFA Site 27 in Lake Tallac did not reduce AIP and had no consistent effect on nutrients in the water. The only trend over the three years was a slight increase in Eurasian watermilfoil. The results for nutrients and AIP at this site are consistent with LFA sites in the West Lagoon (Sites 25 and 26).

The other consistent effect in all the LFA sites is increased water column mixing, which reduces the frequency of low DO in the bottom water, and also stabilizes pH, but does not reduce pH to WQO ranges. Since pH is elevated by AIP photosynthesis, and since AIP was either unaffected or increased in some LFA sites, it is not surprising that LFA would not result in lower pH compared to untreated control sites.

8.2 Effects of LFA on Organic Matter

In the Lake Tallac Lagoon and the West Lagoon, this component of the LFA/CMT project is ongoing in spring 2025 when the last of the bottom organic sediment-filled mesh bags will be removed for analysis. To date, there appears to be no effect of the LFA on the percent organic matter, and no consistent effect on nutrients in the bottom soils as measured from the mesh bag analyses in 2023. The mesh bag analysis results from Year 2 and Year 3 are provided in Appendix A (Year 2 CMT Annual Report, Year 3 Annual Report). The final results from analysis of mesh bag contents and the metal sediment levels on the anchored settling plates and staff gauges affixed to pylons will be provided at a later time.

9.0 GROUP B RESULTS (DASH, SPOT-UV, AND BB TREATMENTS)

After Group A methods were used in Year 1, their effectiveness was determined as described in Section 4 (Monitoring) of this report. Group B methods are described in Section 3.7 and listed in Table 3-5. The locations and types of Group B methods by year are shown in Figures 3-7 and 3-8. Rake sample data and heat maps informed the selection of Group B areas and types of methods. The primary criterion for Group B site selection was successful, achieving a 75% reduction of AIP in Year 1, with an emphasis on reducing Curlyleaf pondweed populations. Figures 9-1 and 9-2 summarize the results of Group B treatments.

9.1 DASH and Spot-UV Treatments

These treatments produced variable results and were overall, partially effective, meaning they resulted in less than a 75% reduction in AIP in some sites while other sites achieved 75% reduction in AIP abundance. (Figure 9-1). Scale was observed to be an important variable for success, with larger areas more effectively treated, for example, Sites 5 and 2. Limitations for DASH are (a) the divers' visibility, (b) slow operational pace, and (c) high density of AIP. Divers' visibility is very limited in the lagoon waters due to existing high turbidity levels, increasing turbidity throughout the growing season, and some increased turbidity associated with the DASH activities. Turbidity also reduces light, making it difficult for divers to easily differentiate plant species below 4 to 6 feet deep. Poor light conditions, logistical requirements for diver operations, and high densities and stands of AIP make it hard for divers to efficiently remove AIP without removing some desirable native plants. For these reasons, follow-up DASH treatments (e.g., following BB removal) tended to be more efficient and effective than the first DASH event since AIP biomass was less and visibility was improved.

Advantages of DASH include removal of AIP, especially Curlyleaf pondweed turions, rather than killing and leaving the plants to remain in the water; although the removed plant volumes are small, this reduces potential releases of nutrients that can occur with both UVC treatments and herbicide applications. However, the time required for DASH operations limits its applicability to small areas at a time.

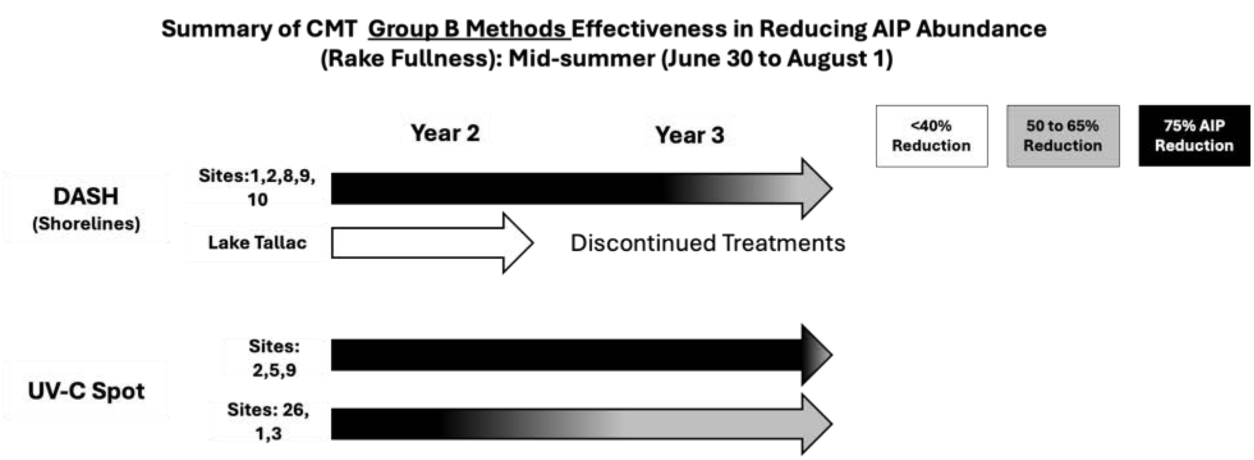


Figure 9-1. Effectiveness of DASH and Spot-UV Group B methods.

9.2 Bottom Barriers

These types of materials are very effective at killing and suppressing AIP if installed early in spring and kept in place throughout most of the AIP growing season. If the scale of use is too small compared with the surrounding AIP infestations and/or the barriers are removed too soon, the previously covered area will become re-infested with AIP within a few weeks. Figure 9-2 summarizes the effectiveness of BB deployments in CMT Group B areas.

BBs were effective until removed in fall of each year. After barriers were removed, AIP were found at various densities (usually low density) including newly sprouting Curlyleaf pondweed turions and Coontail moving into the treated areas.

9.3 Post-Barrier Removal Sequential Treatments

In Year 3 and as part of the CMT Project adaptive management, the addition of DASH or Spot-UV treatments after removal of BBs resulted in partial reduction in AIP (Figure 9-2). However, these methods could only be used once before the onset of winter, so their effect may have been limited and the data generated is likewise limited. For both UVC and DASH, the limited available time (prior to lagoon freezing) and practical scale of use after barrier removal also limit the spatial effectiveness of this strategy. The impact of these "sequential" treatments on subsequent spring AIP infestations will necessitate monitoring these areas in spring 2025. This approach may have merit if it extends the effectiveness of BBs.

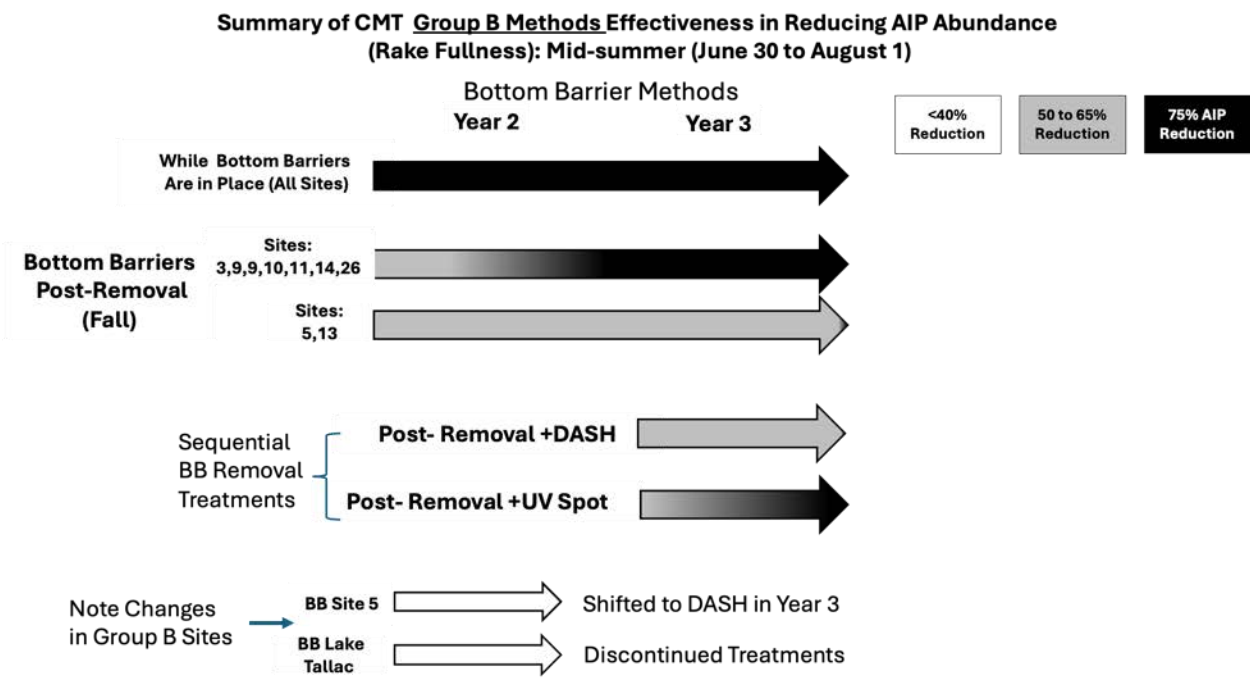


Figure 9-2. Effectiveness of BB Group B methods.

10.0 SUMMARY AND CONCLUSIONS

10.1 Were the goals and objectives of the CMT accomplished?

Yes. The CMT outlined three-year plans for multiple AIP management methods that were successfully tested alone, in combination, and in conjunction with a highly intensive environmental monitoring program in compliance with Lahontan Water Board and TRPA permit and EIR/EIS requirements. The successful, adaptive approach to the CMT method implementation and monitoring enabled adjustments to be made in response to the expected and unexpected variations in uncontrolled environmental conditions at the project sites from 2022 through 2024.

Communications and reporting were important project elements through which regulatory agencies were kept informed, interested stakeholders were periodically updated, and interim results of the CMT were disseminated. The communications to homeowners and the public throughout the CMT provided opportunities for interested party suggestions, for addressing concerns, and for keeping the public aware of the status of the CMT.

