Rapid Response and Eradication Plan for the Invasive Green Alga *Caulerpa prolifera* in San Diego Bay

Southern California *Caulerpa* Action Team

September 2023[1]

BACKGROUND

In September 2023, the non-native alga *Caulerpa prolifera* was confirmed growing in the Antigua Village Community within the Coronado Cays in San Diego Bay, California. The species has previously invaded seagrass and soft-bottom habitats in the Suez Canal (A-F.A. Gab-Alla 2007), the Canary Islands (Tuya et al. 2013), and Portugal (Parreira, et al. 2021), dramatically displacing native biota. Further, based on environmental impacts of other *Caulerpa* species, this alga is a potentially serious invasive species. In 2021, *Caulerpa prolifera* was identified in Newport Bay, California. Efforts to eradicate *Caulerpa prolifera* in Newport Bay are ongoing. Other species of *Caulerpa* are well- documented as having aggressively displaced native habitats when introduced, both in California, Australia (Creese et al. 2004), and the Mediterranean Sea (Meinesz et al. 2001).

Allowing any species of *Caulerpa* to become established and spread within California coastal areas and embayments is likely to result in considerable economic, recreational, and biological impacts. In 2000, the seriousness and acknowledged threat from its close relative, *Caulerpa taxifolia,* prompted an effective, highly successful *C. taxifolia* eradication project in two southern California locations. This effort occurred over a period of eight years at a cost of more than seven million dollars (Merkel & Associates 2006). The action and investment protected local resources and led to the recovery of critically important eelgrass habitat, and protected California's coastal ecosystems (Anderson 2005).

Responses to *Caulerpa* infestations in California have been directed by the Southern California *Caulerpa* Action Team (SCCAT). This team is made up of federal, state, and local governmental agencies, scientists, consultants, and local stakeholders. The SCCAT directs and supervises all aspects of the response and is detailed later in this document.

At the time of the discovery in Antigua Village in San Diego Bay, the dive team mapped the portion of the seabed where *Caulerpa prolifera* was identified (MTS 2023). The team mapped a primary bed area of 22.5 square meters and a satellite patch that consisted of three fronds and covered an area less than 0.1 square meter (Figure 1).

The *C. prolifera* occurrence varies from a dense central portion to a low-density perimeter with rhizomes that appear to be growing outward in an expansive manner. No eelgrass or other submerged aquatic vegetation was observed growing within or immediately adjacent to the *C. prolifera* patch. However, minor amounts of eelgrass were observed nearby in other portions of the Antigua Village survey area.

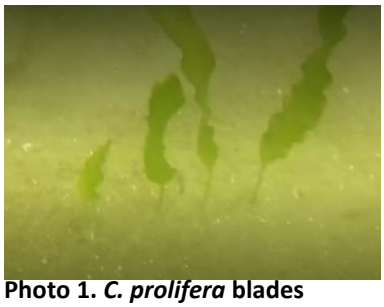


Photo 1. *C. prolifera* blades growing along a rhizome at Antigua Village.

[1] Note that this plan may change during eradication efforts due to operational and other needs.

Figure 1. Distribution of *Caulerpa prolifera* at Antigua Village in the Coronado Cays (known as of 9/27/23). Inset shows the specific location (green polygon and green point.)

C. prolifera is known to grow in fine sediments, sand, and on rocky substrate. Within the San Diego Bay infestation at Antigua Village, *C. prolifera* has only been identified as growing on soft substrate. Thus, the present plan does not address eradication of this alga on rocky surfaces. If the alga is found growing on rocky substrates or in other areas, this plan will be amended to address those areas and any additional specific methodologies required to address the additional infestation area.

ACTION NEEDED

It is presently believed the extent of the alga is likely limited to the Coronado Cays area, and the scientific consensus is that immediate action to eradicate this population must be undertaken. Due to the ease with which this species spreads by small fragments, the aim is to initiate a removal as soon as possible.

CONTAINMENT

Disturbance of the alga by boat anchors, boat wakes, divers, swimmers, and other human activity can release even very small fragments that can drift away and start new infestations. The identified infestation area was immediately visually isolated by the actions of the Coronado Cays Homeowners Association (CCHOA). Homeowners utilizing docks that are adjacent to the *C. prolifera* were notified and requested to coordinate any vessel movements with the CCHOA. The CCHOA moved one vessel to an alternate vessel slip and put up signage notifying homeowners of the need for caution.

PHASE 1 – INITIAL REMOVAL

Eradicating an invasive species is a multi-step process, with an extended element of re-survey, re-treatment, and verification necessary to declare the invasive species formally eradicated. This process can be lengthy (up to several years) to address repeated peak growing seasons and resurgence of growth from previously missed occurrences.

As of the initial draft of this plan, initial treatment and surveys are proposed. The purpose of these initial steps is to first isolate and eliminate the known occurrences of *C. prolifera* and to survey the areas immediately surrounding the infestation.

This plan will have to be amended as more information is gathered. Additional discussions with regional experts and resource managers will be required to identify additional appropriate areas to monitor, how to determine success, and when to terminate efforts.

Removal Methods

There are limited options to eradicate the alga. Algae across the Caulerpa genus have similar growth and dispersal tactics, therefore examining attempts to control other Caulerpa species is helpful. With the Caulerpa taxifolia discovery in San Diego County that occurred in June 2000, many techniques were tested and evaluated (e.g., dredging, barriers, handpicking, various chemicals). In that case, sealing the alga under heavy benthic barrier material and pumping chlorine underneath was determined to be the best course of action for the conditions present in the area, an approach that proved effective. Review of this methodology has determined that comparable efficacy can be achieved without the use of chlorine, provided the barriers can be maintained in place with certainty.

Given the calm conditions present at the infestation site, placement of benthic barriers is the primary

proposed means to isolate and eliminate the currently known *C. prolifera*. Two divers will first systematically survey the area depicted in red (infestation area) (Figure 2). Any loose fragments of *C. prolifera* will be picked up by hand and placed in a fine mesh bag (pore size less than 1 mm) and brought to the surface for disposal. Once the infestation area survey is complete, divers will place benthic barriers over the currently known patches of *C. prolifera*.

