Presidio Trust Mountain Lake Restoration Update

Monitoring Report #2 (Year 7)
Conditional Water Quality Certification
for the Mountain Lake Enhancement Project, San Francisco County
(Permit File #2012-00285S)
January 2021

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Table of Contents

TABLES

FIGURES

Images

EXECUTIVE SUMMARY

Seven years have passed since the Mountain Lake Adaptive Management Plan (MTL AMP) implementation began. The MTL AMP describes a conceptual approach to the ecological restoration and management of the lake and defines a series of target goals and objectives. Each goal and objective has associated performance measures with targeted timeframes of success and monitoring strategies. This document is an update on the progress that has been made since the last report in 2017.

To date, much progress has been made and the health of the lake has greatly improved. Although the stated goals and objectives are ongoing and will require indefinite management to maintain desired conditions, the project has so far reached several important milestones. Water quality has generally improved, with average water clarity holding steadily within the target range over the last several years. Although the nutrient level indicator has come down greatly from a high peak in 2017, the 2020 average was just shy of falling within the upper threshold target. A lot of progress has been made in the installation of infrastructure that will reduce future nutrient run-off into the lake and help further drive down undesired nutrient input. Known native biodiversity has increased with the reintroduction of six species of once extirpated wildlife. As is expected with most reintroductions, some of those nascent populations are exhibiting the anticipated fluctuations that are common in the early establishment phases. Although establishment of submerged aquatic vegetation has continued to be a challenge, many valuable lessons have been gained through experience and the lake's ecosystem continues to change for the better, providing opportunities for renewed attempts under more suitable conditions. Unfortunately, non-native fish (bass) were introduced and have become established, but their predatory behaviors have significantly helped reduce the nuisance invasive crayfish, which has had several positive benefits.

Finally, this project has continued to achieve great success in terms of the human-dimension. Many students and people of all ages and backgrounds have been educated on this unique project. From local elementary schools and college classes to zoo interns and retired locals, thousands of people have been involved hands-on with this project and we have surpassed our five-year goal of directly engaging 10,000 individuals. Media coverage has continued to generate excitement through dissemination of these stories to untold numbers of people near and far, while scientific research at the lake has advanced the field of urban ecology and informed the management of the lake and other similar projects. Mountain lake is a living system becoming healthier every year due to proactive management that requires continued assessment and adaptation informed and guided by the results described in this document.

1 INTRODUCTION

In accordance with the Presidio Trust Mountain Lake Enhancement Project (Project) commitments to the San Francisco Bay Regional Water Quality Control Board (RWQCB) and as outlined in the *Mountain Lake Adaptive Management Plan* (MTL AMP) (Presidio Trust, 2014), various qualitative and quantitative monitoring programs are being conducted at the site for a period of nine years. The purpose of these monitoring programs is to provide data to guide adaptive management in order to achieve and maintain the plan's success criteria. The MTL AMP describes the conceptual foundation and adaptive management objectives, goals, and monitoring methods of the overall project. This is the second report, in a total series of three reports, which includes updates on the progress of each component since January 2017. The first report covers January 2014 to December 2016, and in some cases this document reports cumulative information from January 2014 to December 2020. Each report was originally intended to describe progress at three-year intervals for a total of nine years. Unfortunately, due to an editing error in the original MTL AMP reporting schedule for Report #2, this document describes and discusses progress for a four-year interval.

1.1 PURPOSE

As per the AMP, reporting on the progress of the Project is required every three years from year zero for a total of nine years, resulting in three reports. These reports were originally due on December 31st of the designated reporting year, however, in the interest of streamlining other reporting commitments with RWQCB the Presidio Trust will submit these progress reports by January 31st of the following year. This report covers the years from January 2017 to winter 2020 and will provide updates of activates since the last report. Report #1(2017) acted as a baseline, which this report (Report #2) will be compared against in order to assess relevant trends and progress towards the objectives and goals stated in the MTL AMP.

1.2 REPORT OUTLINE

This document will first recap the stated objectives, goals, and associated performance measures of the MTL AMP in section 2. Section 3 provides details of the actions, relevant associated methods, and performance measurement(s) progress that has occurred to date towards each objective and goal. A final Discussion section will synthesize all the above information together in order to assess more broadly the current state of the lake and provide management recommendations that will continue the advancement of long-term success through an adaptive approach.

1.3 PROJECT DESCRIPTION

Mountain Lake is one of the few natural lakes left in San Francisco and has significant recreational, ecological, and historic value. The lake is currently 4.02-acres, surrounded by several acres of wetland, riparian, woodland, and coastal scrub habitats, all managed to varying degrees. The lake is located at the southern border of the Presidio, bounded by the Presidio Golf Course to the north east, Park Presidio Boulevard (Highway 1) to the west, and the densely populated urban neighborhoods of San Francisco to the south.

The lake's ecosystem has been significantly altered since European settlement of the area began in 1776. Sedimentation of the lake and surrounding wetlands has been accelerated by human activities. Farming and grazing, along with urban and golf course development, contributed to increased sedimentation and a buildup of organic debris. In the late 1930s, the construction of Park Presidio Boulevard (Highway 1) led to the introduction of a large amount of fill, which greatly reduced the size and depth of the lake. Road construction and non-native tree planting sheltered the lake from the winds that originally stirred oxygen down to its deeper waters. Highway 1 was designed to discharge runoff directly into Mountain Lake via drop inlets. Core samples taken in 2000 found high levels of lead and other contaminants in the sediments at the bottom of Mountain Lake. These were removed via remediation dredging under the oversight of the Department of Toxic Substances Control (DTSC) in 2013 (Kennedy/Jenks, 2012).

Runoff from the urban watershed enriched the lake with nutrients (Blankinship & Associates, 2010; Booth & Rodoni, 2012) along with a lack of oxygen in the bottom waters, which led to regular blue-green algae blooms in the summer and fall. Non-native invasive fauna dominated the lake throughout the 20th century introduced through public releases of unwanted, and/or recreational fishes and turtles. These non-natives further increased the nutrient load and habitat degradation. These exotic animals were a primary cause of the extirpation of many native species and the decline of the lake's ecological health.

Environmental remediation work began in 2013 with the dredging and removal of 17,500 cubic yards of sediment. With the completion of remediation, ecological restoration of the aquatic system began in early 2014. This augmented ongoing terrestrial restoration that began in 2001.

This project seeks to restore the environmental health and function of Mountain Lake through various direct holistic ecological management approaches, as well as indirect public, community-based engagement programs.

2 PROJECT OBJECTIVES AND GOALS

The health of the lake's ecosystem is largely based on these three outcomes: non-native fish eradication, establishment of submerged aquatic vegetation (SAV), and the alteration of detrimental human behaviors. In order to clarify conceptual targets of restoration success a series of objectives and goals were outlined with associated performance measurements in the MTL AMP. The subsections below outline these goals and objectives.

2.1 OBJECTIVE 1: Increase the body of knowledge in urban ecosystem restoration

Performance measurements include the following:

a. Complete three research (adaptive management) studies regarding the ecology of urban aquatic restoration: 1) SAV, 2) turtles, and 3) mussels.
b. Complete an education strategy to minimize non-native species introduction to Mountain Lake. Success will be determined through the following measurements:
    1) no non-native fish discovered during the monitoring occurring every 3 years
    2) no visual observation of individuals feeding wildlife over a 2-hour period over 3 consecutive days after 5 years.
c. Develop and implement strategies to monitor faunal population increases and decreases for Years 6 and 10.

2.2 OBJECTIVE 2: Increase water clarity

Performance measurements include the following:

a. Achieve an average Secchi Disk of 160 centimeters (cm) (range 120-210 cm) during the growth season (March-October) within 5 to 7 years.

2.3 OBJECTIVE 3: Lower nutrient levels / eliminate point source nutrient inputs

Chlorophyll concentrations will be used as an index of nutrient levels and performance measurements include the following:

a. Obtain an average Chlorophyll a concentration range of 9-17μg/L in open water during the growth season (March-October) within 5 to 7 years.

2.4 OBJECTIVE 4: Non-native Fish management

Although the eradication of non-native fishes, or at the very least the significant and sustained reduction of their populations, was not expressly listed as an objective or goal in the MTL AMP, this was an oversight, and should be reflected as a goal in all future reporting about the Project. Non-native fish management is intimately linked to the successful outcome of many of the overall project goals and objectives described in the AMP.

2.5 GOAL 1: Reestablish submerged vascular plants (SAV)

The goals for SAV are identified in three stages: Years 1, 6, and 10. Performance measurements include the following:

a. Year 1: 50% survival in unprotected SAV colonies, which demonstrates the persistence of SAV either in its presence with carp activity or because of a reduction in carp abundance. Early detection of non-native SAV will be monitored for its presence through visual identification.
b. Year 6: 25% aerial coverage of SAV after 5 years, with 80% maximum in shallow areas (< 3 meters depth). If there is an overabundance, it will trigger an analysis of potential harvest action (i.e., raking). If no establishment occurs, this triggers an analysis of potential causes and actions such as replanting and/or more exclusion fencing.
c. Year 10: 25% to 30% SAV cover of suitable shallow areas (< 3 meters) of the lake. The number of discrete colonies may decline over time as colonies grow and merge. A less-than-3-meter depth perimeter will have SAV densities of 20% to 80%. Densities over this will trigger the analysis of potential harvest action, while densities of less than 20% will trigger an analysis of possible limiting factors.

2.6 GOAL 2: Increase native fauna diversity

Performance measurements include the following:

a. Reestablish a population of three-spine stickleback by Year 2.
b. Reestablish two additional native fauna species within 5 years.