10.2 Effectiveness of CMT Methods – AIP Abundance, Vessel Hull Clearance, and Desirable Native Plant Abundance

10.2.1 Group A Methods

- Nearly all CMT Group A and Group B methods were successful in reducing AIP, but at different scales and to substantially different extents. The only exception was LFA, which, based on the monitoring results, did not reduce AIP populations but did facilitate increased growth and occurrence of Eurasian watermilfoil in the Lake Tallac Lagoon and Curlyleaf pondweed in the West Lagoon.

▪ When defined as the multiyear criterion of 75% reduction in AIP abundance, the only successful CMT methods were Endothall and Triclopyr alone and as part of Combination treatments (See below bullets).

▪ Endothall alone controlled Eurasian watermilfoil and Curlyleaf pondweed successfully at least one year and partially for two years. Low water levels in Year 1 prevented herbicide application treatments in many of the near-shore zone areas, which then became inundated with rising lake levels in Years 2 and 3 and reinfested with AIP.

▪ Triclopyr alone controlled Eurasian watermilfoil for all three years (and unexpectedly Curlyleaf pondweed for Years 2 and 3 as well).

- When larger scale and both types of lagoon habitat (near-shore zone and mid-channel) effectiveness are considered, only Endothall and Triclopyr, followed by Group B implementation, achieved the 75% ‘knock-back’ goal.

- For mid-channel habitat, UVC reduced AIP by 75% with adequate exposure (10-15 minutes light exposure on the top of the plant canopy), and with sufficient repeated (3-4) treatments per year. This was primarily observed in Year 3 when four repeated UVC treatments were applied.

- Combination methods (herbicide in near-shore zones and UVC in mid-channels of the same sites) successfully reduced AIP by the 75% reduction target. However, this method may have underperformed for two reasons: (1) the intended UVC mid-channel treatments in Year 1 did not occur; and (2) as noted above, increased water levels in Years 2 and 3 provided more near-shore zone AIP habitat that had not been exposed to Endothall or Triclopyr in Year 1. It is likely that this approach would have yielded even better results had the UVC treatments in mid-channel areas started in Year 1 and near-shore zones above water level in Year 1 had received Endothall or Triclopyr.

- LFA did not reduce AIP or increase the presence of desirable native plants. All other Group A methods were found to measurably increase the presence and populations of desirable native plants.

10.2.2 Group B Methods

- For near-shore zone habitats, DASH was variably successful in sustaining 75% reduction in AIP abundance in relatively small areas (< 0.15 acre). However, DASH also had the added benefit of removing plant biomass and Curlyleaf pondweed turions from the water during spring and early summer, thereby reducing nutrients and reproductive invasive propagules from the sites.

- For near-shore zone habitats, BBs provided 100% reduction in AIP while in place. However, the barriers (similar to DASH) covered relatively small areas (<0.15 acre) and did not prevent Coontail from occupying space above the barriers, though it was reduced. When barriers were removed in fall, some AIP re-occupied the spaces and Curlyleaf pondweed turions were found sprouting in these areas.

- Sequential DASH or Spot-UV treatments were effective in areas where BBs were removed in the fall. However, late year sequential treatments are limited in time (before winter icing) and therefore this limits the area that can be treated. In addition, the efficacy of sequential treatments has not yet been evaluated since this adaptive management treatment was implemented in fall 2024 and effects would be expected to be seen in spring 2025.

10.3 Monitoring and Environmental Reponses to CMT Methods

- The CMT test sites, similar to the untreated CMT Control sites, exhibited a consistent seasonal increase in turbidity in mid-summer, and low DO in bottom water areas. Nutrient levels in both treated and untreated sites were nearly always above WQOs.

- UVC did not affect bottom or surface water temperature.

- No herbicides or their degradants entered (nor came within 1,000 feet of) Lake Tahoe.

- The double turbidity curtains contained herbicides with two minor exceptions that were quickly remedied.

- Applications of Endothall and Triclopyr in Year 1 resulted in elevated turbidity due to decomposition of target AIP, release of nutrients and subsequent increase in algae. TP was commonly elevated 2 times higher than levels in untreated Control sites. This condition lasted about two months, but nutrient levels were variable. In subsequent Years 2 and 3, these metrics had returned to levels similar to those in untreated Control sites.

- Endothall and Triclopyr, due to their effective AIP reduction, resulted in lower pH levels that were within the WQOs, whereas untreated Control sites regularly had pH levels exceeding WQOs (over pH 8.4) in each year of the CMT.

- Endothall degraded and dissipated to below effective levels within 15 days after application. Endothall was non-detectable in water 45 days after applications.

- Triclopyr degraded and dissipated to below effective levels within 7 days after application. Triclopyr was non-detectable in water about 100 days after application.

- Spot-UV Treatments resulted in variable, and transient increases in nutrients in some sites. TP and OP were more commonly elevated 2 to 3 times higher than untreated Control sites, but these increases did not last.

- DASH activity modestly affected turbidity in the sites where used, but not to the extent that required stopping DASH or to levels that exceeded allowable levels.

- Installations of BBs negligibly affected turbidity within the sites where used.

- LFA effectively mixed the water column, which resulted in more uniform top and bottom temperatures and DO in Years 2 and 3. However, since AIP increased in LFA sites, pH often exceeded the WQO (greater than 8.4 pH). To date, there appears to be no consistent effect of LFA on bottom organic material and some beneficial effect on the growth of AIP. Additional analyses of organic material at test sites will be completed in spring 2025.

- The CMT was not observed to adversely affect fish or wildlife. Monitoring and analysis of benthic macroinvertebrates showed no effect from the CMT methods.

10.4 Environmental Conditions Affecting the CMT Project and AIP

During the CMT project, two uncontrollable environmental events affected the implementation and resulting outcomes of CMT Group A and Group B methods: 1) extreme storm events in 2022 and 2) significant year-to-year increases in lagoon water levels. These also underscore the critically important adaptive components of the CMT, and the need for incorporating flexibility in implementing long-term management of AIP in the Tahoe Keys lagoons. Both were weather related and both provided “lessons” learned. The importance and relevance of these conditions are discussed in Section 11 below.

10.4.1 Storm Events

Lake Tahoe weather in spring is quite variable, and two severe, strong wind events occurred in the first year of the CMT: a) within a few days after the applications of herbicide in late May 2022, and b) about 2 weeks after herbicide applications in mid-June. The wind velocities and directions were sufficient to disrupt the anchoring of the double turbidity barriers, which led to transient movements of RWT Dye and herbicides past those barriers. The dislodging of the curtains was remedied with the installation of a second set of curtains in one instance, and re-anchoring of the curtains at a separate location in the second instance. These events are more fully described in Appendix D. Both events were resolved within 24-48 hours and reports of these incidents were promptly provided to the Lahontan Water Board. The other two double turbidity curtains remained stable and intact during both wind events.

10.4.2 Continued Deployment of Turbidity Curtains

The slow degradation of Triclopyr to non-detect levels of 1.0 part per billion required the extended deployment of turbidity curtains. The curtains created stagnant water in sites where herbicide had been applied, which in turn provided conditions for algae growth. The resulting algae-driven high turbidity in these areas reduced light that is necessary for degradation of Triclopyr. The net effect was a slower than anticipated reduction on Triclopyr. Therefore, although the curtains kept herbicide where they were intended to be effective and ensured that herbicides did not reach Lake Tahoe or the West Channel, they probably partially impaired water quality. However, since there were no untreated “control” sites that had similar curtain constraints installed, it is not possible to discern how much the curtains alone affected water quality.

10.4.3 Lagoon Water Levels

Storms are not always predictable, but one of the time constraints on herbicide application in the West Lagoon was the requirement for net inflow of water from Lake Tahoe through the West Channel. The snowpacks in both 2021 and 2022 were below average, resulting in very low lake levels and low water levels in the Tahoe Keys lagoons in spring 2022. These conditions reduced the amount and duration of inflow through the West Channel. Some flexibility in timing of herbicide applications might alleviate this potential. However, it is critically important to start management methods in early spring for the most effective reduction of AIP, and particularly to stop Curlyleaf pondweed from producing millions of turions annually (see Section 11.2). Depending on future management plans, weather conditions will continue to be a major variable during deployment of any methods in the spring, as well as the fall.

As discussed in Section 11, the findings of the CMT indicate that treatment methods will be needed in the future and used in the fall to control sprouting Curlyleaf pondweed turions. Fall is when lagoon water depths and volume are lowest, and when vessel traffic is also reduced. These conditions may be favorable for the use of various types of fall treatment, which could include extended Bottom Barrier maintenance, DASH, or localized aquatic herbicides.

11.0 IMPLICATIONS OF CMT RESULTS FOR AIP MANAGEMENT

AIP colonizes bottom (benthic) areas through rooting and also freely moves throughout the water column. These are separate but closely connected habitats in which AIP grow, reproduce, and disperse. The bottom habitat provides most of the nutrients for AIP, and the AIP cycles these nutrients from the roots to their shoots during spring and summer, and eventually back to the water column and to the bottom sediments in fall (Barko et al.1991, Ribaugo et al. 2018, Tamayo and olden 2014; Verhofstad et al. 2017; Vander Zanden et al. 2024). The senescence of Eurasian watermilfoil and Coontail in the fall results in an accumulation of organic matter and nutrients on the bottom, that are available for growth the next spring. The mid-summer senescence of Curlyleaf pondweed contributes nutrients that, combined with midsummer high temperatures, fuels algae production. This appears to be the cause of rising turbidity (including the untreated CMT Control sites) during July and August.

Coontail presents a unique problem because its lack of roots makes it highly mobile throughout the lagoons. Coontail is also less affected by high turbidity and low light conditions (discussed below), and it utilizes nutrients released into the water during senescence of Curlyleaf pondweed (mid-July), and senescence of other AIP or native plants in the fall (Estlander et al. 2024; Foroughi et al. 2013; Kitaya et al. 2003; Lombardo et al. 2003; Van et al. 1976).

The development and refinement of UVC methodologies for AIP management is a major step and opportunity to improve control strategies in the Tahoe Keys. The CMT has helped identify both the utility and constraints of UVC and these results should help advance UVC efficiency and efficacy. This approach is now receiving national and international attention and the CMT has contributed to advancing this new tool (Udugamasuriyage, et al. 2024).