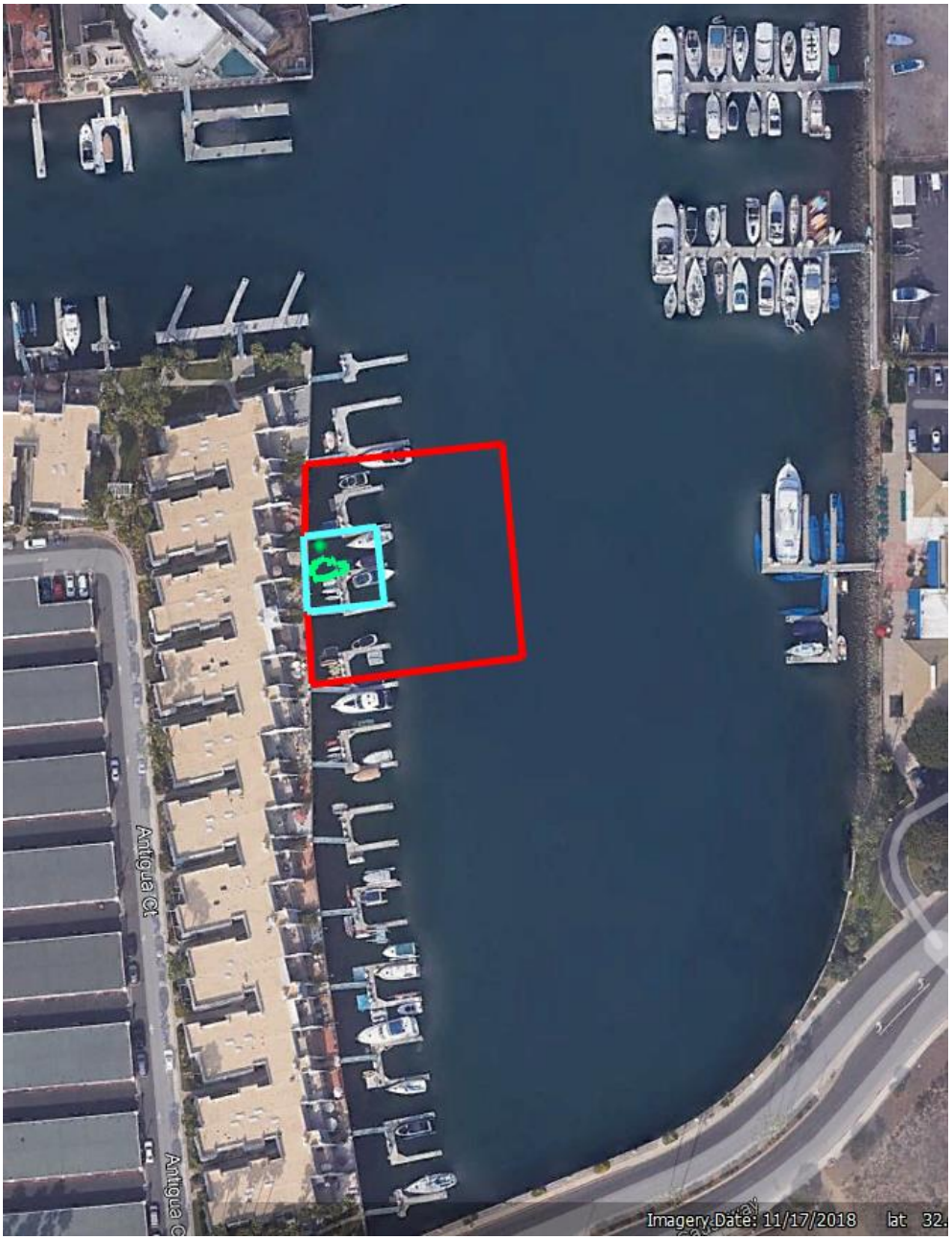


Figure 2. Distribution of *C. prolifera* (green) with the area designated as the infestation area (red) for the purpose of focused surveys and the area designated to receive barrier (treatment area; blue) at Antigua Village in the Coronado Cays, San Diego Bay.

The barriers will be placed over an approximately 17 x 17-meter treatment area. This will require approximately 9 benthic barriers. Each benthic barrier measures 6 x 7.6 meters. Barriers will overlap 0.6 meter along the long sides and approximately 1 meter on the short ends. Barriers will be secured to the bottom with rebar pins and sandbags. Barriers will be composed of pond liner material consisting of between 20 and 40 mil HDPE or EPDM or similar.

Dive teams will begin with individual barriers that are rolled up. The rolled-up barriers will be gently placed at the toe of the seawall. The corners will be pinned to the seabed and the barriers will be slowly unrolled to minimize water movement that could dislodge any *C. prolifera*. As the barriers are unrolled, rebar pins will be placed along the margin every 1.5 meters. Once all barriers are unrolled and pinned to the bottom, bins of sandbags will be lowered to the bottom and placed on top of the barriers. Divers will then move the sandbags to seal the perimeter of the barrier complex. Sandbags will be placed continuously along all seams and the entire perimeter. Additional sandbags will be placed in the middle of each barrier to further secure the barriers to the seafloor.

There will be no application of chlorine in this treatment effort.

Survey Methods

Surveys will be conducted to determine if there are any additional patches of *C. prolifera* present in the areas surrounding the currently known infestation area. These initial surveys are not intended to be exhaustive of all surveys that will be required. However, the methods used to survey are generally anticipated to be the primary means by which surveys are to be conducted.

Prior to removal of the alga, an intensive survey will be conducted within Antigua Village and the surrounding area. Intensive eradication level surveys (100% coverage) will use vessel positioned transects and divers to systematically search the area. A tending vessel will deploy and retrieve a series of parallel survey transects placed with a high degree of precision using a real-time kinematic (RTK) global positioning system (GPS). The vessel has a motorized spool of nylon survey rope and will deploy an anchor to secure the start point of the survey line at a designated waypoint. The vessel will then back up over the intended transect position while deploying the rope from the bow. At approximate 40-meter intervals, a 5-pound weight will be attached to the transect line.

Because the position of the primary dense patch of *C. prolifera* is already known, care will be taken to deploy the survey line weights well outside the known locations of the alga. During the deployment, the vessel will track the intended transect placement to within 2 meters by observing the cross-track error on the vessel's navigation computer. After deployment of each weight, the deployed transect spool will be stopped and the vessel aligned to within 0.25-meter of cross-track error by reversing against the anchored line. Once on target, the spool can then be slowly released to allow continued placement of the transect. Once at the end of the transect, a 10-pound weight is placed on the end of the transect line. A buoyed marker will also be placed on the end of the line. A technician then holds the buoy line and slowly lowers the weighted end while the vessel operator aligns the vessel to within 0.25-meter of cross-track error while keeping the line taught. Transects will be placed parallel to one another at a spacing relative to the number of divers present and visibility.