2.7 GOAL 3: Manage detrimental human activities

The success of ecological management of Mountain Lake's aquatic ecosystem will in large part depend on the effective management of human activities, stemming ecologically detrimental behaviors and fostering positive ones. To reach this goal, outreach will be conducted on a regular basis through interpretation, education, and volunteerism. The performance measurements are as follows:

a. 3,000 volunteer hours at Mountain Lake within 5 years.
b. Installation of all planned regulatory and educational signage by the end of 2014. Monitoring and repair will be performed as needed. Maintenance will be performed as needed in case of vandalism or other damage.
c. Within 5 years, receipt of 10,000 pledges to protect Mountain Lake.
d. Initiation of a multifaceted Mountain Lake-based educational program with a pilot beginning in spring 2014.

e. Regular, curriculum-based programming implemented at six neighborhood schools, at each of the elementary, middle, and high school levels, with two junior high programs piloted in spring 2013.
f. Establishment of a weekly docent/collection area for unwanted aquarium organisms.
g. Visual observations identifying minimal individuals feeding wildlife.
h. Establishment of containment netting on the public shoreline areas to prevent released animals from entering the body of the lake.

2.8 GOAL 4: Manage mosquito populations

To protect human health and the quality of experience, mosquito populations will be treated with the use of bacteria-based larvicides (*Bacillus spp.*). if in a single monitoring night more than three individuals of a species that can transmit human disease are found. The performance measurement is as follows:

a. No significant increase (compared to pre-project mosquito populations) in mosquito numbers for species with the potential to transmit human disease.

3 OBJECTIVES AND GOALS PROGRESS UPDATE

The subsections below review and describe progress to date towards each objective/goal and associated methods/actions.

3.1 Increase the body of knowledge in urban ecosystem restoration

The Trust is committed to applied science and adaptive management, collaboration, and the advancement of science through research. The Mountain Lake project continues to offer many opportunities to support these three commitments, all of which increase the body of knowledge of urban ecosystems. Since 2014 more than three research projects have occurred or are/will be occurring. Updates on current research projects are below.

a. Three research/adaptive management studies

1) See Report #1 for details on past turtle and mussel research that has occurred at the lake.
2) The completion of the acoustical tracking of western pond turtles resulted in a large robust dataset of turtle underwater movement. How do these turtles use the lake's underwater habitat? Is there a preference of submerged habitat type? These are the types of questions this research seeks to answer. No study accumulating underwater movement habits of this species has occur

before, and this research represents a novel underwater perspective relevant to the conservation and management of this species. The sheer size, complexity, and potential of this dataset required collaboration with biologists at the United States Geologic Survey (USGS) Western Ecological Research Center. A collaboration/sharing of data has been ongoing and USGS biologists have been analyzing these data. Results are pending.

3) Researchers at San Francisco State University have begun investigating chorus frog breeding calls across a gradient of urban to rural sites with different levels of anthropogenic soundscapes throughout the Bay Area, including Mountain Lake. Mountain Lake, being close to a busy highway, has a significant level of anthropogenic noise, which can potentially impact the auditory breeding calls of these frogs. Research such as this has important implications to urban wildlife conservation and better understanding of anthropogenic soundscape impacts and management.

b. Education strategy to minimize non-native species introduction to Mountain Lake.

Strategies include direct engagement through volunteer programs, school groups/field trips, public presentations, interactive tabling, multi-media stories, and interpretative/regulatory signage. More details on the education strategy can be found in Report #1 section 3.7 and relevant progress can be found below in section 3.7.

Performance measurements

1) No non-native fish discovered during the monitoring occurring every 3 years

   In 2016 non-native black bullhead catfish were confirmed present and in 2017 largemouth bass were discovered in the lake. Since 2017, four red-eared sliders have been found in the lake

2) No visual observation of individuals feeding wildlife over a 2-hour period over 3 consecutive days after 5 years.

   Bird feeding was once a popular activity along the south shore of the lake. See section 3.7 for more information regarding public engagement/regulatory signage on this topic. No formal protocol was developed/implemented to track this human behavior. Since 2017, based on anecdotal opportunistic observations, bird feeding has become very few and far between, though a few events have been observed or were intercepted before feeding occurred.

c. Develop and implement strategies to monitor faunal population increases and decreases for Years 6 and 10

Our community science “Mountain Lake Turtle Watch” program has been ongoing since 2016 and has allowed us to track the reintroduced population through time (results below).

Stickleback monitoring via opportunistic visual surveys and minnow trapping has been ongoing since the initial reintroduction efforts in 2015 and will continue indefinitely (results below).

A monitoring protocol was developed to monitor the reintroduction efforts of the San Francisco forktail damselfly and was implemented in 2020, Unfortunately it was severely restricted due to the covid-19 pandemic.

Long-term avian monitoring at the lake, the adjacent East Arm wetland restoration site, and surrounding upland habitats has been occurring since as early as 2002 primarily through Point Blue Conservation Science (formerly Point Reyes Bird Observatory). In 2019 a community science based avian monitoring protocol was developed and piloted, which includes the open water of the lake, the surrounding riparian habitat, and the east arm wetlands. Both of these monitoring programs follow similar methods (i.e. area search surveys) and are intended to track population/community trends through time.

3.2 Increase water clarity

As described in Report #1, the aeration system was installed in 2015. Over the last several years this system has had several issues around vandalism and unforeseen breakages. As of fall 2020 the system is functioning as intended. For at least one season (2017) the system was not functional, which may explain to some extent the low water clarity of that year’s seasonal average (see figure 1 below).

Performance measurement

Achieve an average Secchi Disk of 160 centimeters (cm) (range 120-210 cm) during the growth season (March-October) within 5 to 7 years.

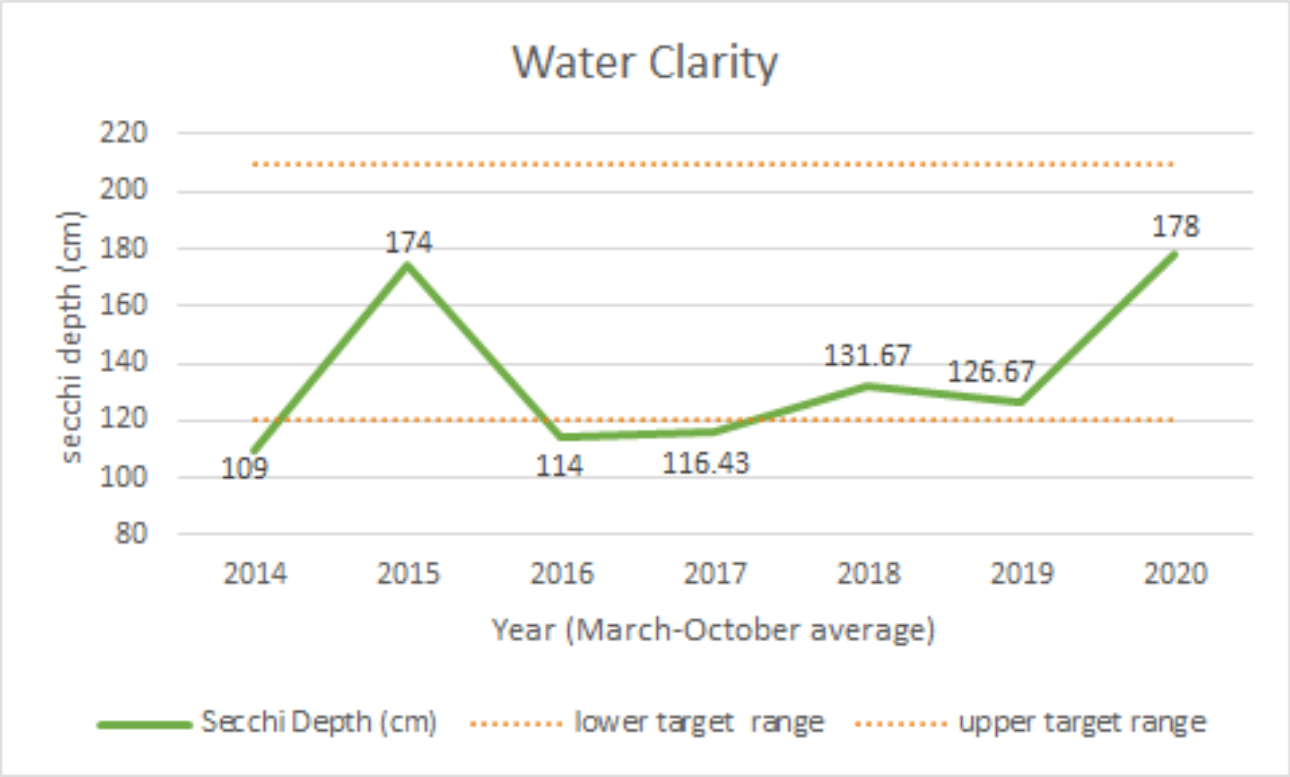
Monitoring methods

Water clarity will be measured by boating to the middle of Mountain Lake and lowering a black and white Secchi Disk into the water until it can no longer be seen. The depth of the disk at that point will be measured. Three repetitions will be completed and an average calculated.

Table 1: water clarity monitoring results

March-October	Secchi Depth (cm)
2014	109
2015	174
2016	114
2017	116.43
2018	131.67
2019	126.67
2020	178

Figure 1: average water clarity monitoring results



3.3 Lower nutrient levels / eliminate point source nutrient inputs

In addition to the previous storm/surface water management projects described in Report #1, including highway drainage modification and erosion/flow control around the East Arm, more significant North Arm modification has occurred since Report #1. A novel “bio-reactor” denitrification trench system, intended to capture nutrient-rich surface water flow from the golf course, was installed in 2018. The design utilizes the natural processes of bacterial denitrification (reduction of nitrate, NO_3 to N_2-gas), which occurs in low-oxygen environments, and is powered through bacteria metabolism of woodchips that fill the trenches. Approximately 202 linear feet of trenching, roughly 7 feet wide and 5 feet deep, were excavated along the northern surface water input flow zone. These trenches were lined with filter fabric and backfilled with woodchips, then covered with plastic and gravel (see images 1-7 below). Water monitoring wells on both the upper and lower ends of these trenches were installed, though there have been no significant rains since installation, so no data exists to assess the system’s efficacy.