11.1 Water Level

The depth of water represents a major driver in the growth and reproduction of submersed aquatic plants by affecting available light for photosynthesis (Photosynthetically Active Radiation or PAR) and by altering how much near-shore zone habitat is submerged and thus available for AIP establishment and growth. Water depth also affects how rapidly water temperature and light increase between early spring and summer, a critical period for AIP growth and reproduction (Ren et al. 2024; Tobiessen et al. 1984; Wan et al. 2022; Wang et al. 2021; Yu et al. 2025.)


Example of low water levels in 2020
(Site 1, Endothall only)

The changes in water depth and water volume in the West Lagoon are shown in Figure 11-1. Taken together, this means that Years 2 and 3 of the CMT had optimal conditions for rapid AIP growth in both near-shore zones and deeper mid-channel habitats. However, these conditions also meant that the near-shore zone areas in the Combination Sites in 2022, as well as the near-shore areas in the Herbicide Only sites in 2022, did not receive the intended herbicide applications in areas that became submerged in 2023 and 2024.

When water levels in in the CMT sites increased by 3-4 feet in 2023, and an additional 1 to 2 feet in 2024, this created very different near-shore zone conditions compared with 2022:

(a) Near-shore zones had additional, new AIP habitat that had not received any herbicide treatment in 2022. Near-shore areas (from the outer edges of docks to shore) represent about 45 acres in the West Lagoon. If the increased water depth resulted in only a 15% increase in near-shore zone habitat, then that would have added about 6-7 acres of ideal AIP habitat in the shallower lagoon waters of the CMT sites: warm conditions, high light levels, and nutrient sources in the newly submerged soils.
(b) Increased water depth between 2022 and 2024 roughly doubled the water volume in the West Lagoon, which roughly doubled the space and added roughly 40-50% more vertical habitat for AIP overall. Note that if the average CMT site was 1.5 acres in Year 1, then by Year 3, the water volume in the site would have increased by about 5 to 7 ac-ft, or up to over 2 million gallons of water, which provided the AIP with substantial room to expand. This may explain the increase in Curlyleaf pondweed abundance and continued spread of Coontail in the mid-channel areas by 2024.
(c) The deepest mid-channel areas receive very little light, and this was reflected by lower AIP growth in untreated Control sites, especially in 2023, the first year of increased depth.
(d) By 2024, Curlyleaf pondweed, which is more competitive in deeper water, dominated the deep-water areas, but also moved into the newly submerged near-shore zones (Tobiessen and Snow 1984; Wang 2021).
(e) Eurasian watermilfoil also increased in the newly available near-shore zones, but decreased in relative abundance in the deeper, mid-channel areas.

With the water level and AIP habitat changes described above during the CMT, similar Lake Tahoe water level (and AIP habitat) changes are expected in the future. See the past 5 years shown in Figure 11-1, with similar changes as far back as 2015 (Figure 11-2). Water levels typically range from about 6,221 to 6,229 feet, are greatly affected by winter/spring snowpack/rainfall conditions, and are regulated at the Tahoe City Dam according to the Truckee River Operating Agreement (TMWA 2025). Designing and implementing effective AIP management will require sufficient flexibility and latitude to adapt to lake level changes because that directly affects where plants grow, how deep they grow, and how fast and how dense their growth will be in the critical spring/early summer period. Year to year substantial changes in water levels suggest that AIP control methods need to be strategically applied where and when they will have the most success in reducing the capacities for AIP growth, reproduction and dispersal.

The future mix and use of integrated AIP control methods should be flexible to match the likely AIP responses to those conditions. This suggests that reviewing current models (e.g., the CA-NV River Forecast Center) that project lake levels from spring snowpack need to be part of the AIP strategic and logistical planning. The environmental conditions driving AIP growth also strongly suggest that a successful management program must include year-to-year flexibility in the integrated use of all effective methods, based on AIP population monitoring. This provides a sustainable basis for any effective, integrated management program.

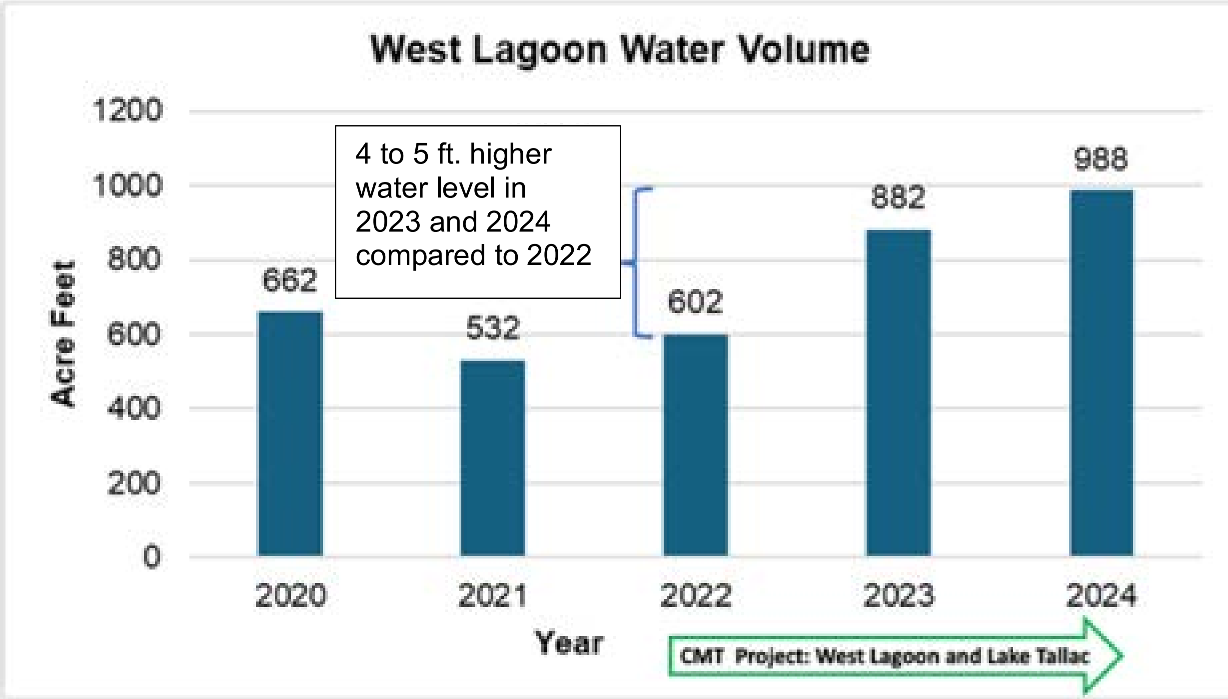


Figure 11-1. Water levels and water volume in the Tahoe Keys West Lagoon.

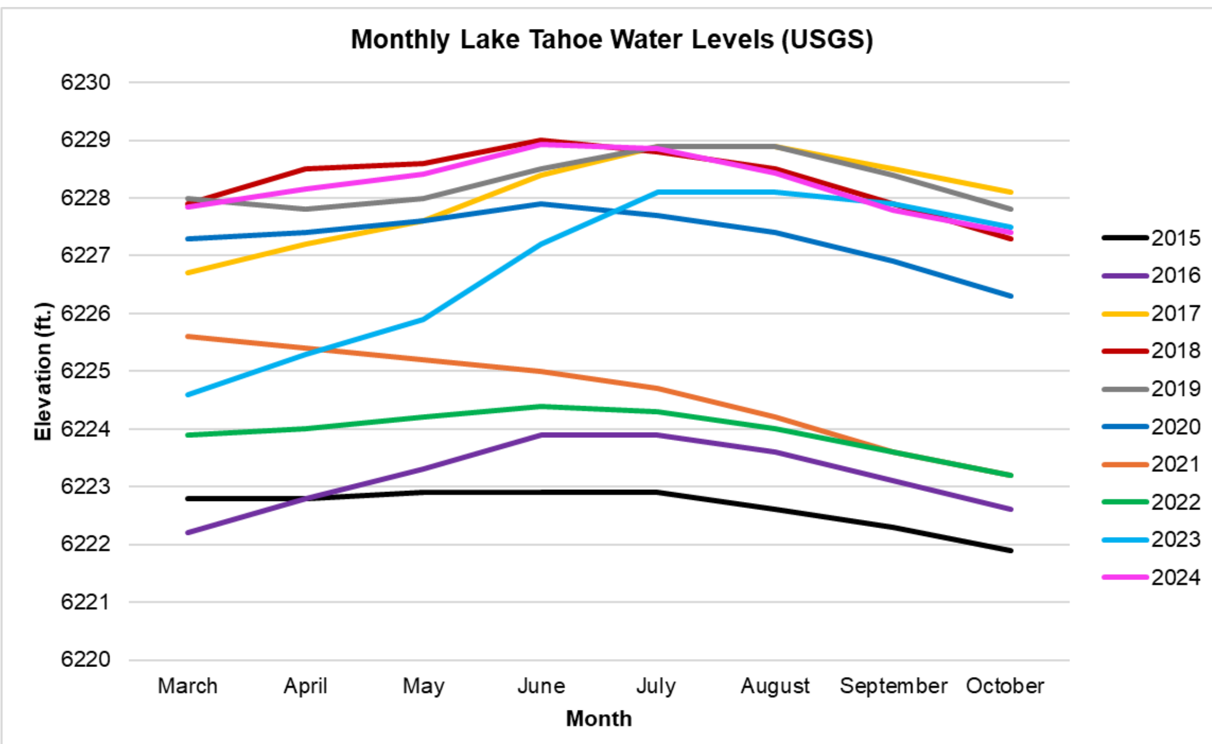


Figure 11-2. Monthly Lake Tahoe Water Levels (USGS)

11.2 The Curlyleaf Pondweed Threat

Regarding the status of AIP in the Tahoe Keys lagoons, the most concerning finding of the CMT is the extent to which Curlyleaf pondweed is spreading and producing reproductive turions in the lagoons, and the implications if this species becomes established in Lake Tahoe proper. The significance of this AIP threat is described in the following subsections.

11.2.1 Growth and Dispersal

The ability of Curlyleaf pondweed to establish new growth and occupy new space during early to late fall distinguishes it from other AIP and from desirable native plants such as *Elodea canadensis,* which typically senesce, decompose, or at least go dormant during this time. The production and dispersal of viable, fall-sprouting turions enables this advantage. Not only do the turions occupy new space, their initial shoot and leaf growth in the fall also allows them to utilize light at the bottom early the following spring when turbidity is very low. The TKPOA CMT light measurements (PAR profiles) in 2023 and 2024 confirm that in April to late May, light penetrates the deepest, which is also when lagoon/lake levels are lowest prior to the spring snowmelt runoff. This gives Curlyleaf pondweed a significant advantage early in the growing season and allows this plant to outcompete desirable native plants and other AIP for available light.