To survey a transect, divers will be aligned perpendicular to the transect. A short length of rope with a

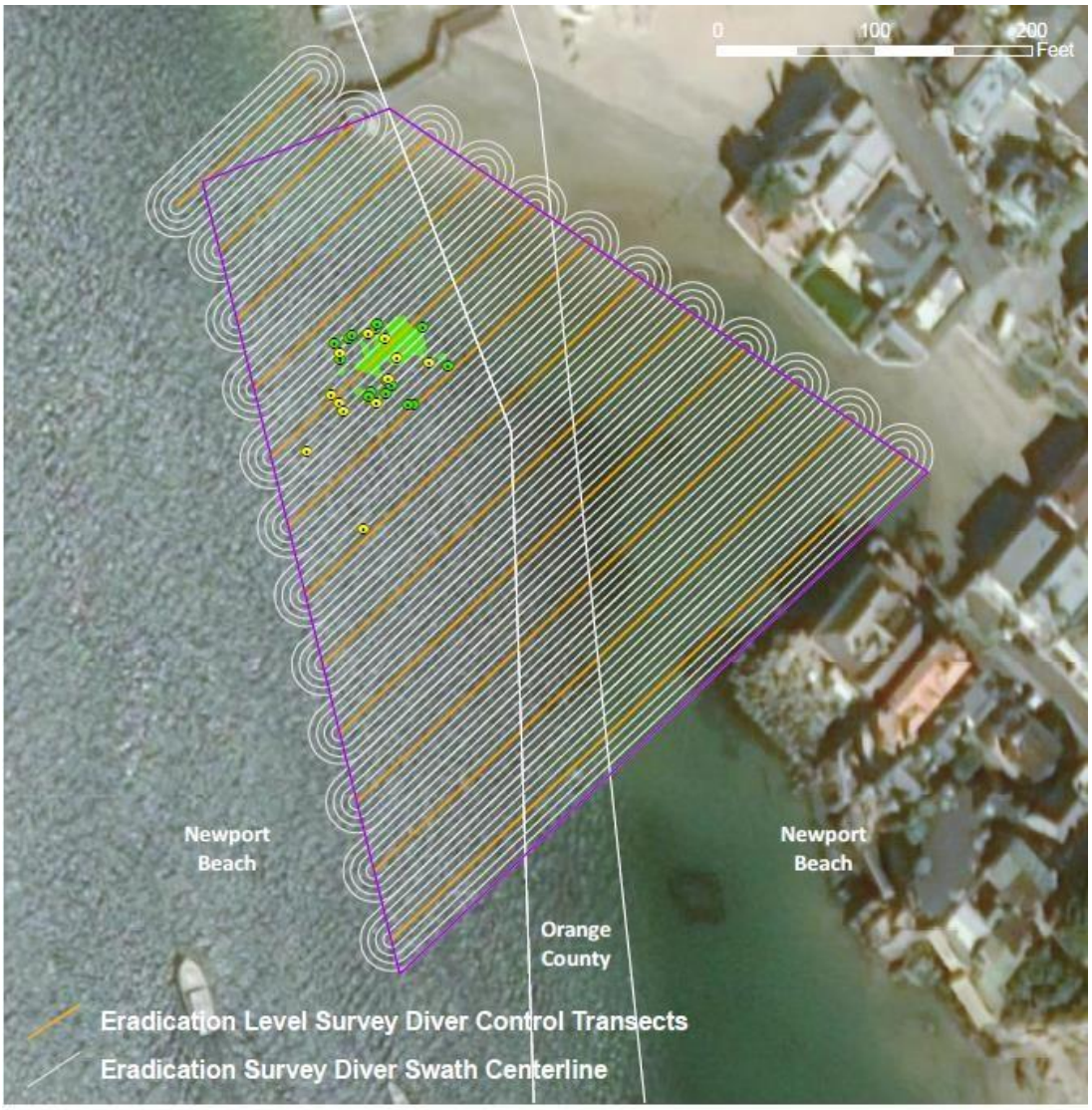
knot tied at each diver's position will be created to assist divers in maintaining spacing during the survey. A diver spacing of no more than 1.5 meters is recommended. Thus if 4 divers are utilized, the diver rope would be 6 meters long. The lead diver will then follow the transect line approximately 0.75 meters to its side. Each subsequent diver will keep pace with the lead diver but follow slightly behind on their transect side. This arrangement prevents the team from circling inward toward the transect line. At the end of the transect, the lead diver tugs the line to indicate that the team should pivot 180 degrees around the lead diver and then proceed along the opposite side of the transect line toward the start point. The water clarity and habitat complexity (e.g., bare bottom, eelgrass cover) dictates the speed and spacing of the survey team. All divers will be qualified and trained in *Caulerpa* and native species identification.


Photo 2

Photo 3

Photo 2. Divers spaced by a section of knotted rope during training on signals and procedures used during the survey. Photo 3. A team of divers aligning themselves at the surface and preparing to swim a laid transect.

The above procedure is illustrated in Figure 3. The procedure would be followed with transects being placed and surveyed throughout the survey area (Figure 4). All transects will be placed on 12-meter centers (assuming the above 4 diver and 1.5-meter scenario). Although transect endpoints can readily be controlled, intra-transect accuracy is a function of keeping the vessel on track during deployment to prevent the transect from becoming fouled on obstacles that cause the line to be placed off the intended track. Keeping the line taught during deployment helps keep the vessel on track. Any bows in the line can cause unnecessary overlap and survey gaps when surveying adjacent lines.



Example Eradication Survey Configuration For Four Diver Survey Team

Figure 3. Example survey design for eradication level survey. The example shown is from a representative *C. prolifera* survey performed at Newport Beach, California.