In addition to the trench system above, an over-flow bioswale/retention basin was constructed to capture excess water overflow from the trench system (see image 8 below). Both of these systems are intended to retain and process (i.e. reduce nutrients) the northern input of storm water flowing off the golf course before ultimately ending up in the lake.

Performance measurement

Chlorophyll concentrations within the lake: Obtain an average Chlorophyll-a concentration range of 9-17μg/L in open water during the growth season (March-October) within 5 to 7 years.

Monitoring methods

Water quality monitoring of a representative Central Index Station in the middle/deepest part of the lake began in February 2014. Using a Van Dorn horizontal water sampler, a 1L depth-integrated chlorophyll-a sample was collected from the center of the lake (this composites water from 1m deep with surface water), and a separate 1L grab sample was collected from the surface. Conditions permitting, this sampling occurred each month. Analytical Sciences, LLC processed all chlorophyll-a samples and reported values for results above their reporting detection limits.

Modification note: As per the recommendation of Dr. Alex Horne, in July 2020 chlorophyll monitoring methods were modified to eliminate the collection of the redundant subsurface sample and only sample surface level chlorophyll.

Table 2: nutrient level indicator monitoring results

March-October	µg/L
2014	15.43
2015	38.61
2016	27.80
2017	57.75
2018	28.64
2019	34.43
2020	18.21

Figure 2: average chlorophyll concentration monitoring results

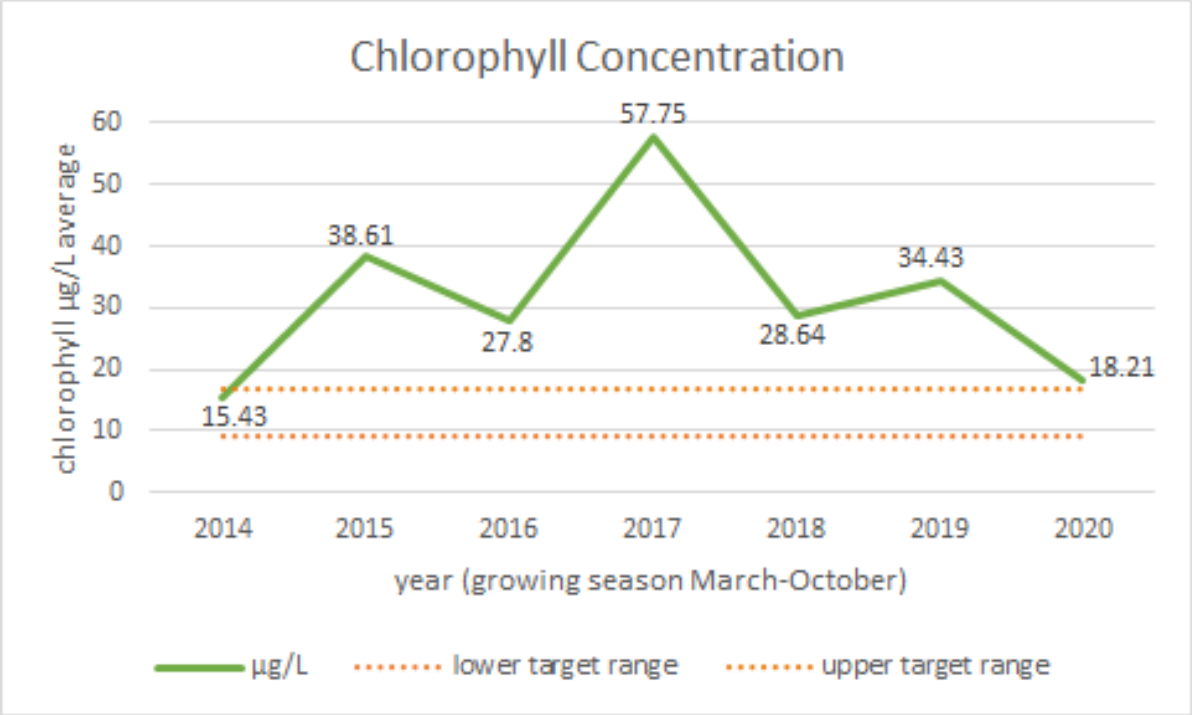


Image 1: construction plan of north arm de-nitrification trenches and bioswale

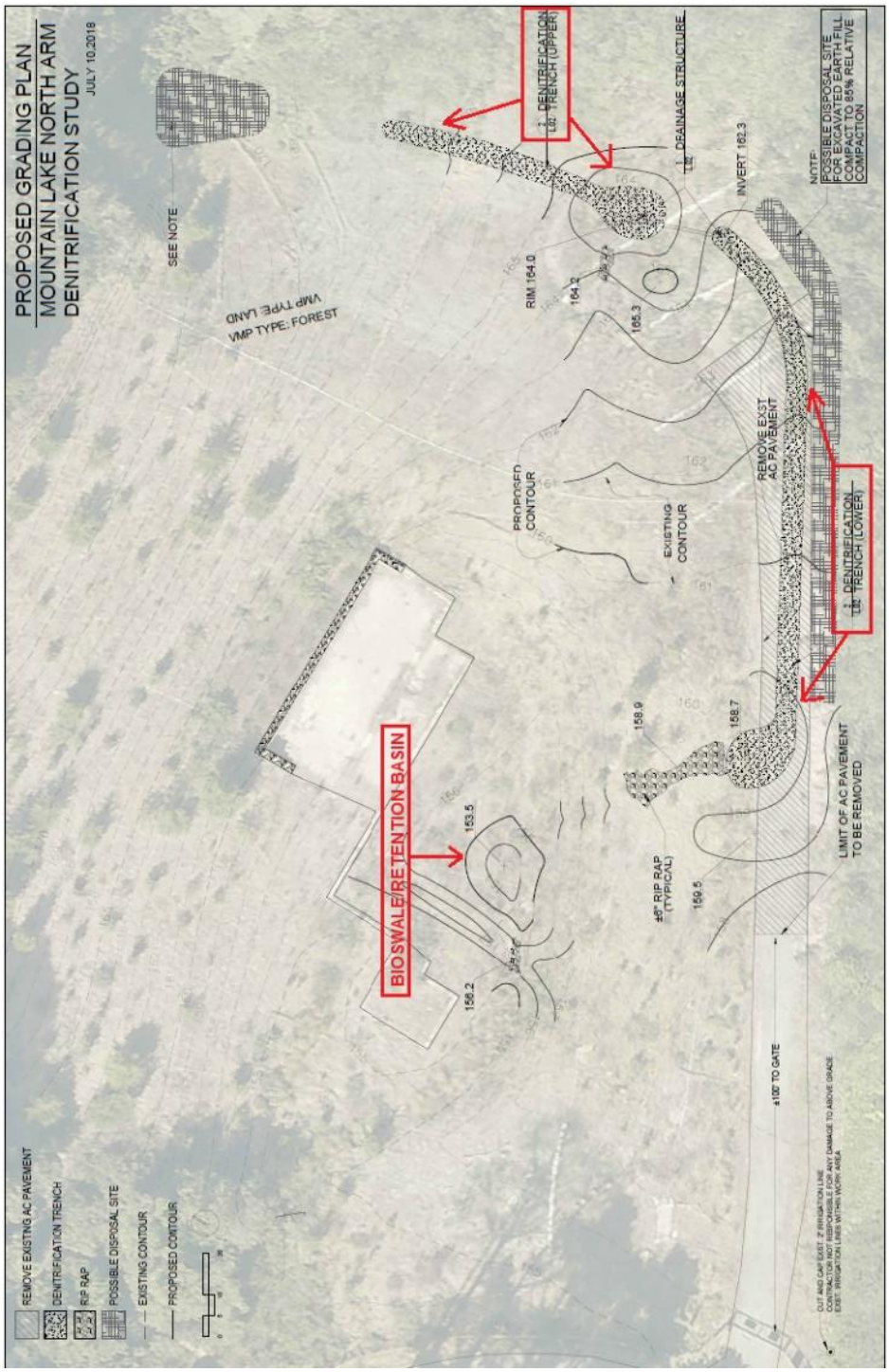


Image 2: upper trench looking downhill

Image 3: lower trench looking downhill (Highway 1 bridge on right)

Image 4: lower trench looking uphill

Image 5: lower trench towards top end

Image 6: upper trench covered with fabric

Image 7: bulb end of lower trench

Image 8: north arm bioswale/retention basin, looking south east

3.4 Non-native fish Management

In November 2014 the application of rotenone, a fish toxicant, was applied to the lake which resulted in the complete eradication of the entire fish community, which was comprised of entirely non-native and invasive species. See Report #1 for more details. By 2016 black bullhead catfish were confirmed in the lake and removal efforts began. As noted in Report #1, the rotenone treatment did not have a negative impact on the invasive red swamp crayfish (*Procambarus clarkii*), but rather, had an indirect positive impact through the removal of the predatory bass, which resulted in a drastic population explosion. The increase of crayfish in turn had negative impacts to other restoration efforts due to their voracious omnivorous behaviors. This increase of the crayfish population required management through trapping and reduction, as reported below.