11.2.2 Life Cycle and Reproduction

Understanding the growth and reproduction patterns in Curlyleaf pondweed is founded in a robust published record (see: Adamac 2018; Heuschele et al. 2014; Poovey et al. 2002; Rogers and Bren, 1980; Sastroutomo et al. 1979; Sastroutomo, 1980, 1981; Woolf and Madsen, 2003; Wells 2009; Kunii 1989). Figure 11-3 depicts a summary of the life cycles of Curlyleaf pondweed and Eurasian watermilfoil in relation to typical water level change in Lake Tahoe, and thus the Keys lagoons. Note that when Eurasian watermilfoil senesces in the fall, Curlyleaf pondweed turions are sprouting. This fall sprouting gives Curlyleaf pondweed a “head start” in the next spring. Data obtained in the CMT (and cited previously as noted in Gettys 2020) shows that the key to reducing the spread of Curlyleaf pondweed and eventually reducing its impact is to interfere with the three phases of its life cycle: (1) production of turions in early-mid Summer, (2) dispersal of turions from mid-summer to fall, and (3) sprouting and establishment of turions in the fall. How this can best be achieved will require careful assessment of CMT treatment effects and determination of how to optimize the available methods that address all three critical phases of the plant’s lifecycle. This strongly suggests that management of Curlyleaf pondweed requires effective methods be used in both early spring and fall.

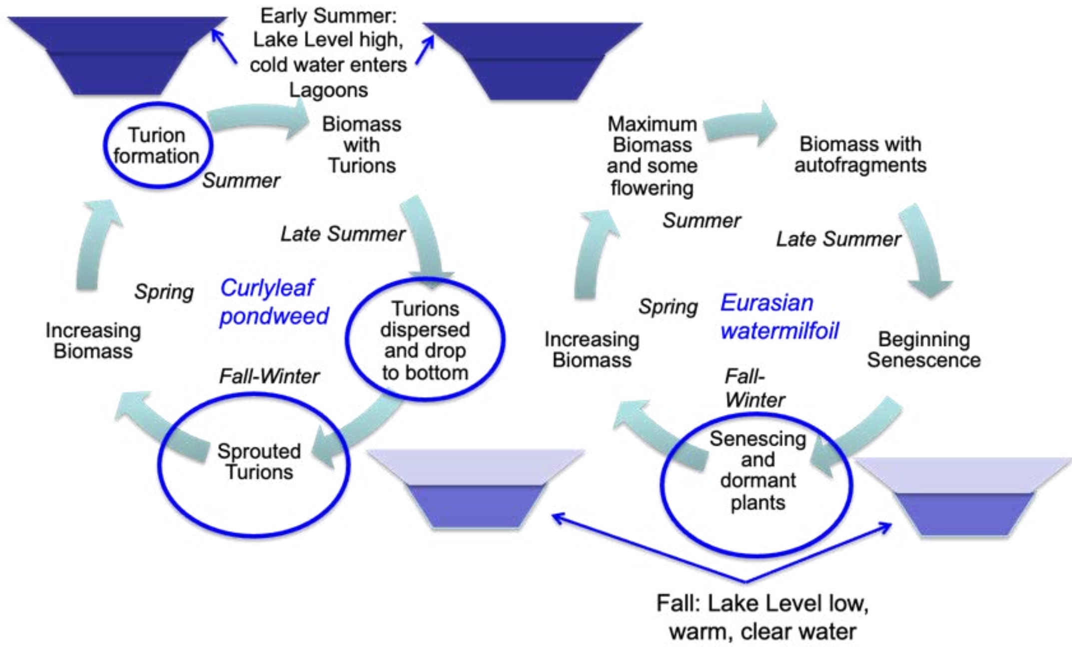


Figure 11-3. Life cycles for Curlyleaf pondweed and Eurasian watermilfoil.

The most significant change in AIP during the CMT was the expansion of Curlyleaf pondweed in both near-shore zone and deeper mid-channel areas. Even though the frequency of occurrence of Curlyleaf pondweed was somewhat reduced in Triclopyr sites and some Endothall sites, it expanded in other sites probably from: 1) prior year 'banks' of turions that sprouted, 2) turion dispersal from the current year's growth, and 3) more suitable habitats due to deeper water, less competition from other AIP, and greater volume of water in 2024 (Figure 11-4).

(a) Curlyleaf Pondweed:
Near-shore Zone Occurrence in Control Sites

(b) Curlyleaf Pondweed:
Mid-Channel Occurrence in Control Sites

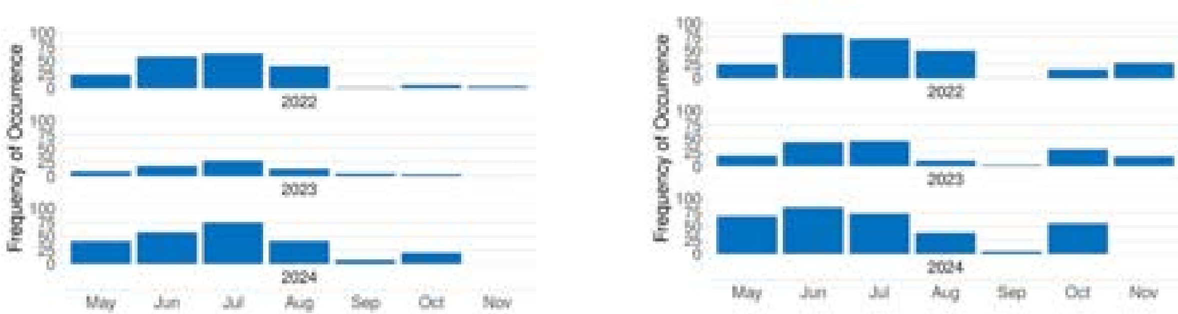


Figure 11-4. Occurrence of Curlyleaf pondweed in near-shore zone (a) and mid-channel (b) areas within Untreated "Control sites" in the West Lagoon during Years 1 ,2, and 3 of the CMT.

11.2.3 Turions Produced Per Acre

Two methods were used to estimate Curlyleaf pondweed turion production per acre in the Keys West Lagoon. The CMT 2024 DASH treatments and physical rake samples provided the data to estimate the numbers of Curlyleaf pondweed turions produced.

Turions counted in sub-samples of DASH plants removed from areas of known size provided an estimate of turions produced per square foot or per acre. Each rake sample retrieves plants from approximately 0.15 to 0.2 sq meter. Using these two sources of data, the estimated range of turion production per acre is from 109,000 to 150,000 for rake and DASH samples, respectively. In a 50-acre area, about half the size of the West Lagoon, this translates to about 5 to 7 million turions produced in one season (Figure 11-5).

Considering that the sources of the estimates are very different (DASH counts vs. rake samples), the estimated numbers are reasonably in agreement. Regardless of the variations in estimates, the propagule pressure from turions has become enormous and helps explain the rapid spread of the plant within the Keys (including regrowth in CMT treatment areas), as well as the appearance of this plant along near-shore zones of Lake Tahoe proper.

The Annual Efficacy Reports, provided in Appendix A, will help provide the basis for developing strategies for this AIP species. The high reproductive and dispersal capacity of Curlyleaf pondweed suggests that control and reduction of its occurrence and abundance should be the highest priority for the immediate future. With a propagule pressure of millions of turions each season, it will be essential to apply methods to address the existing 'bank' of turions, stop new turion production, and stop their successful establishment in the fall.

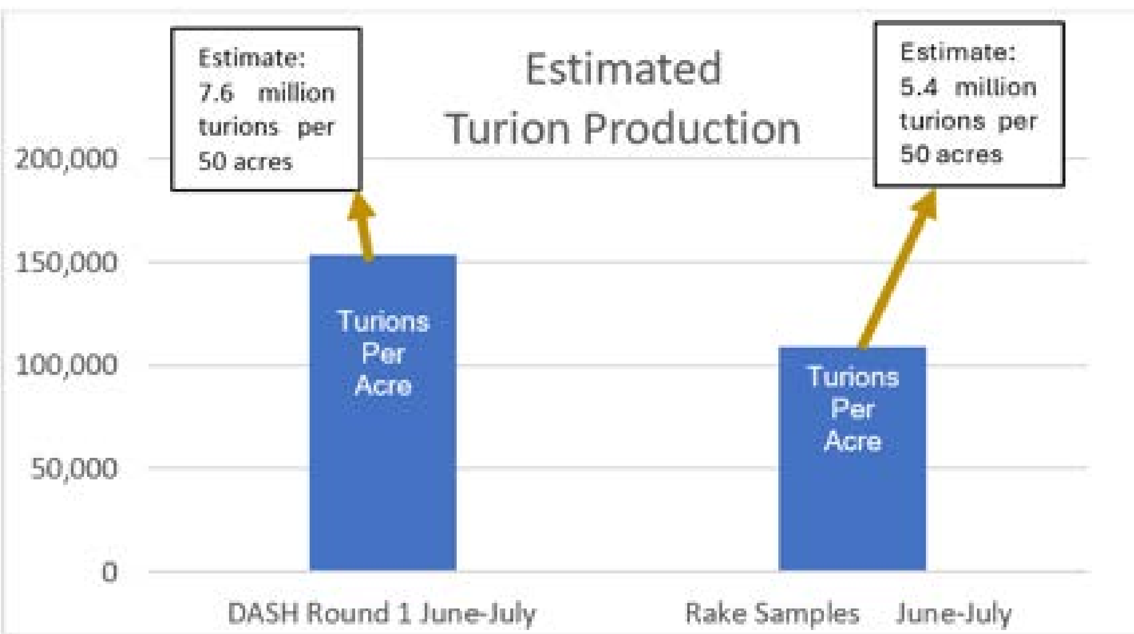


Figure 11-5. Estimated Turion Production in the West Lagoon.