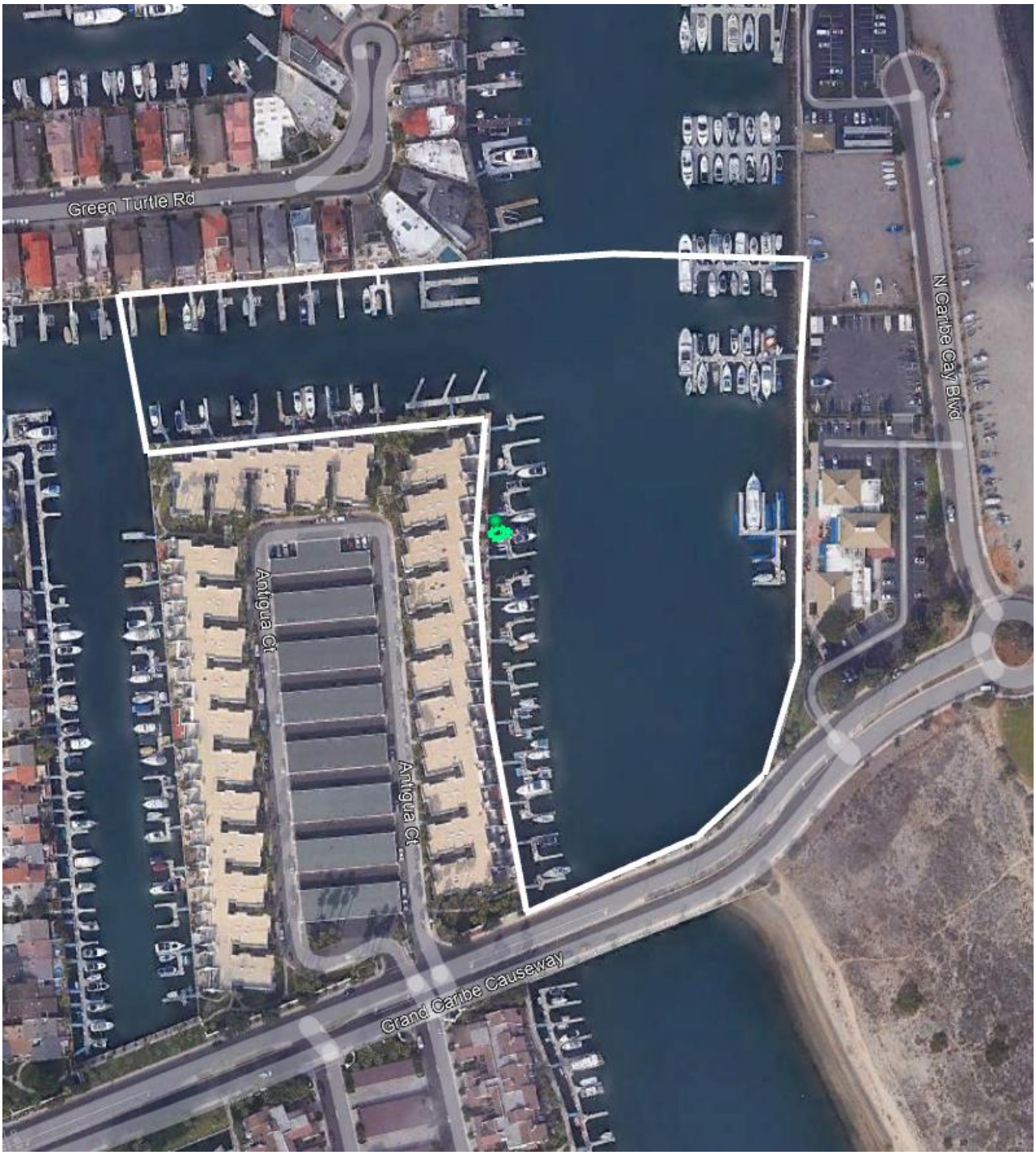


Figure 4. Initial area proposed for eradication level surveys by divers (white boundary). Green polygon is the current area known to support *C. prolifera*.

Any seafloor-attached *C. prolifera* encountered will be flagged near the occurrence by florescent pin flags and its position recorded using surface GPS on the tender vessel. Where divers encounter *C. prolifera* that is not attached to the bottom but rather is mobile in the detrital drift, the algae will be collected within a 1-mm or finer mesh bag carried by the diver and taken immediately to the surface where the material will be transferred to a tender vessel for upland disposal; the position of the encounter will be recorded by GPS. This methodology is consistent with research on the viable fragment size for *C. prolifera* and a desire to remove vegetation that is mobile and can drift if left unattended. An infestation map will be generated and used to systematically guide the removal strategy. The mapping will note both the attached and unattached algal distribution. These recorded positions will be used to target smaller patches and allow the site to be revisited to ensure removal.

If new rooted patches are detected using the above procedures, they will be treated with the placement of benthic barriers. The size of the barriers will be appropriate to the size of the identified C*. prolifera* patch. For instance, a patch less than 0.1 square meter can be covered with a barrier measuring about 1 square meter.

The surveys will be implemented before and after the removal of the C. prolifera. Additional surveys will be needed, including QA/QC survey efficacy assessments to ensure the *C. prolifera* can be declared eradicated with some degree of certainty (Phase 2). Efficacy of the survey is measured by seeding the survey area with fake *Caulerpa* prior to survey and then assessing the return of fake *Caulerpa* as a quantitative measure of how much and what size of *Caulerpa* would likely have been found had it been present.

PHASE 2 –ERADICATION DETERMINATION

This phase involves the determination of whether *C. prolifera* has been eradicated from the site to a high degree of certainty. The criteria for successful eradication of the *C. prolifera* infestations are 1) the containment and complete removal of *C. prolifera* at the infestation site, and 2) verified absence of *C. prolifera* from the infestation site.

The first criterion can be determined through survey of the site for regrowth over time. This can be further supported by planting sediment cores from the infestation site into laboratory aquariums and monitoring them in a controlled study for regrowth of *C. prolifera*.

The second criterion is evaluated by quantifying the confidence in the post-removal surveillance efforts. Patches of artificial *C. prolifera* are placed within the site during the regular diver surveys. Confidence in the results of each survey for live *C. prolifera* can then be quantitatively estimated based on the amount of artificial *C. prolifera* found during the surveys (Merkel & Associates 2005). The results of these consecutive assessments of the surveys ultimately allow for an estimation of the Eradication Certainty: the certainty that all real *C. prolifera* existing at the treated site had been found and that eradication had been achieved.

Photos 4 & 5. Artificial *Caulerpa* placed to quantitatively assess the confidence level for each survey, key to calculation of Eradication Certainty. Photo 6. Viable fragments of real *Caulerpa* as small as several millimeters (right) can be easily missed by divers.

The number of repeated surveys necessary to achieve full eradication is not known. If new patches of *C. prolifera* are detected during the follow-up surveys, they will need to be removed and the survey timeline reset. It is important to have surveys repeated annually during active growing seasons.

Caulerpa species often die back during colder seasons, particularly when they occur in waters in the lower end of their temperature tolerance. For the purposes of this document, it has been assumed to be a two-year process, with four surveys per year, though it could be longer based on recurrences and quality assurance and control of survey efficacy findings. A Determination of Eradication Plan identifying the metrics by which the alga can be designated as eradicated will be developed and agreed upon by the SCCAT once the infestation has been removed.

This robust and scientifically defensible process of determining eradication was developed, tested, and implemented by the SCCAT during the *Caulerpa taxifolia* Eradication Program in San Diego and Orange Counties (Merkel & Associates 2006).

PUBLIC OUTREACH

Signage has been posted at the infestation area by the CCHOA to inform the public about the response operations. Outreach to homeowners in the area may be undertaken via direct mailings, public workshop, and online resources. Outreach would include cautions to avoid releases of pet and aquarium contents to the bay, either directly or by dumping into storm drains, and provide information on the threat posed by *C. prolifera* to San Diego Bay and the outer adjacent coastal areas.