Monitoring/Removal/Management Methods

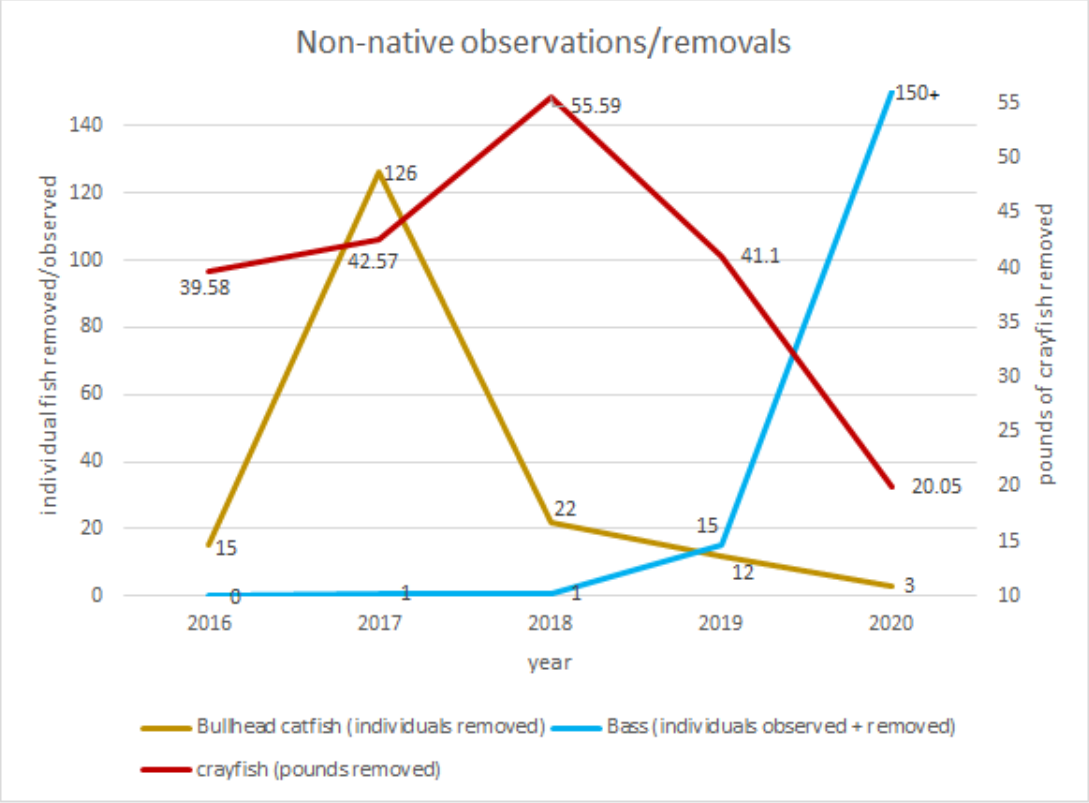
Since the presence of non-native catfish were confirmed in 2016 monitoring methods shifted to removal/management efforts, which focused more on the use of minnow traps/larger funnel traps as these types of traps were found to efficiently capture these non-natives while avoiding non-target captures of western pond turtles and diving birds. We deployed and maintained an average of 25 traps continuously operating along the

entire perimeter of the lake across all seasons. These traps ranged in size from smaller ~60cm length minnow traps to ~2.5m custom made funnel traps. Traps were baited with canned cat food and served dual functions as fish and crayfish traps. Crayfish caught were dispatched and used as bait. Gillnets were occasionally deployed but were not left unattended for longer than an hour without checking. In addition, when feasible, traditional rod and reel methods were found to be an effective means of catching medium to larger fish. Visual observation monitoring, primarily of bass, occurred opportunistically and reported here as an estimated index, not hard quantified numbers.

Table 3: invasive species monitoring results/removal results

	Bullhead catfish (individuals removed)	Bass (individuals observed + removed)	Crayfish (pounds removed)
2016	15	0	39.58
2017	126	1	42.57
2018	22	1	55.59
2019	12	15	41.1
2020	3	150+	20.05

Figure 3: invasive species monitoring/removal results



3.5 Reestablish submerged vascular plants (SAV)

Attempts to reestablish SAV began in 2014 prior to the eradication of the non-native fish community. Since then many attempts have been made, using a variety of herbivory-exclusion cages/floating baskets and different species across different locations of the lake (see report #1 for more details). As of winter 2020, there has been no successful establishment of any SAV in the lake. Several short-term establishments occurred over the last several years only to fail due to dabbling ducks and/or non-native crayfish and/or complete coverage of plants by filamentous algae.

Although dabbling ducks are relatively easy to exclude with cages, non-native crayfish have proven very difficult to exclude. Smaller cages (i.e. smaller patches of protected SAV potential) allow for a more full-proof crayfish exclusion (e.g. prevent burrowing under or climbing over), however, once SAV becomes established within these small patches the next step in allowing expansion is where vulnerability occurs. Removing/expanding these cages creates less control of exclusion and allows more opportunities for crayfish to infiltrate. In an attempt to avoid all these issues the concept of floating baskets was piloted. Floating baskets just below the surface keep the SAV off the bottom of the lake and reduce/eliminate crayfish accessibility, with some caveats depending on the anchor line used (i.e. crayfish can climb up the line depending on material and design). This approach showed initial signs of momentum, however, throughout the growing season (spring-fall) abundant filamentous algal growth was observed completely covering the entirety of the plants. Plants were unable to survive due to the loss of light from the algae.

Given that the east arm wetlands east of Mountain Lake have very low numbers of crayfish, relatively shallow clear water, and minimal dabbling ducks, SAV establishment efforts began focusing at that site in 2018 using the same cage methods refined in the previous years. Both *Stuckenia* and *Myriophyllum* quickly grew and spread during the 2019 season. With the successful establishment at this site, it was identified as the new source for future materials for continued establishment attempts in the lake. Having a "natural nursery" for in-house collections of material allowed for the dismantling of the resource intensive traditional SAV nursery operation. In 2019, water fern (*Azolla* sp.) and duckweed (*Lemna sp.*), small floating mat-forming plants, were observed at the site. Throughout the 2020 season the *Azolla* mats dominated the entirety of surface of the main basin of the site where all the SAV was. These floating mats blocked out most of the light and a decline in SAV patches was observed. Some patches of SAV still remain and attempts to manage open patches of surface water to allow light penetration are on-going and include novel approaches such as the use of floating innertubes (see image 9 and 10 below).

Image 9: east arm SAV management

Image 10: opening up duck weed/water fern to allow light penetration for SAV growth

Monitoring methods

Monitoring will be completed using visual sighting along transects from a boat and mapped to estimate canopy coverage.

As stated in the MTL AMP, "*Initially, for the first few years of establishment, any new colonies will likely occur as discrete patches that will be inefficient to measure in a grid system or transects. A high sample error would be inherent due to low percent cover. For initial establishment, the canopy dimensions will be measured directly*."

Monitoring Results

As of winter 2020, no successful long-term establishment of SAV has occurred within the lake.

3.6 Increase native fauna diversity

Various extirpated native wildlife species were identified in the MTL AMP for potential reintroduction. Since the non-native fish removal of 2014, a variety of species reintroductions have occurred and/or have begun. Below is a breakdown of progress towards this goal.

Three-spine stickleback (*Gasterosteus aculeatus*)

Beginning in April 2015 stickleback reintroductions began. Throughout the remainder of the year approximately 1000 individuals were collected from near-by Lobos creek and released at the lake (Presidio Trust, 2015a).

Monitoring methods

Establishment/reproduction confirmation monitoring began in spring of 2016 with the use of both minnow traps as well as opportunistic hand nets and gill nets (during non-native fish monitoring). Minnow traps were dispersed throughout the shallow perimeters of the lake and checked/cleared regularly. Visual surveys occurred from boat or on foot along the shoreline. When fish were observed, the use of a hand net allowed for species identification. The gill nets that were used to monitor for non-native fishes were also sufficient to capture larger brooding female stickleback for monitoring purposes.

Monitoring results

Since 2016 the stickleback population expanded significantly throughout the lake. So much so that monitoring and tracking numbers seen or trapped was not feasible as there were too many to count. During summer-fall 2020 however, many dead/dying stickleback were observed along the perimeter of the lake. As of winter 2020, stickleback are still occasionally found in the minnow traps, but visual observations are now rare. The population has been severely reduced.

Pacific Chorus Frog (*Pseudacris sierra*)

Beginning in late February 2015 chorus frog egg masses were translocated from the only other Presidio population into predatory exclusion cages within Mountain Lake. Over the next month a total of 83 egg masses (representing approximately 2870 embryos) were moved to the cages in the lake. Tadpoles were allowed to develop in two cages, with occasional supplemental feeding with algae pellets, until metamorphosis into froglets occurred. From late April until mid-July a total of 1291 froglets were released along the perimeter of the lake.

Subsequent translocations of 34 egg masses occurred in April 2016 in order to bolster the newly established population at the lake/east arm. A total of 500 individuals were released. No more translocations of egg masses will occur at the lake unless future monitoring suggests action is required (Presidio Trust, 2015b).

Monitoring methods

Chorus frogs were surveyed for during the breeding season (January-March). Adult breeding male calls confirmed presence. Nocturnal surveys occurred at the site until chorusing was confirmed. Daytime egg mass surveys were conducted in late winter and early spring consisting of visually counting egg mass numbers present.

Monitoring results

Chorus frogs are abundant throughout the north arm and east arm wetlands and are observed in the lake's tules and are commonly seen/heard in the upland habitats around the lake including the golf course and playground. Monitoring efforts have been drastically reduced to primarily opportunistic observations due to the clearly confirmed establishment.

Note: in October of 2019, 31 chorus frogs in the East Arm wetlands were sampled for the Chytrid fungal pathogen *Batrachochytrium dendrobatidis*. Five (16%) were found to be positive for the pathogen.

Western Pond Turtle (*Actinemys marmorata*)

A total of 55 San Francisco Zoo-reared western pond turtles (WPT) were released in early Fall 2015 (Presidio Trust, 2015c).