11.3 The Coontail Threat

Coontail lacks roots and moves freely within the water column and around the Keys lagoons. It is easily transported and moved around by all types of floating craft, swimmers or wildlife. It is easily fragmented, and each small fragment can spread to new locations. This was evidenced in its relative abundance with increased water depth by Year 3 and by the frequency of its occurrence in CMT sites that had been previously treated and had reduced AIP. The density of Coontail also makes UVC exposure less effective because large masses "self-shade" or shade other SAV from the UVC exposure. From the macrophyte sampling during the CMT, coupled with the responses to increases in water levels from 2022 to 2024, it is clear that Coontail can rapidly adapt to increased habitat created by increased water volume. With no roots, Coontail is well-adapted to capture both increased water volume space as well as nutrients within that space.

11.4 AIP Fragment Threats

One of the common characteristics of submersed aquatic plants (SAV) is their ability to form new populations from very small pieces, or fragments of whole plants, as well as other more specialized structures such as turions and seeds, as well as rhizomes. AIP fragments in the Keys lagoons are produced in abundance from harvesting and boating (Anderson 2014). It is also clear that AIP fragments can persist, travel and disperse easily and successfully establish (Barnes et al. 2013; Barrat-Segretain et al. 2002; Chou et al. 1992; Jiang et al. 2009). The proliferation of Curlyleaf pondweed and mobility of Coontail suggest that any management strategy, to be effective, must also focus on both minimizing fragment production and containment. The most effective approach is to prevent AIP from growing and to stop using control methods that produce and disperse fragments.

11.5 CMT Cost Implications

The CMT was a test project designed to assess the capabilities of herbicide and non-herbicide control methods to reduce ("knock-back") and sustain the reduction of AIP. The CMT also aimed to assess the impacts of the various methods on water quality and non-target biological resources, and to evaluate whether herbicides could be contained within the test areas without diffusion into Lake Tahoe (Lahontan and TRPA 2020). Because of these multiple investigation objectives, field data collection and monitoring and associated labor, laboratory analyses, reporting and management costs were much greater than is typical for AIP control projects.

To present the comparative costs of the control methods under these test conditions, all direct and most all indirect costs for each of the three years of the CMT were collected from TKPOA/TRPA staff, contractors, and consultants. This data was then organized according to herbicide application and non-herbicide treatment method. Regulatory agency staff and agency management time (costs) were not collected.

The annual costs were compiled according to type of control method (herbicide application/non-herbicide treatment) and then separated into four cost categories: 1) application/treatment, 2) data collection/monitoring, 3) reporting, and 4) project management. To present the relative costs, total costs for each treatment type were then divided by the number of acres treated to roughly estimate a $ cost/acre for each method.

The cost per acre presentation breaks down expenditures across the four different CMT cost categories, assigning expenditures by CMT treatment method as noted above. Cost categories reflect major expense areas. It should be noted that cost allocations were assigned to the four cost categories by each agency/contractor organization that supplied the cost data, and it is likely that there were some variations in how costs were allocated by organizations between categories.

The four cost categories described above were then grouped into two divisions of Project activities: 1) In-field Activities, and 2) Regulatory Compliance and Implementation. This was done to show the relative magnitude and compare the costs of the field activities to the post-field (i.e., data evaluation and permit compliance reporting) activities. Costs were further assigned to detailed subcategories, which are summarized in Table 11-1 below.

Table 11-1. Cost Categories and Example Activities

Main Cost Category	Cost Subcategory	Example Activities
In-Field Activities	Applications/Treatments	• Herbicide applications (Year 1) • UVC • LFA • BB • DASH • Construction services (culvert seals, ADP installation, turbidity curtains) (Year 1) • Equipment/supply purchases (LFA systems, bottom barriers, etc.)
	Monitoring	• Herbicide sampling • Water quality sampling (nutrients, HABs, macrophytes, BMI) • Hydroacoustic scans • Data logger operations • LFA organic material surveys • Lab analyses
Regulatory Compliance & Implementation	Reporting	• NPDES/MMRP deliverables • Project coordination • Data analysis and management • Public outreach • Spill response planning (Year 1) • Biovolume calculations (Year 3)
	Project Management	• Meetings • General project planning and logistics • Equipment/supply purchases (GPS units, boats, misc. supplies etc.)

Over the 3-year period, CMT costs varied significantly across application/treatment, monitoring, reporting, and project management categories, as well as among different Group A and Group B treatment types. Monitoring consistently represented a major cost component, with the highest in Year 1 at over $3.6 million. Reporting (e.g., analysis and documentation) costs saw a gradual increase throughout the years, reflecting more extensive documentation and compliance reporting requirements, particularly in Year 3. Project management expenses varied, reaching their highest in Year 1 at $1.3 million, largely due to the number and complexity of contractor management, equipment purchasing, field logistics coordination, and herbicide application events. Among treatment types, Endothall and Triclopyr were the most expensive in Year 1 due to permit monitoring requirements, whereas UVC treatments and LFA became more costly methods in later years. Notably, DASH and BB showed relatively uniform costs.

Overall, the total costs for implementation and completion of the 3-year CMT were approximately $11.5 million, excluding regulatory agency personnel costs and post-project reporting. The following tables summarize costs per category and field/post-field activity cost divisions, as well as costs per acre per method for each year of the CMT separately.

Table 11-2. CMT Year 1 Costs Totals

Year 1 Cost Totals	Treated Acres	**In-Field Activities**			**Regulatory Compliance and Implementation**			**Year 1 Total**	Year 1 Cost Per Acre
		Application/ Treatment	Monitoring	Subtotal	Reporting	Project Management	Subtotal		
Control	7.5	$ -	$ 392,838	$ 392,838	$ 36,148	$ 111,694	$ 147,843	**$ 540,680**	$ 72,091
Endothall Only	7.1	$ 242,562	$ 1,266,556	$ 1,509,118	$ 64,027	$ 86,990	$ 151,017	**$ 1,660,135**	$ 233,822
Endothall Combo	1.6	$ 52,880	$ 315,512	$ 368,392	$ 14,191	$ 19,603	$ 33,795	**$ 402,187**	$ 251,367
Triclopyr Only	5.3	$ 179,423	$ 922,625	$ 1,102,048	$ 47,576	$ 64,936	$ 112,512	**$ 1,214,560**	$ 229,162
Triclopyr Combo	1.5	$ 52,616	$ 295,286	$ 347,902	$ 13,709	$ 18,378	$ 32,087	**$ 379,989**	$ 253,326
UV-C Only	2.35	$ 282,220	$ 150,800	$ 433,020	$ 11,327	$ 34,998	$ 46,324	**$ 479,344**	$ 203,976
UV-C Combo	2.23	$ 271,153	$ 59,868	$ 331,020	$ 10,748	$ 33,210	$ 43,959	**$ 374,979**	$ 168,152
LFA	12.9	$ 83,789	$ 430,340	$ 514,129	$ 62,175	$ 158,051	$ 220,227	**$ 734,356**	$ 56,927
Bottom Barriers	0	$ -	$ -	$ -	$ -	$ -	$ -	**$ -**	$ -
DASH	0	$ -	$ -	$ -	$ -	$ -	$ -	**$ -**	$ -
UV-C Spot	0	$ -	$ -	$ -	$ -	$ -	$ -	**$ -**	$ -
BB / UV-C	0	$ -	$ -	$ -	$ -	$ -	$ -	**$ -**	$ -
BB / DASH	0	$ -	$ -	$ -	$ -	$ -	$ -	**$ -**	$ -
Total	40.48	**$ 1,164,642**	**$ 3,833,825**	**$ 4,998,468**	**$ 259,902**	**$ 527,860**	**$ 787,762**	**$ 5,786,230**	

Table 11-3. CMT Year 2 Costs Totals

Year 2 Cost Totals	Treated Acres	**In-Field Activities**			**Regulatory Compliance and Implementation**			**Year 2 Total**	Year 2 Cost Per Acre*
		Application/ Treatment	Monitoring	Subtotal	Reporting	Project Management	Subtotal		
Control	6.5	$ -	$ 253,630	$ 253,630	$ 54,823	$ 63,131	$ 117,954	**$ 371,585**	$ 57,167
Endothall Only	0	$ -	$ 24,529	$ 24,529	$ -	$ -	$ -	**$ 24,529**	$ 3,455
Endothall Combo	0	$ -	$ 60,447	$ 60,447	$ -	$ -	$ -	**$ 60,447**	$ 12,593
Triclopyr Only	0	$ -	$ 17,521	$ 17,521	$ -	$ -	$ -	**$ 17,521**	$ 3,306
Triclopyr Combo	0	$ -	$ 42,050	$ 42,050	$ -	$ -	$ -	**$ 42,050**	$ 10,782
UV-C Only	1.52	$ 214,032	$ 48,927	$ 262,959	$ 12,820	$ 14,763	$ 27,583	**$ 290,542**	$ 191,146
UV-C Combo	2.48	$ 356,720	$ 62,677	$ 419,397	$ 20,917	$ 24,087	$ 45,004	**$ 464,401**	$ 187,258
LFA	12.9	$ 21,056	$ 409,460	$ 430,516	$ 108,803	$ 104,236	$ 213,038	**$ 643,554**	$ 49,888
Bottom Barriers	0.76	$ 71,005	$ 19,207	$ 90,212	$ 6,410	$ 35,798	$ 42,208	**$ 132,421**	$ 174,238
DASH	1.12	$ 104,639	$ 28,306	$ 132,944	$ 9,446	$ 10,878	$ 20,324	**$ 153,269**	$ 136,847
UV-C Spot	1.55	$ 221,959	$ 39,173	$ 261,132	$ 13,073	$ 15,054	$ 28,128	**$ 289,260**	$ 186,619
BB / UV-C	0	$ -	$ -	$ -	$ -	$ -	$ -	**$ -**	$ -
BB / DASH	0	$ -	$ -	$ -	$ -	$ -	$ -	**$ -**	$ -
Total	26.83	**$ 989,409**	**$ 1,005,927**	**$ 1,995,336**	**$ 226,293**	**$ 267,948**	**$ 494,241**	**$ 2,489,577**	

*Per acre calculations for Herbicide Only and Herbicide Combination sites are based on the acreages presented in APAP 1.