SOURCE IDENTIFICATION

This is the second known introduction of *C. prolifera* on the west coast of the United States. It would be useful to know the source of the introduction. Possibilities to pursue include intentional release of aquarium contents to the bay, inadvertent introduction through storm drain discharge of aquarium water, or natural range expansion from Mexican waters (considered unlikely). A source identification plan will be developed at a later date; the first priority is eradicating the known occurrences of *C. prolifera*.

RESEARCH

While the present program is focused on the direct and immediate eradication of *C. prolifera* from San

Diego Bay, it will be of scientific interest to collect as much information as is practical concurrent with its eradication. For this reason, data collection by biologists may occur coincident with survey and eradication efforts. Information may include morphologic and growth parameters of the species, documentation of ecological impact on benthic communities, epiphytic communities, and environmental characteristics of the infestation area. Genetic analysis by the California Department of Food and Agriculture is anticipated to confirm the preliminary identification.

The eradication program would be documented using video, still cameras, detailed notes, and GIS records so that a future retrospective maybe prepared to aid in the application of information learned to future infestations.

ORGANIZATION

During the 2000-2008 *Caulerpa taxifolia* eradication, the SCCAT was formed. This team was made up of federal, state, and local governmental agencies, scientists, consultants, and local stakeholders. The SCCAT was reactivated in 2021 to respond rapidly to the Newport Beach infestation of *C. prolifera*. The SCCAT is now additionally responding to the San Diego Bay infestation. The Steering Committee is made up of representatives from NOAA Fisheries, Santa Ana Regional Water Quality Control Board, California Department of Fish and Wildlife, City of Newport Beach, and Orange County Parks. Given the finding in San Diego, the SCCAT is anticipated to include members from the San Diego Regional Water Quality Control Board, the City of Coronado, the Port of San Diego, and the CCHOA. The SCCAT will direct and supervise all aspects of the response, including coordination of authorizations, securing response funding, reviewing work progress and efficacy, and determining eradication point.

TIMELINE

The following is an estimated containment and eradication timeline (Table 1). The estimate is based on treatment of the currently known infestation area and survey of the immediately surrounding waters. The area to be surveyed will likely grow as the SCCAT will wish to evaluate the extent to which there may be additional *C. prolifera* infestation sites within south San Diego Bay and potentially beyond. The expansion of the survey area will also impact the timeline. These considerations will take time and will be added to this document as they develop.

Table 1. Estimated containment and eradication timeline with specified work elements. Note that the exact timeline may vary depending on survey results and the funding acquisition timeline.

WORK ELEMENT	EST. TIMING	NOTE
Inform SCCAT and assemble additional members and member agencies.	September 22-29, 2023	
Containment/public exclusion measures/site signage	September 2023 22-May 31	CCHOA
Authorization/permit acquisition	September 25 – October 6, 2023	RGP 63, CDFW LOA, Emergency CDP. Additional approvals to follow emergency approvals.
PHASE 1- Initial Removal		
Eradication level Survey	October 2 – 13, 2023	Will take 2-4 days but may be spread out dependent upon funding.
Initial barrier installation	October 2 - 13	Will take 2 days to implement but timing dependent upon securing funding.
Post barrier surveys	1 day, 3 days, 7 days, 14 days and 30 days following installation.	Check integrity and check for *C. prolifera* surrounding the barriers.
Barrier removal	6 months following placement	
Post-removal surveys	0-12 months post-removal	
PHASE 2- Eradication Verification	1-2 years beginning end of Phase 1	Verification surveys and testing

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Southern California Caulerpa Action Team

Rapid Response and Eradication Plan for the Invasive Green Alga *Caulerpa prolifera* in San Diego Bay

Adaptive Management Memorandum #1 (November 2023)

November 1, 2023

SUMMARY OF KEY POINTS

- The eradication plan was drafted in September after the initial discovery of *Caulerpa prolifera* and prior to completion of surveys at nearby areas.
- Additional *C. prolifera* has been discovered in adjacent areas increasing the size of the infestation site.
- This memo provides an update on surveillance performed beyond areas initially proposed, the area designated as the known infestation site, the area to be treated, and the timing of treatment and follow up surveys. The treatment and survey methods remain unchanged.

INTRODUCTION

In September 2023, the Southern California Caulerpa Action Team (SCCAT) adopted a Rapid Response and Eradication Plan (RREP) describing the concern with the discovery of, and distribution of, *C. prolifera* in the Coronado Cays located in south San Diego Bay. The RREP provided a general approach to treating *C. prolifera*, and a proposed timeline for surveying post-removal. The plan was written before divers had taken action to fully map, study, or remove it, and was therefore drafted with the understanding that the eradication process would involve considerable adaptation of the planned approach based on actual field observations.

Rather than repeatedly updating the September 2023 RREP as new information, funding, or insight becomes available, the SCCAT instead plans to prepare adaptive management memoranda as needed that will be attached to the RREP. This memorandum addresses needed adjustments to the RREP based on findings from the survey effort between September and October 2023. The plan elements that are being updated include surveillance performed beyond areas initially proposed, *C. prolifera* infestation site to date, an expanded treatment plan, and a schedule to complete treatment actions. Future memoranda will be prepared as necessary to document additional updates to the RREP.

TERMINOLOGY

Several terms are used in this document that do not have universal meaning and are therefore defined here as they relate to the planning and execution of the effort to eradicate *Caulerpa prolifera* from San Diego Bay.

SCCAT- the Southern California *Caulerpa* Action Team, formed in 2000 to respond to an infestation of *Caulerpa taxifolia* in San Diego and Orange County, and reconvened in 2021 to respond to the *Caulerpa prolifera* discovery in Newport Bay. The SCCAT Steering Committee is made up of representatives from NOAA Fisheries, Santa Ana Regional Water Quality Control Board, California Department of Fish and Wildlife, City of Newport Beach, and Orange County Parks.

Rapid Response and Eradication Plan- a planning document finalized by the Southern California *Caulerpa* Action Team in September 2023, describing a general approach to removing *Caulerpa prolifera* from San Diego Bay. It was written before divers had fully evaluated the distribution and conditions of the *C. prolifera* infestation and was therefore drafted with the understanding that the eradication process would evolve as field experience dictated. The full document title is: Rapid Response and Eradication Plan for the Invasive Green Alga *Caulerpa prolifera* in San Diego Bay, September 2023 (SCCAT 2023).

Adaptive Management Memorandum - this document is intended to provide updates to the RREP approach and schedule in light of findings in the field and add additional information as needed. This document does not provide a comprehensive report of work completed to date.

Initial Treatment – the removal or treatment of the known *C. prolifera* biomass and any additional occurrences around Antigua Village discovered during surveillance work. The removal is not yet complete. Removal of the initial discovery was performed on October 9, 2023 by Merkel & Associates, Inc. (M&A) and MTS, Ltd., with considerable additional removal work from new areas urgently needed. Initial Removal does not equate to eradication of *C. prolifera* in San Diego Bay; it is just the first step of a longer eradication process.