Monitoring methods

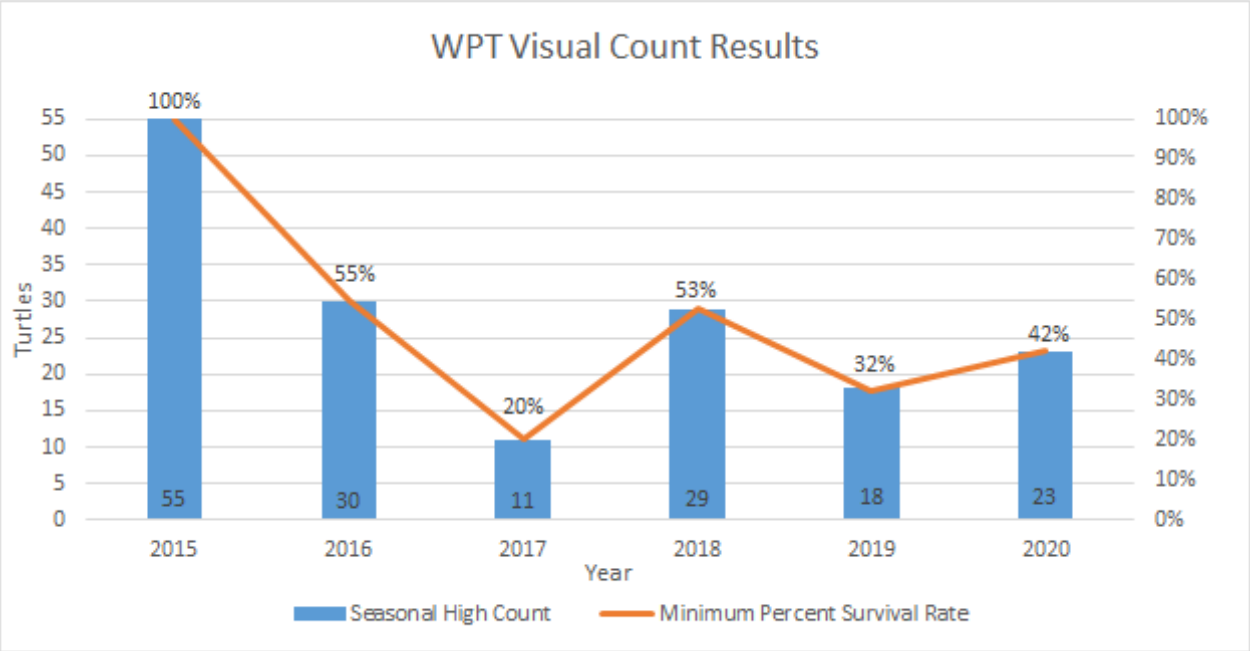
As per the Mountain Lake Adaptive Management Plan: "*Western pond turtles will be identified at an index site with high basking activity. Success will occur if 50% of the number of original reintroduced turtles are counted on a sunny day. Basking sites will be visually surveyed mid-day, 5 days in a row, observing the lake for 1 hour each day."*

The methods outline in MTL AMP for western pond turtle monitoring were altered in order to capitalize on this management necessity as an opportunity to engage the local community while simultaneously monitoring this new population. Monitoring methods suitable for a community science project were developed with our SFZ and SSU partners following the methods of Marin Municipal Water District's similar western pond turtle community science program. More details can be found in Report #1.

Monitoring results

Since monitoring began in 2016 visual counts (i.e. highest count of turtles in one session per season) have gone down from 55 to 23. No breeding/recruitment has been observed/confirmed. Four non-native red-eared sliders have been released in the lake over the last few years. Three have been captured and removed, but at least one remains loose.

Figure 4: community science turtle monitoring results



Anodonta Mussel (*Anodonta californiensis*)

Since 2016 the first batch of 500 lab-reared mussels from Missouri State University were placed in the lake within floating baskets, with several other batches following over the years. Unfortunately, many of these lab-grown mussels succumbed to non-native crayfish predation. Our basket designs began to improve and focus on deeper areas of the lake, with specific focus on the anchor line, which appeared to have been the only point of crayfish connectivity. We started to see more survival and growth of these vulnerable small mussels. In 2017 we began a new approach in concert with continued lab-rearing, which involved stickleback catch-inoculate-release. Stickleback were trapped in Mountain Lake, brought back to our lab and kept in close quarters with brooding mussels. After 24-48 hours the stickleback would generally be covered with glochidia (larval mussels) and then released back into the lake in various areas. Since 2017 approximately 1600 inoculated stickleback have been released into the lake.

Monitoring methods

Monitoring for successful recruitment was initially done with a small Ekman grab opportunistically sampling around the perimeter of the lake from a boat and opportunistic mussel rake sampling along the wadable area of the south shore. When conditions permit, opportunistic snorkeling and/or scuba diving will be employed for more thorough coverage. Once confirmation of establishment and recruit have been

confirmed a more standardized quantifiable protocol will be developed and implemented.

Monitoring Results

Monitoring with Ekman grab and rakes occurred in 2019 with no successful confirmation. In 2020, the water level was very low and clarity very high and many live mussels were observed just outside the south shore containment net in waist deep water. Subsequent snorkeling around the entire perimeter of the lake confirmed thousands of live mussels, of various sizes, throughout most of the suitable areas up to depths of around 8-10 feet. Standardized quantifiable monitoring methods will be developed/implemented in 2021.

San Francisco Forktail Damselfly (*Ischnura gemina*)

Since fall 2016 San Francisco Zoo has collected adults from Fort Point seep, bred them, reared the offspring, and then released 20,716 naiads (aquatic larval stage) and 649 adults in the lake and both the north and east arm wetlands. In late 2018 through 2020 releases focused only on the east arm wetlands as it provides more consistent suitable habitat (e.g. managed/no willow canopy, open water mixed with dense emergent vegetation, and sun).

Monitoring methods

Initial monitoring will consist of visual observations around the lake's perimeter emergent vegetation in Spring 2017 when the adults emerge to take flight.

Monitoring results

Few flying adults have been seen over the years of monitoring, which is not unexpected as the habitat around the lake/east arm is complex and the damselfly is relatively small. Given that both adults and naiads were released, when a flying adult was observed it was impossible to confirm if that individual was released as an adult or emerged on site. In 2020, a standardized protocol was developed and implemented, in addition, the zoo began marking the wings of all released adults on site to identify individuals that were released as adults versus others. Even though the 2020 season was impacted by the coronavirus pandemic, a total of survey 1245 minutes occurred at the East Arm, resulting in 18 flying adults where all but one were marked. The most significant observation made during monitoring was that of a marked female actively mating with an unmarked male in the East Arm wetland.

Rough-skinned Newt (*Taricha granulosa*)

Beginning in September 2019 the reintroduction of rough-skinned newts began with the translocation of approximately 405 larvae/metamorphs collected in the Marin headlands. 2020 translocations resulted in an additional 122 released, and a third and

final translocation season will occur in 2021. The first cohort of newts won't reach sexual maturity until their third year and will be spending most of their lives in the upland terrestrial habitat until the breeding season (late winter-spring) at which point they will begin to occupy the aquatic habitat for mating, egg laying, and the subsequent larval generation.

Monitoring methods

Monitoring over the first few years will be opportunistically surveying the upland habitat by flipping cover objects like logs and boards. After they start reaching sexual maturity (spring 2022) monitoring will focus on seasonal breeding surveys by walking within the east arm wetland and boating along the lake's tules visually looking for mating pairs or balls, singletons, and/or eggs.

Monitoring Results

No newts have been found in the upland habitat. This is expected as they would have dispersed across the site and likely burrowed deeply during the dry months.

3.7 Manage detrimental human activities

The performance measurements and progress:

a. 3,000 volunteer hours at Mountain Lake within 5 years.

- Since January 1st, 2017, 1175 adults donated 4407.5 volunteer hours at Mountain Lake at 101 volunteer programs. 894 youth volunteers [those 24 years old and younger] worked an additional 876 hours at 44 volunteer programs. Together, this totals 5283.5 volunteer hours in three years. We exceeded our goal, despite all volunteering being placed on hold during the coronavirus pandemic from early March-late November 2020.

- These volunteer hours are in addition to the 9,102 volunteer hours from January 2013-December 2016. This makes a cumulative total of 14,385.5 volunteer hours worked at the lake since January 2013, not including intern work hours.

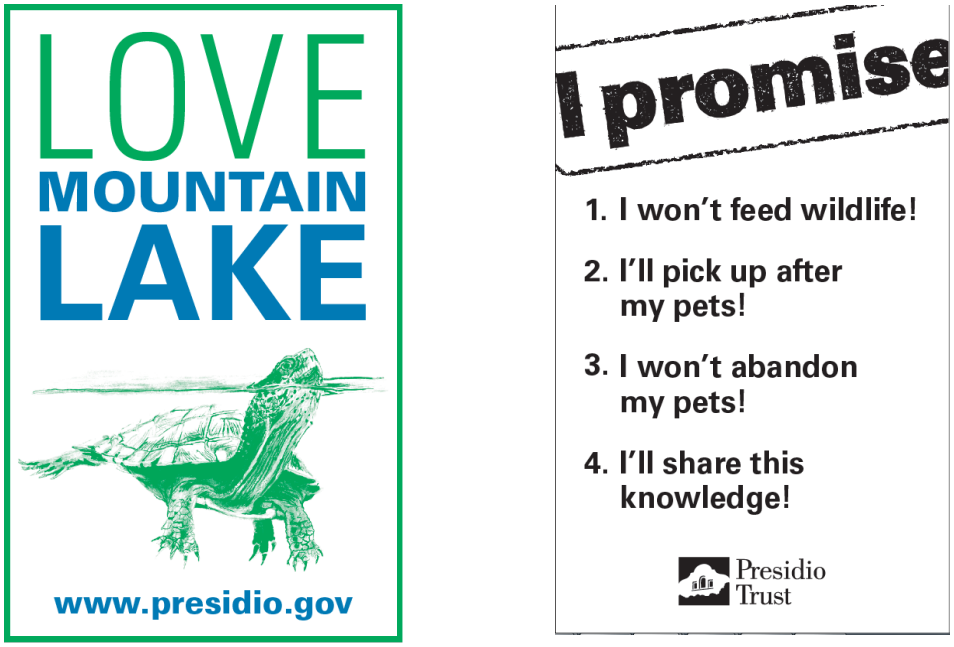
b. Installation of all planned regulatory and educational signage by the end of 2014.