Table 11-4. CMT Year 3 Costs Totals

Year 3 Cost Totals	Treated Acres	In-Field Activities			Regulatory Compliance and Implementation			Year 3 Total	Year 3 Cost Per Acre*
		Application/ Treatment	Monitoring	Subtotal	Reporting	Project Management	Subtotal		
Control	6.5	$ -	$ 293,318	$ 293,318	$ 86,142	$ 43,855	$ 129,997	**$ 423,315**	$ 65,125
Endothall Only	0	$ -	$ 64,724	$ 64,724	$ 3,423	$ 3,067	$ 6,490	**$ 71,214**	$ 10,030
Endothall Combo	0	$ -	$ 62,203	$ 62,203	$ 2,316	$ 2,075	$ 4,390	**$ 66,594**	$ 13,874
Triclopyr Only	0	$ -	$ 53,386	$ 53,386	$ 2,517	$ 2,255	$ 4,772	**$ 58,158**	$ 10,973
Triclopyr Combo	0	$ -	$ 43,786	$ 43,786	$ 1,812	$ 1,624	$ 3,436	**$ 47,222**	$ 12,108
UV-C Only	2.35	$ 184,663	$ 86,532	$ 271,196	$ 31,144	$ 15,855	$ 46,999	**$ 318,195**	$ 135,402
UV-C Combo	3.13	$ 243,755	$ 68,392	$ 312,148	$ 41,481	$ 21,118	$ 62,599	**$ 374,746**	$ 119,727
LFA	12.9	$ 1,300	$ 381,193	$ 382,493	$ 170,959	$ 87,036	$ 257,995	**$ 640,488**	$ 49,650
Bottom Barriers	0.92	$ 94,777	$ 20,103	$ 114,880	$ 12,192	$ 15,011	$ 27,204	**$ 142,083**	$ 154,438
DASH	1.3	$ 133,924	$ 28,406	$ 162,330	$ 17,228	$ 8,771	$ 25,999	**$ 188,329**	$ 144,869
UV-C Spot	3.83	$ 295,461	$ 83,688	$ 379,149	$ 50,757	$ 25,841	$ 76,598	**$ 455,747**	$ 118,994
BB / UV-C	0.22	$ 14,773	$ 4,807	$ 19,580	$ 2,916	$ 1,484	$ 4,400	**$ 23,980**	$ 109,000
BB / DASH	0.48	$ 49,449	$ 10,488	$ 59,937	$ 6,361	$ 3,239	$ 9,600	**$ 69,537**	$ 144,869
Total	31.63	**$ 1,018,103**	**$ 1,201,026**	**$ 2,219,128**	**$ 429,248**	**$ 231,231**	**$ 660,479**	**$ 2,879,607**	

*Per acre calculations for Herbicide Only and Herbicide Combination sites are based on the acreages presented in APAP 1.

12.0 CMT MANAGEMENT IMPLICATIONS

The CMT results have shown the importance of habitat locations and how changing environmental conditions can affect AIP growth and efficacy of management methods. A graphic depiction of how changes in water affected AIP growth and efficacy of CMT methods is summarized in the graphic representations below (Figures 12-1 to 12-6). These graphs are based on the results of extensive rake sampling during the CMT. The typical conditions in untreated Control sites during the CMT are represented in Figure 12-1 for Years 1 and 2. Note that the first large increase in water depth in Year 2 actually suppressed AIP abundance. This was most likely due to low light levels in the deeper CMT sites as documented in the Year 3 Annual Report (See Appendix A). However, as Figure 12-2 shows, by Year 3, Curlyleaf pondweed was able to respond to the deep water and increased dramatically. Coontail was also able to utilize the increased water volume by Year 3. The Increased water levels also resulted in more near-shore zone habitat for AIP.

Figure 12-3 represents the conditions where Endothall or Triclopyr was applied to the entire CMT site and total volume of water in the site. Note that in Years 2 and 3, the areas now submersed by the large increase in volume of water (that was not exposed to herbicide in Year 1) provide more near-shore zone habitat for both Curlyleaf pondweed and Coontail.

The effect of water level changes on the Combination sites is shown in Figure 12-4. In this situation, the near-shore zones that had been exposed to either Endothall or Triclopyr in Year 1, were submerged by several feet, and the newly submersed near-shore zone provides good AIP habitat. Also, the mid-channel areas, which were not treated by any method in Year 1, produced abundant AIP. However, UVC treatments in the mid-channel areas in Year 2 and 3 were effective in reducing AIP abundance by 75%.

The use of UVC only (no herbicide) in the mid-channel areas was effective in reducing AIP abundance by 60 to 75% in Years 2 and 3 (Figures 12-5). The effectiveness of UVC only in Year 1 was limited due to fewer repeat treatments and shorter exposure times.

LFA did not reduce AIP abundance in any of the three CMT years (Figure 12-6). The rake sampling data also showed the Curlyleaf pondweed abundance was greater in some LFA sites than in un-treated CMT Control sites.

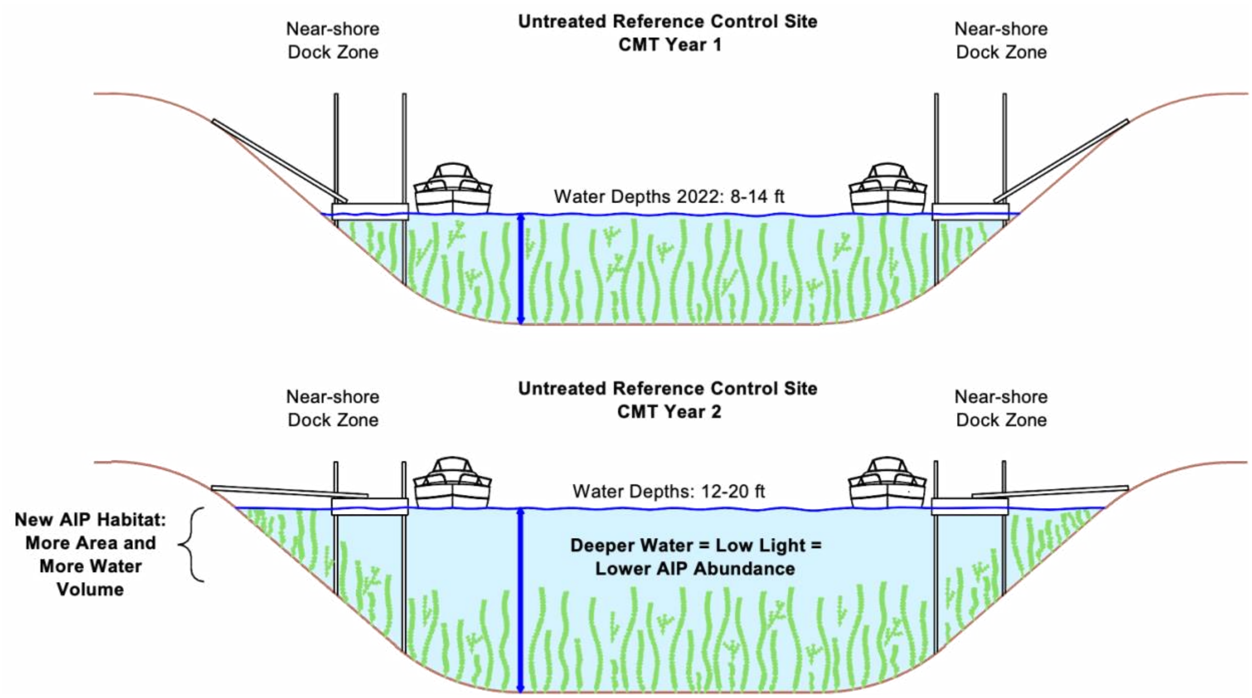


Figure 12-1. Depiction of AIP and water level conditions in un-treated Control Sites in CMT Years 1 and 2. Note that deeper water in Year 2 suppressed AIP abundance primarily in the deep areas.

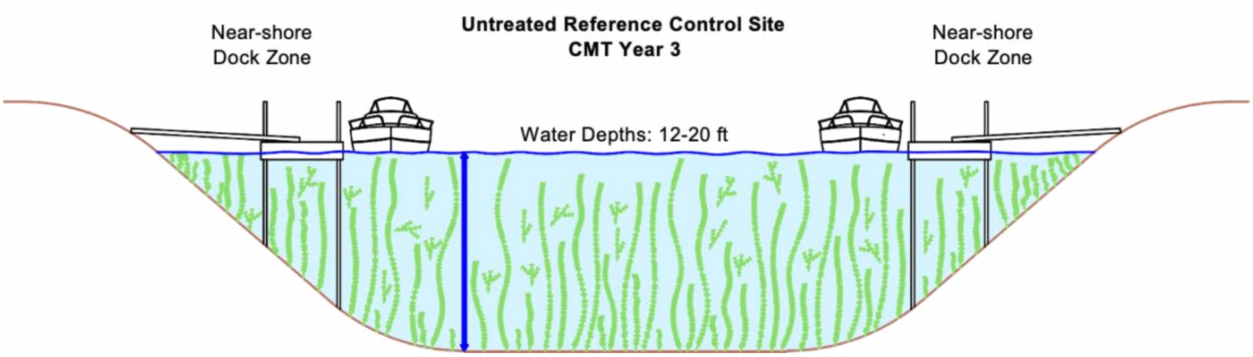


Figure 12-2. Depiction of AIP abundance in un-treated Control Sites in CMT Year 3. Note that both increased near-shore zone habitat and increased overall water volume and depth increased habitat for AIP to expand.