Find – discovery of discrete occurrence of *C. prolifera*, further designated as either a loose fragment or a rooted patch.

Known Infestation Site - an area defined as all seafloor that has had a recorded occurrence of *C. prolifera*, with a 10-meter buffer extended around it. This is the bounded area of follow-up surveillance and removal efforts within an active treatment area. The known infestation site expands whenever finds are made beyond the previous maximum outer extent of *C. prolifera*.

Eradication – complete removal and sustained absence of the known infestation of *C. prolifera* from the known infestation site. The time to achieve this goal has not yet been predicted but will be several years at a minimum.

Eradication Determination – the final conclusion that eradication has been achieved, based on collection of data that satisfactorily demonstrate that all *C. prolifera* has been found and removed from the known infestation site. Criteria will be developed by SCCAT to make this determination based on elements such as: sediment assays testing for viability of remaining material, current understanding of the reproductive strategy of the *C. prolifera* strain occurring in San Diego Bay, efficacy of surveillance for remaining occurrences, and verified absence from the infestation site.

SURVEY AREA

After the initial discovery of *C. prolifera* on the east shore of Antigua Village on September 21, 2023, additional adjacent areas were surveyed with funding provided by the Port of San Diego to the Coronado Cays Homeowners Association. Approximately 3.84 hectares (9.48 acres) were surveyed, extending from Grand Caribe Causeway north to the C Dock at the Coronado Cays Yacht Club, and in the channel between Antigua Village North and the south facing shoreline of Green Turtle Road. As more *C. prolifera* was discovered, the survey was expanded further with the goal of finding the local boundary of the *C. prolifera* infestation. Additional survey areas included waters further north toward the Coronado Cays Yacht Club at the mouth of the Coronado Cays where it joins south San Diego Bay, and the Antigua Village docks at Antigua Village West. Figure 1 shows the initial survey area and the larger area surveyed between September 21 and October 26, 2023. As of October 26, 2023, the total area surveyed at the eradication level is 6.86 hectares (16.95 acres).

The survey and infestation area occur under two ownerships: the Port of San Diego and the City of Coronado. The initial small discovery was in Port of San Diego waters, while bulk of the infestation found shortly after is in City of Coronado waters. The boundary line is shown in Figure 1.

INFESTATION SITE ADJUSTMENT

At the time of the initial discovery, an area of seafloor covering 22.6 square meters was identified as supporting *C. prolifera*. This area was comprised of a 22.5 square meter *C. prolifera* bed and a small (less than 0.1 square meter) patch. The known infestation site is the portion of the seafloor supporting *C. prolifera* plus a 10-meter buffer. Thus, at the time of the initial discovery, the known infestation site was approximately 396 square meters (0.1 acre) (Figure 2).

The initial discovery resulted in the Port of San Diego providing funding to the Coronado Cays Homeowners Association to treat the initial discovery and perform surveys of the surrounding area as described under the RREP. Those additional surveys resulted in finding 901 square meters (0.2 acre) of additional *C. prolifera* beds and patches. This brought the total area of *C. prolifera* to 923 square meters (0.2 acre). With the 10-meter buffer the known infestation site as of November 1, 2023, is 6,593 square meters (1.6 acres) (Figure 2).

TREATMENT PLAN ADJUSTMENT

The initial treatment of the patches discovered on the east shore of Antigua Village occurred on October 9, 2023 (Figure 3). At that time, the 22.5 square meter *C. prolifera* bed and an adjacent 0.1 square meter patch were covered with a benthic barrier following the methods in the RREP. Also covered was another 3.6 square meter patch that was found during surveys performed on October 6, 2023. The additional covered patch was located approximately 25 meters south of the initially discovered *C. prolifera* bed. In addition to these treated areas, two other very small patches were treated opportunistically while surveying. One was located about 12 meters west of the initial bed. Another was located on the opposite site of the embayment near the Coronado Cays Homeowners Association offices. These patches and their treatment have been previously reported to SCCAT.

Moving forward, a much larger area of *C. prolifera* requires treatment with barriers, as shown in Figure 3. The red polygons represent the potential treatment area to cover most of the remaining *C. prolifera* that has not been treated. There are a couple of minor *C. prolifera* patches that occur beyond the boundary. Those would likely be covered with very small pieces of barrier (less than 1 square meter) or