- All planned regulatory and interpretive signage continue to exist around the lake. In 2019, we added temporary signage promoting responsible cigarette waste disposal in front of the east access benches, along with a new trash can. See Report #1 for more details on interpretive and regulatory signage.

c. Within 5 years, receipt of 10,000 pledges to protect Mountain Lake.

- We achieved our goal and reached the 10,000 pledge milestone on February 5, 2019.
- We have delivered a total of 10,612 pledges to protect Mountain Lake since January 2014.
- We now refer to the pledge as the Mountain Lake Promise to eliminate any confusion about donation expectations.

Image 11: second generation pledge sticker



d. Initiation of a multifaceted Mountain Lake-based educational program with a pilot beginning in spring 2014.

All education/volunteer programs incorporate essential talking points around the conservation and management of the lake, as listed in the promise/pledge program outline, which includes the issues of releasing unwanted pets, feeding wildlife, and native species conservation.

- On August 3, 2019 we hosted a community celebration of the restoration of Mountain Lake. Approximately 75 neighbors, community partners, and scientists involved with the project over the past 19 years attended, with local media coverage as well. We provided updates on the lake's health, wildlife efforts, habitat restoration, and historical tours. We also celebrated

the 10,000 promise milestone achieved earlier that year and the opening of the Western Pond Turtle under-trail crossing.

- 561 youth (ages 24 years or younger) participated in 36 Mountain Lake-based educational programs over the last three years, with activities ranging from summer camp volunteering to college ecology class field trips. We continued our youth education partnership with San Francisco Zoo by leading 15 middle-school-aged Zoo Crew youth once a month during the school year in habitat restoration and environmental education activities.

- 668 adults participated in 26 Mountain Lake-based community educational programs such as guided tours and one appreciation event. Approximately 10% of these visitors were from Presidio Trust community partnership programs hosting visitors from under-represented communities in San Francisco. We focused on park access to these communities during the annual City Nature Challenge bioblitz event in April 2018 and April 2019.

- From 2017 to 2019 an interactive educational table, staffed on average by two environmental educators, was regularly present at the lake during summer months, three days a week for four hours. During these events a total of 1450 people (60% youth) were engaged and educated on the Mountain Lake story and inhabitants.

- 121 individuals were educated about Mountain Lake at the Clement Street Sunday Farmer's Market in spring 2018. This farmer's market takes place in the closest residential neighborhood to the lake outside of the park. This neighborhood is also home to aquatic pet stores within walking distance of Mountain Lake, so sharing the Mountain Lake Promise was integral to long-term lake restoration.

- Since 2013 well over 10,000 people have been directly reached through more than 360 Mountain Lake specific programs and events educating them on the saga of the Lake. Notable groups include: Bayview YMCA, California Academy of Sciences, California Native Plant Society, City College of San Francisco, Friends of Mountain Lake Park, Friends of Mountain Lake Park Playground, Golden Gate National Parks Conservancy, International Urban Parks Council, Oakland Museum of California, Presidio YMCA, Richmond YMCA, San Francisco Public Library, San Francisco Recreation and Parks Department, San Francisco State University, San Francisco Zoo, San Jose State University, Skyline College, Sonoma State University, Stanford University, Sunday Streets, University of California-Berkeley, and University of San Francisco.

- All educational programming was placed on hold in early March 2020 due to the coronavirus pandemic. Due to restructuring and layoffs at the Presidio Trust, the Education team was eliminated. The capacity of future educational programs at Mountain Lake is currently unknown.

e. Regular, curriculum-based programming implemented at six neighborhood schools, at each of the elementary, middle, and high school levels, with two middle school programs piloted in spring 2013.

Presidio Trust education and natural resource staff continued partnership programs at several local elementary and middle schools proximal to Mountain Lake. New program streams were developed and piloted, while the service-learning habitat restoration program continued building on the model initiated in 2014. The new programs included: the Presidio Phenology Project (through the USA National Phenology Network [usanpn.org]), and place-based summer camp programs that centered around lake history, restoration, and ecology.

The Presidio Phenology Project, an on-site community science program, engaged partner schools (marked with an asterisk below) during the school year, and a local non-profit organization (Golden Gate National Parks Conservancy) during the summer. Teachers and staff were offered training, on-site support, program resources such as activity guides with tips and protocols for how to take students to the lake to monitor native plants throughout the seasons, and post-field instructions on how to enter data into a national portal for additional learning on climate change.

Service-Learning programs were offered to school day & afterschool programs as a facilitated experience for students to immerse in the habitats of Mountain Lake, and take an active and guided role in the on-going and long-term stewardship while learning about the tools and science of restoration of the lake.

A California Academy of Sciences partnership to put on local events as part of the world-wide City Nature Challenge was leveraged as an opportunity to focus students and the general public on the Mountain Lake's biodiversity. A unique student bird guide project "Birds of Mountain Lake" was completed in August of 2016 by Jonah Benningfield. The guide featured photos and fun facts about 12 commonly seen birds at the lake. The guide was reviewed by natural resources staff, and professionally designed and printed. It has been distributed to students, and general visitors as a free resource to learn more about the lake's avian community.

Elementary schools

- Alamo Elementary (0.9 miles, public) – 2 programs serving 63 youth
- Peabody Elementary* (0.5 miles, public) – 15 programs serving 150 youth
- Sutro Elementary* (0.2 miles, public) – 4 programs serving 124 youth

Middle schools:

- Hamlin School* (2.3 miles, private, K-8th) – 3 programs serving 180 youth
- Presidio Hills School* (0.8 miles, private, K-8th) – 12 programs serving 180 youth
- Golden Gate National Parks Conservancy, Urban Trailblazers* (0.2 miles, youth summer program) – 14 programs serving 435 youth

High schools:

- College Prep High School* (16 miles, private) – 2 programs serving 75 youth

In total, this represents 52 programs with neighborhood public and private schools and partner youth program serving 1207 students since 2017. Cumulative total since the beginning of this curriculum-based program in spring 2013 includes eight schools, 122 programs, engaging 3407 students. We continued partnerships with Peabody Elementary and Sutro Elementary that were initiated in 2014. We also partnered with the California Academy of Sciences to raise awareness about biodiversity through the *City Nature Challenge* with elementary students at Sutro Elementary. This year's City Nature Challenge 2020 event would have further engaged families and the broader general public in bioblitzes to document the biodiversity of Mountain Lake, but had to be cancelled due to public health concerns related to the coronavirus pandemic.

f. Establishment of a weekly docent/collection area for unwanted aquarium organisms.

An educational docent presence was active during the summer months from 2017-2019 as described above in section 3.7d. Beginning in January 2015 a "pet amnesty" drop box was built and installed near the south shore (image 12). This drop box is accessible 24 hours a day, 7 days a week, and signage around the south shore guide the public to its location (image 13). Signage on the box explains the purpose in four different languages (image 14). The box is checked daily by staff.

Organisms intercepted in the box since 2015 include:

- 33 exotic fishes (miscellaneous species)
- 12 red-eared slider turtles
- 8 miscellaneous species including: toads, crustaceans, and exotic aquatic plants

Image 12: south shore aquatic pet rescue drop box

Image 13: regulatory/educational signage on south shore directing to pet rescue box

Image 14: informational signage attached to pet rescue box in four languages

g. Visual observations identifying minimal individuals feeding wildlife.

Bird feeding was once a popular activity along the south shore of the lake. No formal protocol was developed/implemented to track this human behavior. Since the 2017, based on anecdotal opportunistic observations, bird feeding has become very few and far in between, though a few events have been observed or were intercepted before feeding occurred. If/when feeding is observed, all staff are encouraged to engage with the person(s) and discourage the feeding through education and persuasion.

h. Establishment of containment netting on the public shoreline areas to prevent released animals from entering the body of the lake.

In early 2015 a containment net was installed along the south shore (images 15 and 16). The net, approximately 430 feet long and 7 feet tall, is essentially a seine net; a bottom chain acts as an anchor, while top floats allow the net to move with the ever-changing water level. Regular maintenance is required as post rain sedimentation builds up on the base of the net preventing the floats from functioning as the water level rises.

Image 15: south shore containment netting from above

Image 16: south shore containment netting looking east

3.8 Manage mosquito populations

The performance measurement is as follows:

a. No significant increase (compared to pre-project mosquito populations) in mosquito numbers for species with the potential to transmit human disease.

The Presidio Trust mosquito monitoring program traps adult mosquitoes at Mountain Lake April through October each year, approximately twice per month. *Culex* is the only genus detected at Mountain Lake known to transmit disease to humans. No significant increase in *Culex* has been documented at Mountain Lake since restoration began.

Note: since 2019 the Presidio Trust has sent the majority of *Culex* caught for testing, and have had no positives for West Nile virus, Saint Louis Encephalitis virus, or Western Equine Encephalitis virus (the public health concerns associated with *Culex* under the California Mosquito-Borne Virus Surveillance program).