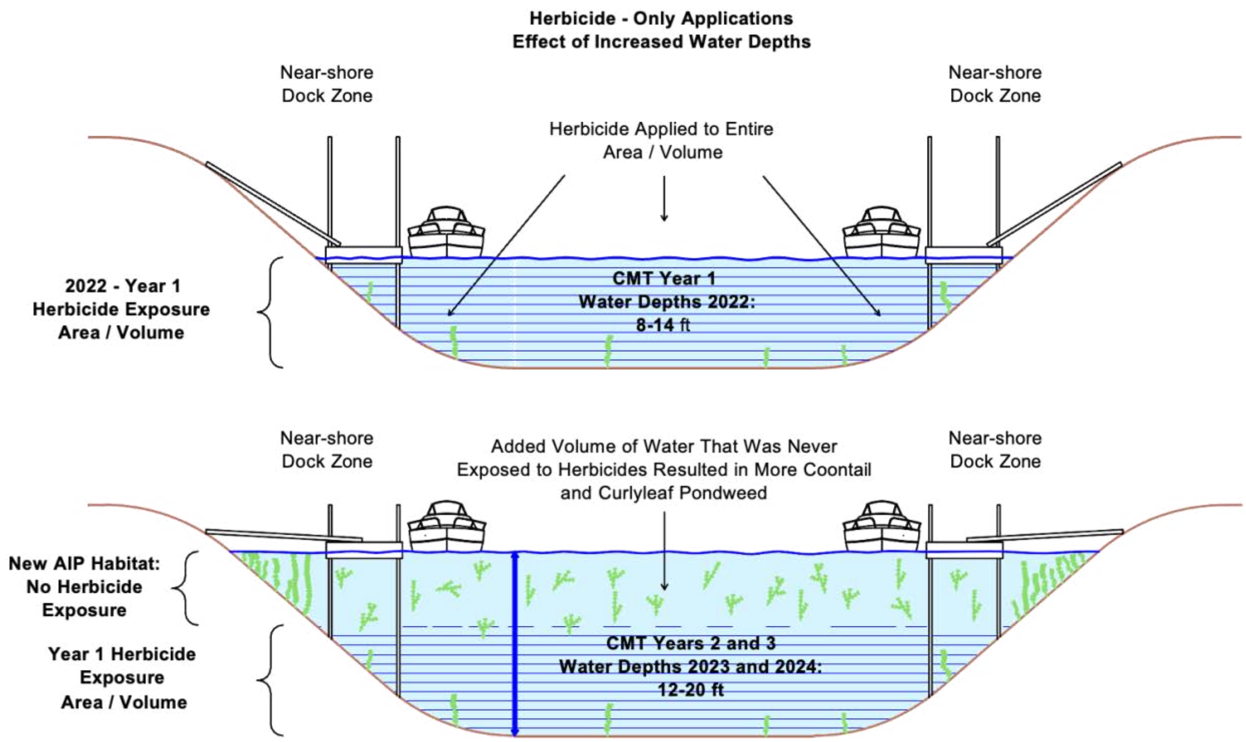


Figure 12-3. Effect of increased water levels in herbicide-treated site between Year 1 (herbicide application) and Years 2 and 3. Note the expanded ("new") near-shore zone habitat and expanded mid-channel volume habitat in Years 2 and 3 due to increased water depth. This provided "new" AIP habitat with no prior exposure to Endothall or Triclopyr applications in 2022.

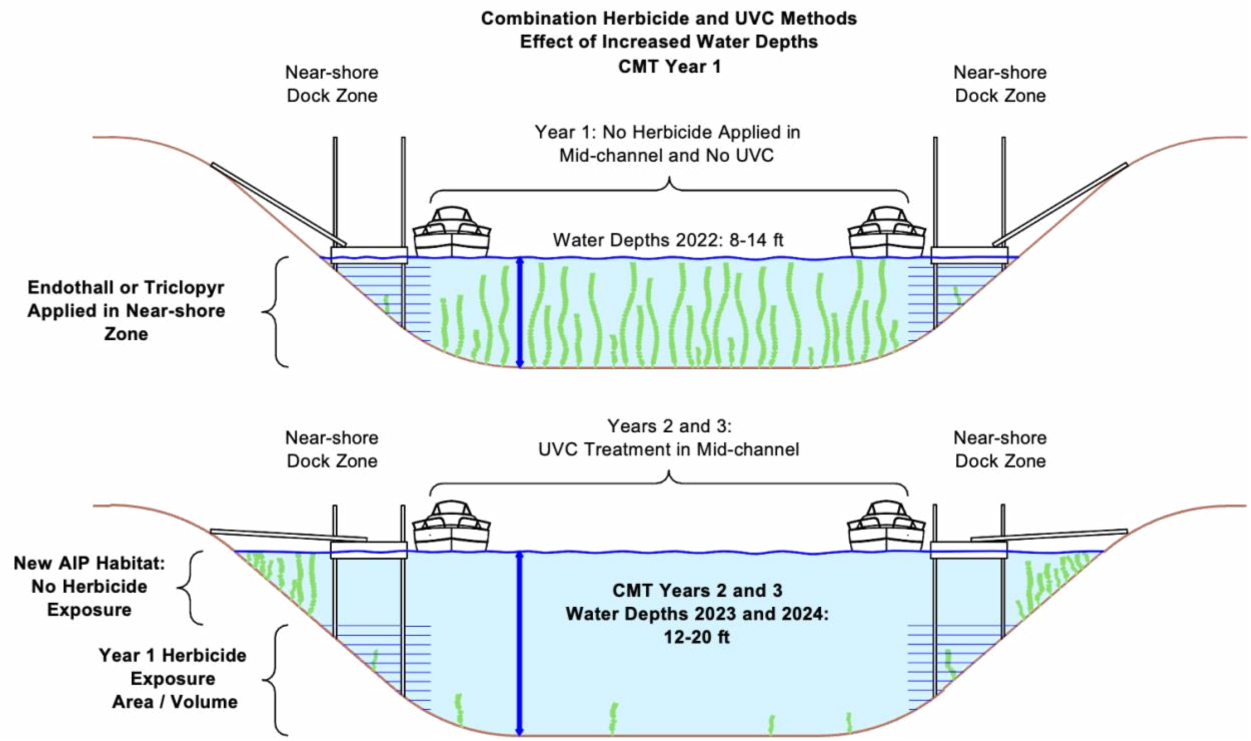


Figure 12-4. Effect of increased water levels in Combination Herbicide-UVC sites between Year 1 (herbicide application) and Years 2 and 3 (UVC mid-channel treatments). The expanded near-shore zone habitat provided "new" habitat for AIP that was not treated by any method in Years 2 and 3. Near-shore zones not treated in Year 1 are now well underwater and only have partial suppression of growth since there were no near-shore zone treatments in Years 2 and 3.

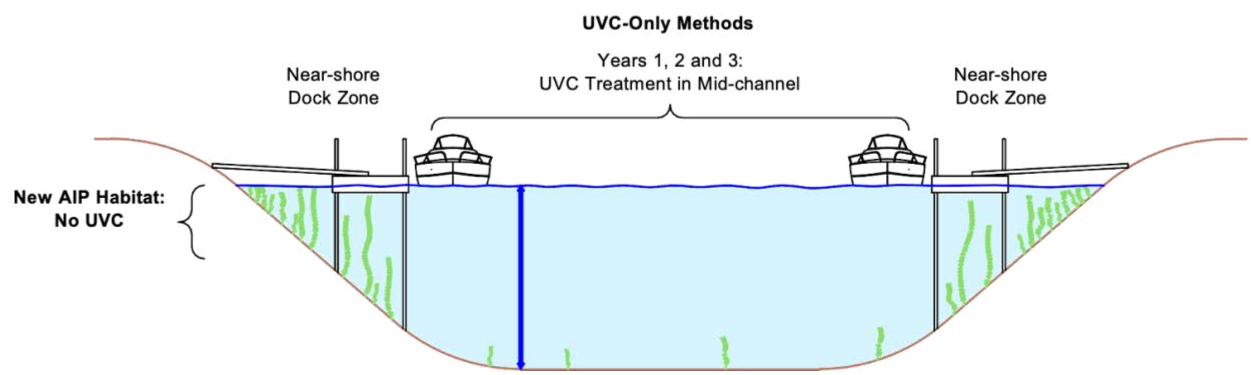


Figure 12-5. Effect of UVC Only treatments. This figure represents the reduction of AIP abundance by 60 to 75% in Years 2 and 3 within the mid-channel areas. Note the lack of AIP reduction in the near-shore zone where UVC was not used.

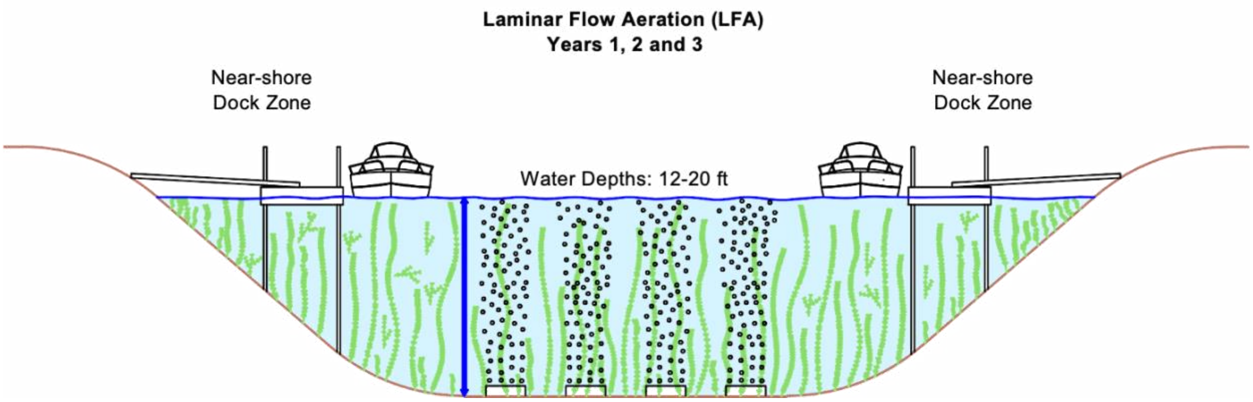


Figure 12-6. Effect of LFA on AIP. Representation of the data that showed that LFA did not reduce AIP abundance in any of the CMT years.

Given the history of water level variations at Lake Tahoe, the magnitude of 2022-2024 changes in water depth in the Keys lagoons is likely to be repeated in the future. In addition to these recent variations, the climate trends already evidenced at Lake Tahoe (Coats et al. 2021), and recent recommendations for adapting invasive species management to climate change (Brewington et al. 2024; Colberg et al. 2024; Marchand and Schoefs 2025), suggest that that long-term AIP management in the Keys lagoons must incorporate a range of integrated tools that can be deployed in response to both weather and climate-driven variabilities, coupled with adequate monitoring data. The changes that occurred during the CMT provide lessons that should inform future plans. AIP do not rest, and they are notorious for utilizing opportunities to expand as suitable habitat expands.