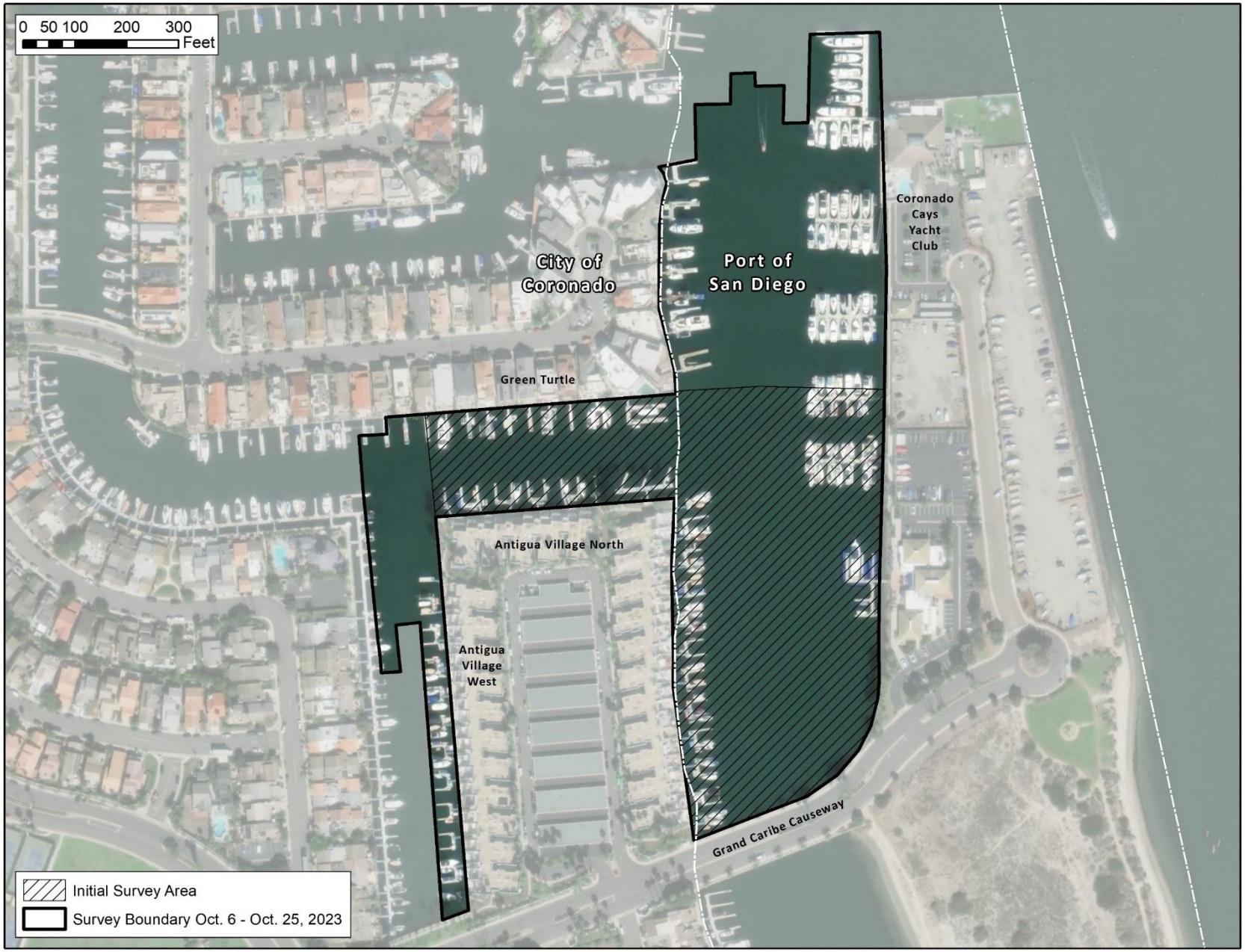


Figure 1. The above figure shows the initial proposed survey area and the actual survey boundary as of October 25, 2023.

Figure 2. The known *Caulerpa* infestation site after the initial survey on September 21, 2023 (left) and the expanded *Caulerpa* infestation site following surveys performed between October 6 and October 24, 2023.

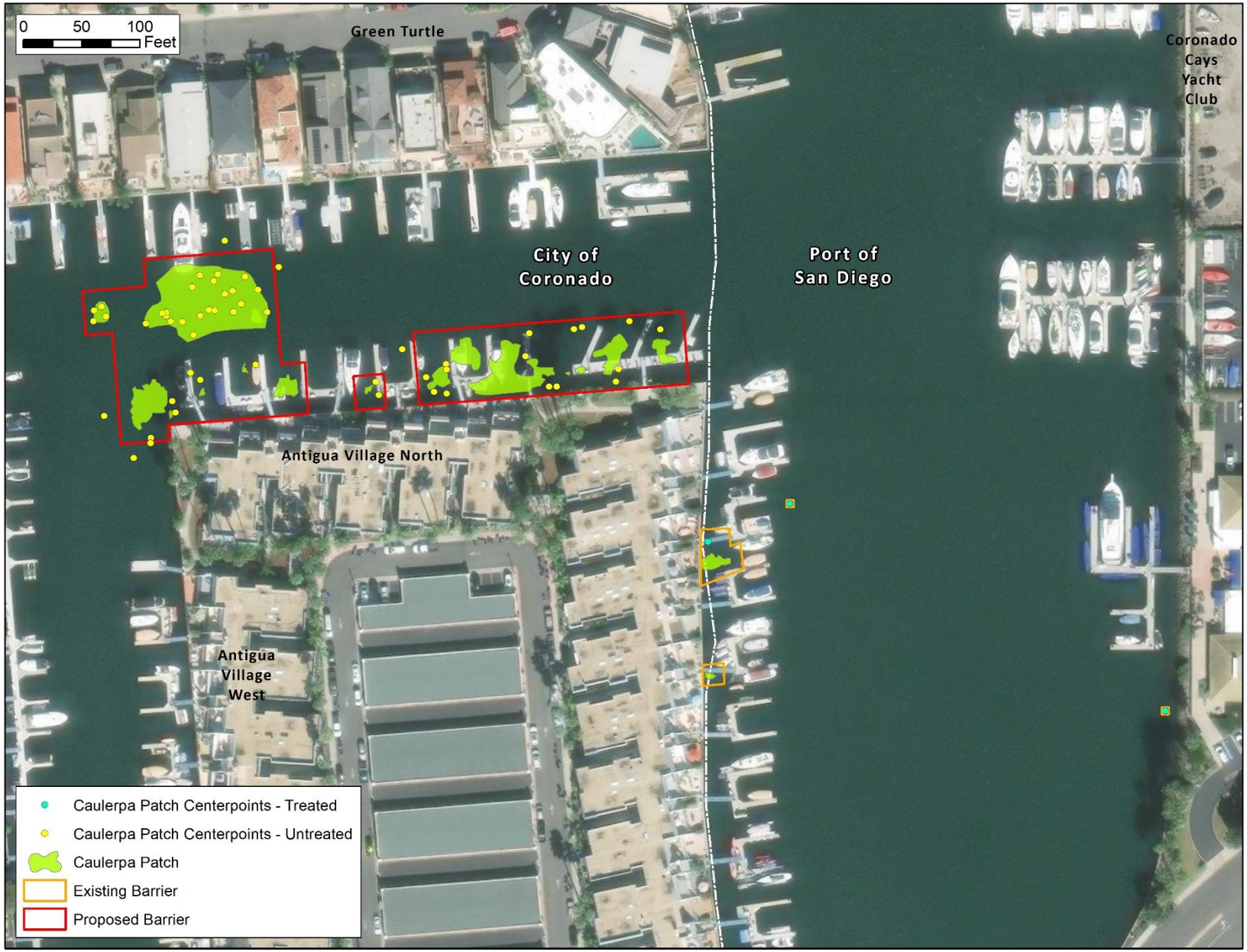


Figure 3. The above figure shows a potential barrier arrangement that covers all of the larger *C. prolifera* beds and most of the small patches. Additional small barriers not shown or hand picking would be used to treat any small patches not shown to be covered by the large barriers shown above in red.

they would be handpicked by divers. The area depicted in Figure 3 for barrier treatment using the same methods as in the RREP is 3,471 square meters. For planning purposes, it should be assumed that up to 4,000 square meters of barrier may be placed to cover the *C. prolifera* at the time of treatment. This added amount may be necessary for any additional patches that are discovered during treatment.

The 6,593 square meter (1.6 acre)-*C. prolifera* infestation site needs to be treated immediately. Each day it remains uncontained, the infestation size, biological impact, and response cost increase due to the ease of spread of this species.

NEXT STEPS

Once the *C. prolifera* is contained by the barriers, a series of follow-up surveys will be conducted to find and treat any occurrences that were missed or emerged from material that had been buried in the sediment and not visible (a common occurrence with *Caulerpa* species). These surveys will be done with high frequency until there is reasonable confidence that visible material has been detected and removed. Investing in intensive post-treatment surveys will translate to savings in the future, with overall containment achieved sooner.