Table 4: mosquito monitoring results

Culex caught per trap night at Mountain Lake annual average	
prior to restoration	0.5 individuals/trap night
after restoration	1.8 individuals/trap night

4 Discussion

The purpose of this section is to summarize and assess the progress and current standing of the outlined goals and objectives above. In the seven years since time zero a significant amount of progress has been made towards the predefined goals and objectives as outlined in the MTL AMP. Each goal/objective has a defined time frame for realistic achievement, many of which are longer than timeframe than this report covers. Some of these goals/objectives have been realized ahead of schedule, others appear to be on track, while others have been challenging and ongoing efforts and innovation is needed. This section is broken into three parts that discusses and assesses the holistic state of the lake which will provide a basis for management recommendations.

4.1 Abiotic

Water clarity was identified as an index of water quality and ecosystem function. The two main factors driving water clarity (measured as secchi disc depth and chlorophyll concentration) are turbidity, mainly caused by non-native carp, and free-floating

phytoplankton, mainly amplified by excess nutrients (measured as chlorophyll). The performance measurements around clarity were identified as measurable indices of the predicted/desired response from management actions detailed in the AMP and are in theory responsive to management actions within our control. The water clarity target range of a seasonal average 120 to 210 cm of secchi disc depth was first achieved in 2015 (174 cm) after the eradication of carp, followed by two years of less that 120 cm clarity, most likely due to remaining legacy nutrients post-dredge. Since 2018 water clarity (secchi disc depth) has been hovering within the target range with 2020 holding the record of 178 cm (figure 1). The seasonal average of chlorophyll concertation has been largely beyond the target range of 9-17 µg/L. The only seasonal average to date that was within the target range was in 2014 (15.43 µg/L), however, 2020 seasonal average was just slightly above the upper range by 1.21 mg/L, which is relatively close to the upper end of the goal range (figure 2). Given that these clarity indices are cumulative seasonal averages, it is likely that the gap in monitoring data, due to the coronavirus pandemic, affected the 2020 average for better or worse. However, anecdotally, fall 2020 was the clearest the author et al. have ever seen the lake and was also one of the lowest water levels in the author's et al. memory. An interesting note, the chlorophyll concentration spike seen in 2017 (57.75 µg/L) was also the year that the aeration system was non-functional due to an air leak in the pipes.

Even though 2020's seasonal chlorophyll average technically fell just outside the target range, progress has clearly been made towards maintaining water quality in terms of secchi disc depth and chlorophyll concentration ranges. A combination of factors, driven by management actions, have been interacting to achieve the desired state, including the aeration system, point-source run-off management, and the eradication of the invasive carp. As noted above, water flowing in/out of the north arm denitrification trench is monitored, however, no major rains have occurred since the installation and therefore no results have been examined to assess efficacy of the structure. If/when a major rain event occurs, the infrastructure is now in place to capture the flow (i.e. nutrient runoff) from both the north and east arm inputs.

Other relevant factors driving these clarity dynamics include legacy nutrients (post dredging disturbance), the lack of significantly established SAV (nutrient sequestering), and climatic factors (temperature and drought). It is assumed that legacy nutrients may have subsided in the water column since the dredging activities in 2013. SAV remains unachieved (see below) but would be an important mechanism for regulating nutrient levels via sequestration. In the medium to long-term, climate change will likely play a significant role, but it is currently unknown to what extent.

In 2014, a toxic algal bloom, caused by a cyanobacteria *Microcystis aeruginosa*, was observed at the lake. *M. aeruginosa* is naturally occurring throughout the state and blooms of it at the lake have likely been regularly occurring over the years, but only in 2014 was the identification confirmed. Due to the concern for public safety over the neurotoxin microcystin, a product of *Microcystis*, monitoring of toxin concentrations occur during the growing season (summer-fall) if/when the bloom is visible (i.e. thick vibrant green sludge, not filamentous, accumulation on the south shore). The threshold for beach access closure is >0.8 ppb (OEHHA/CA EPA, 2012), at which point signage goes up alerting the public of beach closure due to the safety risks. From 2014-2018 concentrations surpassed the closure threshold. However, in 2019 and 2020,

concentrations did not exceed the threshold and no closures occurred.

4.2 Biotic

Submerged Aquatic Vegetation

In the last seven years no significant progress has been made towards establishing SAV in the lake, but many lessons have been learned and the ecosystem dynamics are shifting towards higher suitability. As discussed in section 3.5, a variety of herbivory exclusion cage designs have been attempted across all viable locations within the lake (e.g. at appropriate depths). The herbivory exclusion cages were intended to prevent both dabbling ducks and invasive crayfish impacts. Preventing dabbling ducks is straight forward and manageable but preventing crayfish infiltration has proven to be the most challenging. Crayfish management has been ongoing, but recently a significant decline in the abundance of crayfish has been observed (see below). This drastic decline in crayfish has provided an opportunity to continue to attempt SAV establishment with significantly reduced herbivory pressure. The final challenge with SAV establishment has been due to the filamentous algae that has been observed growing on and completely covering the plants. Algae fouling impacts the plants by reducing/eliminating photosynthesis resulting in poor growth and/or death.

Given the significance of SAV in the long-term restoration goals of this project and the ecosystem transition occurring, including increased water clarity and the reduction of crayfish, attempts to establish SAV will continue to be made under these improved conditions. With the establishment of a variety of SAV species in the nearby east arm wetlands (as discussed in section 3.5), the project will have easy access to source materials to continue out-planting attempts while freeing up resources from the labor-intensive traditional nursery operation. A strategy will need to be developed to address the filamentous algae fouling issues, though it is hypothesized that with the reduction in crayfish there may be an increase of snail (grazers) abundance, which would potentially limit algae growth. See management recommendations below.

Non-native/Invasive Species

After the rotenone application in 2014 it was confirmed via various monitoring techniques that the entire fish community (100% non-native) was eradicated. Within two years catfish (*Ameiurus melas*) had been released and bred in the lake. By 2017 bass (*Micropterus sp.*) were confirmed in the lake. Management actions began in 2016 with the trapping and removal of catfish. Unsuccessful attempts were made to remove the bass beginning in 2017. The monitoring/management data (figure 3) show the change of the fish community with a decline of catfish captures and an increase in bass captures/observations. The increase in predatory bass has coincided with the significant decline in crayfish biomass removed. Visual observations in the lake have shown the dramatic shift, crayfish, once commonly trapped/seen, are now difficult to find.

This predator-prey dynamic is of interest and relevance to the project. When the predatory bass were originally eradicated in 2014, the crayfish population exploded from the release of predation pressure. Now that predatory bass have become established, the crayfish population has plummeted. Although it is unfortunate that non-

native fishes have been released in the lake, it is not surprising in an urban area. Fortunately, carp, the most significant culprit in terms of impacts to water quality, still remain absent from the lake. Although the bass are voracious predators that can have impacts on native wildlife such as frogs, their presence has had a positive impact in terms of crayfish reduction. With the decline in crayfish has come a release of both SAV herbivory and benthic invertebrate (e.g. mussels et al.) predation. This reduction in crayfish omnivory pressure creates more suitable conditions for SAV out-planting and has likely been the driver that has allowed the mussels to thrive in the benthos. It is presumed that the reduction in crayfish may also represent a reduction in food resources for native predators such as western pond turtles and grebes. Non-native fish and crayfish management will continue, see management recommendations below.

Obviously, even with the presence of the signage, the pet rescue box (i.e. drop box) and the south shore containment netting, a variety of non-native species have ended up in the lake via public release. In addition to those discussed above, a few species of exotic fishes (e.g. goldfish) have been observed in the lake, but no indication of establishment has been observed to date. Four red-eared sliders have been found in the lake since the original 2012/13 turtle removal program, three of which have been captured and removed. Finally, invasive bullfrogs (*Lithobates catesbeianus*) were confirmed to have bred (and/or egg mass/tadpoles released) in the lake in 2019. In 2020 seine netting along the south shore resulted in the removal of 375 tadpoles. See management recommendations below.

Stickleback and Chorus Frogs

Since year zero, January 2014, the native wildlife community of the lake has undergone drastic changes. Chorus frogs and stickleback fish were the first natives to be reintroduced and within 12-24 months confirmed to have successfully bred and have done so annually since. The chorus frog population appears to be robust even with the fungal chytrid pathogen present. Although measures were taken in the reintroduction processes to minimize/eliminate the co-translocation of the pathogen, its does not come as a surprise as the pathogen was confirmed on both a historic voucher specimen of a terrestrial salamander (*Batrachoseps attenuatus*) collected at the site circa 2005 and two live specimens of the same species in 2014 at the site. The presence of chytrid within this population is not necessarily a red-flag as it has been shown to be widespread and not result in the same drastic negative effects with this species in coastal areas as with high-elevation amphibian species. However, long-term implications and dynamics of sub-lethal effects on individual and population levels are unknown.

Stickleback appeared to have declined rapidly in 2020, five years after reintroduction, due to a few possible drivers including non-native predatory bass and/or disease. Disease is presumed based on observations of many lethargic, abnormal, and dead and dying stickleback noted around the edges of the lake during the warm summer/fall months. Many were covered by white “furry” fungal growth, which may have been a cause of death or a symptom of another disease or immune system issues. Given that only ~1,000 individual stickleback were released as the founder population, collected from a small and presumed isolated population in nearby Lobos Creek, it is possible that low genetic diversity left the Mountain Lake population vulnerable to a widespread

disease outbreak. Population crashes of reintroduced stickleback within the first few years, due to genetic bottlenecking, is not uncommon and the population may bounce back (pers. com. Hendry, 2020). See management recommendations below.