In summary, the CMT results suggest that the key considerations in developing a successful Integrated Management Plan (IMP) include:

- Biology and reproductive and dispersal capacities and life cycles of target AIP.
- Using methods congruent with the limitations, opportunities, and scales caused by changes in the different habitat types and conditions: mid-channels and near-shore zones and seasonal and multi-year water level changes.
- Optimal timing and frequency of use relative to AIP characteristics.
- Focus on the comparative merits of management methods: Efficacy, Utility, and Feasibility within AIP habitats, AIP life cycle, scale (size) of control needed to minimize re-infestations, and protecting desirable native plants.
- Pre-treatment mitigation actions to reduce potential negative impacts of any management methods on water quality.
- Sequencing and cadence in deployment of methods.
- Adequate (space and time) monitoring to provide useful adaptive feedback; the CMT has produced substantial data and can inform appropriate levels of future data collection
- Regulatory flexibility to accommodate seasonal and year-to-year changes in conditions (water levels).
- Using a “rachet /containment” strategy: Gain incremental net reductions in AIP every year
- Contain existing AIP where possible.
- Reduce organic bottom loading to reduce AIP nutrient sources.

Main Take Away Points from the CMT results: (see Executive Summary also)

1. CMT was completed as planned without any herbicides entering Lake Tahoe and with no long-term effects on water quality.
2. Endothall applications provided 75% reduction of AIP abundance for two to three years depending upon target species.
3. Triclopyr applications provided 75% reduction of Eurasian watermilfoil and Curlyleaf pondweed for 3 years in mid-channel areas.
4. UVC used alone provided 65 to 75% reduction in AIP only in mid-channel areas when applied four times per year (growing season).
5. Mid-channel use of UVC and near-shore zone applications of Endothall or Triclopyr reduced AIP abundance by 75%.
6. Group B methods were effective in several small areas and augmented Group A methods.
7. AIP growth and responses to treatments varied with water level and water volume changes over the duration of the CMT.
8. UVC in mid-channel areas paired with Group B methods at near shore areas should be tested for efficacy.

Table 12-1. Group A Summary Results Relative to Project Goals

	Years Applied	Effective Against CLPW and EWM	Effective Against Coontail	Effective Against Sprouted Turions	Scalable to Large Treatment Areas (> 10 Acres)	Method Feasible to Use in Near-Shore Zone	Method Feasible to Use in Mid-Channel Areas	Cost Feasible for Large Areas (> 10 Acres)
Group A Single Methods (2022 - 2024)								
Herbicide Only								
Endothall	Year 1 only	Yes	Partial/scale Dependent	Yes	Yes	Yes	Yes	Yes
Triclopyr (Eurasian watermilfoil and Curlyleaf pondweed)	Year 1 only	Yes	No	Yes	Yes	Yes	Yes	Yes
UV-C Light Only	Years 1-3	Yes	Partial	Yes	Partial	No	Yes	No
Laminar Flow Aeration	Years 1-3	No	No	No	Yes	No	No	Yes
Group A Combination Methods (2022 - 2024)								
Herbicide Near Shore Zone with UV-C Mid-Channel								
Endothall	Year 1 only	Yes	One Year	Yes	Yes	Yes	Yes	Yes
Triclopyr	Year 1 only	Yes	No	Yes	Yes	Yes	Yes	Yes
UV-C	Years 2-3	Yes	Partial	Partial	Partial	No	Yes	No
Laminar Flow Aeration with UV-C Mid-Channel	Years 2-3	No	No	No	Partial	No	Yes	No

Table 12-2. Group B Summary Results Relative to Project Goals

	Years Applied	Effective Against CLPW and EWM	Effective Against Coontail	Effective Against Sprouted Turions	Scalable to Large Treatment Areas (> 10 Acres)	Method Feasible to Use in Near-Shore Zone	Method Feasible to Use in Mid-Channel Areas	Cost Feasible for Large Areas (> 10 Acres)
Follow-Up Group B Single Methods (2023 - 2024)								
BB (Bottom Barriers) (While in place)	Years 2-3	While in place	No	While in place	No	Yes	Partial	No
DASH (Diver Assisted Suction Harvesting)	Years 2-3	Partial	Partial	Partial	No	Yes	Partial	No
UV-C Spot	Years 2-3	Yes	Partial	Yes	No	No	Yes	No
Follow-up Group B Combination Methods (2023 - 2024)								
UV-C Sequential to Bottom Barriers (One treatment)	Year 3	Yes	Partial	Yes	No	No	Yes	No
DASH Sequential to Bottom Barriers (One treatment)	Year 3	Partial	Partial	Partial	No	Yes	Partial	No

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Tahoe Keys Property Owners Association (TKPOA)

Name	Title	Role(s)
Hallie Kirkingburg	General Manager	TKPOA Management
Kristine Lebo	Water Quality Manager	Project Manager
Pete Wolcott	Former Waterways Committee Chairman/ Board Member	Former Project Lead for TKPOA Board
Meghan Hoffmann	Water Quality Supervisor	Field Lead/Data Analyst
Melissa Thorme	Partner, Stoel Rives LLP	TKPOA Special Counsel
Moire Breslin	AIS Technician	Field Technician/Public Outreach
Katie Terwilliger	AIS Technician	Field Technician/Data Analyst
Bailey Loeb	Former AIS Intern	Field Technician

Tahoe Regional Planning Agency (TRPA)

Name	Title	Role(s)
Kim Carriger	Chief Partnerships Officer	
Kathleen (Kat) McIntyre, PhD	EIP Division Manager	
Dennis Zabaglo	Aquatic Invasive Species Program Manager	Contract management and review of monitoring results
Emily Justice	Aquatic Invasive Species Projects Coordinator	Compilation and review of monitoring results submitted by TRPA contractors
Victoria Ortiz	Community Engagement Manager	Public Outreach and Education

The League to Save Lake Tahoe (The League)

Name	Title	Role(s)
Jesse Patterson	Chief Strategy Officer	Review of monitoring results related to LFA and reporting format.
Laura Patten	Senior Science Policy Analyst	Review of LFA implementation and related monitoring results.

Sierra Ecosystem Associates (SEA)

Name	Title	Role(s)
Rick A. Lind	President	Program Manager
Rayann La France	Administrative Services Manager	Report Coordination, Organization, and Formatting
Jeremy Waites	Senior Ecologist/GIS Specialist	GIS Analysis and Mapping
Summer Abel	Environmental Scientist	Data Collection, GIS Support
Aria Pauling	Assistant Environmental Scientist	Data Management Lead, Report Coordination and Organization Support
Marissa DeFazio	Administrative Assistant	Administrative/Report Organization Support

Environmental Science Associates (ESA)

Name	Title	Role(s)
Toni Pennington, PhD	Sr. Aquatic Biologist	Project Manager
Kathleen Berridge	Sr. Aquatic Ecologist	Deputy Project Manager/Data Analyst/Field Lead/Boat Op
Travis Hinkelman, PhD	Sr. Data Scientist	Data Analyst
Jim Good	Sr. Aquatic Scientist	Senior Advisor
Chris Fitzer	Project Director	Project Director
Rich Miller	Sr. Aquatic Biologist	Data Analyst
Courtney Carpenter	Biologist	Field Technician
Mariah Dietrich	Biologist	Field Technician
Nicole Dunkley	Biologist	Field Lead/Boat Op
Melanie DuBoce	Fisheries Biologist	Field Technician
Aaron Lopez	Biologist	Field Lead/Boat Op
Jacqueline Hewitt	Biologist	Field Technician
Nolan Santala	Fisheries Biologist	Field Technician
Styles Smith	Environmental Scientist	Field Technician

Marine Taxonomic Services Ltd. (MTS)

Names	Title	Roles
Seth Jones	Principal Consultant, Project Manager	Project Manager
Monique Rydel-Fortner	Sr. Scientist, Project Manager	Senior Field Lead
Rachel Beckwith	Marine Technician I	Field Technician
Mike Berg	Marine Technician II	Field Lead/Boat Op
Alexander Gheen	Marine Technician I	Field Technician
Jordyn Green	Marine Technician I	Field Technician
Lilian Iverson	Marine Technician I	Field Technician
Rachael Lamore	Marine Technician I	Field Technician
Hamza Mohmaud	Marine Technician I	Field Technician
Emma Radulovic	Marine Technician II	Field Lead/Boat Op
Janelle Ross	Marine Technician I	Field Technician
Warren Strieff	Marine Technician I	Field Technician
Danyal Thompson	Marine Technician II	Field Technician

Inventive Resources, Inc. (IRI)

Name	Title	Role(s)
John A. Paoluccio, P.E.	CEO	Project Manager
John J. Paoluccio	President	Project Lead Vessel Operator
David Starr	Design Technician	Vessel Operator
Samuil Dichev	Technician	Vessel Operator
Evangelina Paoluccio, P.E.	Engineering Manager	Project Administrator
Dena Genasci	Bookkeeper	Administrative Support Staff
David McClellan	Technician	Maintenance Service
Thomas Davis	Designer/Programmer	Subcontractor
Roy Samol	Electrician	Subcontractor (Samol Solutions)
Margarita Frayle	Technician	General Labor
Daniel Dziubarczyk	Technician	General Labor
Ivan Gonzalez	Technician	General Labor
Francisco Velasquez	Technician	General Labor

Stratus Engineering Associates LLC (Stratus)

Name	Title	Role(s)
Rob Kull	Principal Engineer	Project Manager/Reporting/Data Evaluation
Michael O'Neill	Environmental Technician	Data Downloads
Steven Mok	Staff Geologist	Data Downloads
Story Parker	Staff Geologist	Data Downloads, Reporting/Evaluation
Dominick Gillespie	Staff Scientist	Data Downloads
Anthony Villarreal	Environmental Technician	Data Downloads

Hiuga Diving Co.

Name	Title	Role(s)
Thomas Hiuga	CEO	Supervise/ Boat Operator/ Diver
Carlos Vargas	Deck Hand	Diver Support
Justin Nash	Diver	Diver/ Boat Operator
Quinntin Sette	Deck Hand	Diver Support
Steve Gilmore	Diver	Diver/ Boat Operator
Ben Cortez	Diver	Diver
Crista Sykes	Boat Operator	Boat Operator/ Diver
Dakota Gillespie	Deck Hand	Diver Support

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