Western Pond Turtles

In 2015, 55 western pond turtles were released into the lake. Over the last five years monitoring data has shown a decline by approximately 58%. It is important to note that this figure only represents an index of population size based on the fact that visual monitoring will not allow for an actual count as not all individuals will be visible at one time. Instead, what this figure represents is a minimum population size. As of fall 2020, the minimum population of WPT at the lake is 23 individuals. An initial decline of reintroduced animals is to be expected (Ewin et al., 2012) and the original stated indication of success was to count 50% of the original cohort during visual monitoring. 42% minimum population size is not too far from our 50% success indicator, however, in terms of long-term success of population establishment and sustainability, reproduction and recruitment (i.e. a new generation) is key. To date, neither of these milestones have been confirmed, which was not expected as reproduction is size/age based.

The individuals of the released cohort are only just now getting to the appropriate size/age for reproduction. In anticipation of this, nest site preparation has been occurring around the lake over the last few years. As nesting habitat is a limiting factor around the lake and the turtles have particular preferences for site selection, Presidio Trust and Sonoma State University identified a suitable area near the lake's east arm wetlands. This site has required significant on-going vegetation management in preparation for turtle maturation. In addition, the majority of the lake's upland perimeter was surrounded by a turtle containment fencing in 2016 to prevent turtles from ending up on the highway and golf course. This fencing also prevented access to the east arm wetlands/managed nesting site, which was also surrounded by a separate turtle fence. A turtle corridor was designed and installed in 2019 providing connectivity and safe passage from the many dogs in the area. The corridor is being monitored with a camera trap and to date no turtles have been confirmed using it. A final note, National Park Service and SF Zoo have been actively implementing a similar western pond turtle head-start program in the Marin headlands and have mentioned the possibility of suppling a few supplemental turtles for Mountain Lake (pers. com. Fong, 2018). See management recommendations below.

Mussels

After years of setbacks, trial and error, and many dead ends, initial establishment of Anodonta mussels was confirmed in fall 2020. Not only were numerous "wild" (i.e. not caged) adults found all around the lake, but most importantly, small mussels were observed, indicating natural reproduction and recruitment. These are very encouraging signs of successful establishment; however, the decline of the stickleback host fish is concerning for long-term sustainability of these mussels and whether or not the non-native bass can act as a suitable host is unclear at the moment. See management recommendations below. One of the major challenges in the early years of attempted

establishment was non-native crayfish predation. Although crayfish management was ongoing during this time, crayfish abundance remained high enough to continually impact/kill smaller (≤ 6cm) mussels in the benthos and floating baskets (when infiltrated), leaving little chance of survival past the vulnerable size, maturation, and establishment. This dynamic shifted as predatory bass increased causing a crayfish decrease and thus releasing the mussels from the benthic predation pressure of the crayfish. Although mussel densities have yet to be quantified, anecdotally it appears to be very high. Given this ecosystem engineer's filter feeding behavior, this population is having a positive impact on water quality to some extent and as the population grows so too should the impact (Ismail et al., 2015).

San Francisco Forktail Damselflies

Since 2016, approximately 21,000 San Francisco forktail damselflies, both larvae and adults, have been released at the lake and the east arm wetlands. The majority of releases occurred at the East Arm wetlands which is more ideal habitat, with the idea that if/when they become established there, they will colonize suitable areas around the lake. Both 2020 monitoring data and opportunistic observations, though not thorough due to coronavirus pandemic, have not shown encouraging signs of establishment. However, the most significant indication was the observation of an unmarked male actively mating with a marked female, indicating both survival/persistence of released adult(s) and emergence of released naiads or a generation resulting from previous reproduction. There are a few issues of note that may be driving the lack of establishment. These include, but are not limited to, competition with the abundant Pacific forktail *Ischnura cervula*, predation by the abundant chorus frogs (this was observed during 2020), and/or impact due to the dense duckweed and water fern on site. Due to the economic impacts of the coronavirus pandemic it is unclear whether San Francisco Zoo will have the resources to continue the captive rearing program into the future, but spring 2021 monitoring will indicate whether an over-wintering generation survived.

Additional Wildlife Projects Updates

Beginning in 2019, reintroductions of Rough-skinned newts began at/around the lake and will continue into 2021. Reproduction of the original cohort is anticipated to begin in 2022, at which point more intensive monitoring will begin and population persistence and establishment can be assessed. Additional fauna projects include the initial stages of consultation with the United States Fish and Wildlife Service with the development of a Biological Assessment. This is a complex project and reintroduction is not anticipated to occur for at least another year or more.

4.3 Human Dimensions

Ultimately, the purpose and success of urban ecosystem restoration lays in the realm of the public. The importance of bridging the gap between ecological management, research, and human-dimensions cannot be understated. Mountain Lake, with its metropolitan location and charismatic fauna provides a unique opportunity to bring conservation action directly to an urban audience. One of the obvious benefits of this

project to the local community is that successful restoration of the lake will greatly enhance the area on numerous levels. Replacing seasonal fish kills, unsavory smells, low biodiversity, and potentially high amounts of mosquitoes with clean water and increased biodiversity provides many benefits, some that can be quantified in dollar amounts and others not.

Educating the local community about these various benefits and getting their buy-in is key to the long-term success of this project. An informed and supportive community will result in a reduction of the issues that degraded the lake in the 20th century such as the release of unwanted pets. This general understanding is why education and outreach has been such a significant component of this project. Since 2014 we have exceeded our goal of reaching 10,000 pledges (also known as: promises) within five years and have directly reached many more through both formal and informal events. We have received more than 13,000 hours of volunteer labor towards the restoration in and around the lake and have involved eight local schools in our curriculum-based programs. With more than 85 media stories over the last seven years, including print, radio, and television, the Mountain Lake story has gone far beyond the local neighborhood and city of San Francisco reaching untold numbers of people.

We do not have data on pre-project releases of unwanted pets to assess efficacy of our proactive efforts. However, the consistent use of the pet drop box is proof of concept that you can intercept people before they release unwanted animals. Although it is unsurprising that non-native animals have ended up in the lake, it is likely that many more would have been released without the efforts over the last seven years. It is important to recognize that although it is possible to reduce these releases through education, it is not possible to eliminate all releases. In addition to having appropriate infrastructure in place (i.e. containment netting, drop box, and signage), active monitoring and rapid response is essential in managing this reality of urban ecosystems. Another human-dynamic that has come a long way for the better since 2014 is the significant reduction in bird feeding. Once a very common sight at the south shore beach, where refuse such as noodles, bread, and other leftovers were strewn about resulting in spoiled food and high amounts of bird feces, is now a rare sight. Through tireless efforts from our education attempts most serial bird feeders no longer continue the practice and the south shore beach is much cleaner for it.

In addition to public education, the Mountain Lake project has been discussed/featured in more than seven professional conferences, one peer-reviewed published paper (Ismail, 2015), one published paper in an edited volume (Young, 2018), and has helped inform and guide other relevant projects from San Francisco's Lake Merced and Stanford's Searsville reservoir, to the restoration of Pacheco lake in Novato, Marin county. The proven efficient mussel stickleback-catch-inoculate-release program has also been disseminated to other managers with hopes of starting their own program in their own waterways and is even being included in a manuscript (in prep.) of west coast mussel conservation projects. Managers from all around the state have reached out over the years, and continue to do so, to gain insight from our many trials and errors.

Additionally, the lake's potential for scientific advancement has and is still being used by researchers from a variety of local and national universities and organizations. For

example, excess materials (live 5-dayold lab propagated juveniles) from our mussel project were donated to support research examining toxicity sensitivity levels of ammonia, the results of which will help inform and guide U.S. EPA's recommended discharge criteria around aquatic biodiversity (Pers. com., Jorgenson, 2018). Other future collaborations include Canadian scientists interested in stickleback evolutionary dynamics in isolated systems. The Presidio Trust is generally supportive of collaborative research at the lake and when possible, strives to develop synergistic projects that not only advance science, but also help better inform the management of the lake itself.

With the significant social and economic impacts caused by the 2020 coronavirus pandemic many of the volunteer, internship, and education programs have been paused or terminated. The future of these programs out at the lake is uncertain, but management and progress towards the goals stated above will continue. The priceless value and appreciation of this resource expressed by the public has never been so pronounced as during the 2020 pandemic.

4.4 Management Recommendations

Although many of the goals and objectives stated in the AMP have been achieved or are on track to be achieved, the lake will require management indefinitely in order to maintain and/or achieve these goals and objectives. Much of the management of the lake is adaptive in nature and strategies/actions are regularly assessed relative to the lake's ecological trajectory as described and discussed throughout this document. When needed, management actions and strategies are developed, implemented, assessed, and modified as needed. The below management recommendations are based on the content and assessments discussed above.

- Continue SAV establishment attempts and develop strategies to manage filamentous algal growth, such as regular hand removal to the extent possible.
- Follow up on National park service/SF Zoo western pond turtles for a possible follow-up supplemental release.
- Continue to manage, expand, and maintain turtle nesting habitat and the turtle containment fencing.
- Implement more thorough surveys for stickleback including the obscure areas such as north arm tules/creek. Continued monitoring will elucidate more on these dynamics. If trends continue to decline, or extirpation is suspected, consider translocation from a more genetically robust population i.e. quartermaster reach.
- Continue to monitor/reduce non-native crayfish and catfish through trapping strategies already in place.
- Increase non-native bass management through gillnetting and other strategies mentioned above. Avoid non-target animals in gillnets through thoughtful planning.
- Test host suitability of bass for Anodonta mussels under laboratory conditions. Confirm whether or not bass presence will replace/augment the decline of the stickleback as host role.
- Continue/expand bullfrog management through night gigging/eye shine surveys during appropriate weather, monitoring/removal of egg mass during the appropriate season, tadpole monitoring/removal during appropriate season.
- Continue to maintain infrastructure that has been deployed in and around the lake

and other infrastructure including: the south shore containment netting, the aeration system, bioswales/stormwater catchment/denitrification trenches/highway drainage system, pet drop box, and signage.

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