The next phase of resurvey is spaced more widely, likely quarterly, and involves the determination of when *C. prolifera* has been eradicated from the site to a high degree of certainty. The number of surveys to be performed will be based on the survey team's efficacy at locating *C. prolifera*. Efficacy is determined through the use of a surrogate (e.g., fake *Caulerpa*). Surveys can be discontinued, and the alga declared eradicated, once the SCCAT determines that the efficacy and therefore surveillance effort was sufficient.

During the post-treatment survey process, the *C. prolifera* will be tested for viability under the barriers. Once it has been determined to the non-viable, the barriers will be removed. The specifics of this phase of the eradication will be determined by SCCAT later in the implementation of the RREP and documented in a follow up Adaptive Management memorandum.

SURVEILLANCE OUTSIDE OF THE CORONADO CAYS INFESTATION AREA

It is possible that other areas in San Diego Bay are infested with *C. prolifera*. Based on the size of the infestation known so far, it is likely that it has been there for several years and may have been transported by currents to other locations. Due to potential threats to Port of San Diego activities and the biological resources and National Wildlife Refuge nearby, it is important to budget for additional structured surveillance moving out from the known infestation.

SCHEDULE ADJUSTMENT

The RREP initial schedule was based upon the treatment and survey of the small occurrence of *C. prolifera* that was known at the time of the drafting of the RREP in September 2023. Given that considerably more *C. prolifera* has been found, additional time needs to be dedicated to treatment and surveillance. The timeline in Table 1 is updated from the timeline provided in the RREP, with additional time to treat and perform surveillance.

Table 1. Estimated containment and eradication timeline with specified work elements. Note that the exact timeline may vary depending on survey results and the funding acquisition timeline.

WORK ELEMENT	EST. TIMING	NOTE
Inform SCCAT and assemble additional members and member agencies.	September 22-29, 2023	
Containment/public exclusion measures/site signage	September 2023	CCHOA
Authorization/permit acquisition	September 25 – October 6, 2023	RGP 63 CDFW LOA Emergency CDP – Port of SD. Additional approvals to follow emergency approvals.
Additional authorizations and permits	October 15 – November 30, 2023	Emergency CDP - City of Coronado. SCP from CDFW.
Initial Treatment		
Eradication Level Survey	October 2 – 25, 2023	Completed
Initial barrier installation	October December 2023	Timing dependent upon securing funding.
Post barrier surveys	1 day, 3 days, 7 days, 14 days and 30 days following installation.	Check integrity and check for *C. prolifera* surrounding the barriers.
Additional Treatment		
Additional barrier installation	January-March 2024	Barrier placement over additional discovered *C. prolifera.*
Eradication Verification		Verification surveys and testing
Test viability under barriers	6 months after placement	Ensure *C. prolifera* non-viable, through core sampling and test openings in barriers
Barrier removal	Potentially 12 months after placement	If *C. prolifera* confirmed non-viable, remove and dispose
Verification surveys	Quarterly for 2-3 year post-treatment	Eradication determined by efficacy calculations

REFERENCES

[SCCAT] Southern California *Caulerpa* Action Team. 2023. Rapid Response and Eradication Plan for the Invasive Green Alga *Caulerpa prolifera* in San Diego Bay, September 2023.

Southern California Caulerpa Action Team

Rapid Response and Eradication Plan for the Invasive Green Alga *Caulerpa prolifera* in San Diego Bay

Adaptive Management Memorandum #2 (December 2023)

December 4, 2023

SUMMARY OF KEY POINTS

- The eradication plan was drafted in September after the initial discovery of *Caulerpa prolifera* and prior to completion of surveys at nearby areas.
- This memo provides an estimate of the costs associated with eradicating the known *C. prolifera* infestation in the Coronado Cays and surveying for it in the surrounding waters.
- A proposed schedule is detailed for the eradication and the survey of surrounding waters extending for a two-to-three-year period.

INTRODUCTION

This memo is written to develop an estimate of the potential costs associated with eradicating the known infestation of *Caulerpa prolifera* in the Antigua Village area of the Coronado Cays (as of December 2023). The Coronado Cays is a residential community located in South San Diego Bay where *C. prolifera* was discovered in October 2023. Cost estimates are also made for surveillance of the surrounding areas in the Cays for undiscovered infestation areas or additional infestation areas that establish prior to treatment of the current infestation.

ERADICATION COSTS

Based on the very limited treatment of *C. prolifera* that has occurred to date at Antigua Village, it is estimated that the price to cover one square meter of seafloor with benthic barrier would cost approximately $72. It is currently estimated that 3,471 square meters of seafloor require treatment (Figure 1). Thus, to cover the current distribution of *C. prolifera* that has not been treated would cost approximately $250,000 (Table 1).

Once the barriers have been placed, the known infestation site, defined as the area of seafloor with recorded occurrence of *C. prolifera* plus a 10-meter buffer, must then be promptly examined again at the eradication level to locate and treat missed or resprouted *C. prolifera*. This examination is done with a team of approximately five to seven *Caulerpa* Certified divers systematically surveying the infestation site as described in the Rapid Response and Eradication Plan for the Invasive Green Alga *Caulerpa prolifera* in San Diego Bay (RREP). The next survey to find and treat will be done one month later, and then approximately quarterly thereafter until all *C. prolifera* has been found and treated.

The cost to survey under docks versus open water varies substantially within this area. The costs per hectare are estimated at $14,450 and $8,050 for areas under docks versus open water, respectively, based on eradication level surveys already performed over 6.86 hectares at the site in October and November 2023. These values can be used to estimate the cost of surveying the known infestation site.

Given the difficulty of searching underwater in low visibility conditions, it is possible that *C. prolifera* exists nearby but outside the known boundary of the infestation site. Moreover, it's possible *C. prolifera* will have spread between the time since the initial delineation and the time at which treatment is complete. Given these factors, the area shown in Figure 2 is the anticipated area over which repeated surveys should occur to find and remove *C. prolifera*. This area is defined as the infestation action area (8.64 hectares). Application of the dock mask used to determine the relative proportion of dock and open water area is shown in Figure 2. Application of the above costs to the proportionate amount of dock and open water was used to determine the per survey cost estimates shown in Table 1.

If a 60% diver efficacy rate is assumed, it would take 4 quarterly surveys without finding *C. prolifera* to be 97.4% certain that all *C. prolifera* had been found within the infestation action area. If it assumed that all *C. prolifera* can be found and treated within the first two surveys after the initial treatment, then 6 surveys of the infestation management area would be required to achieve the 97.4% certainty level. These assumptions were used to determine the number of survey units provided in Table 1. However, if the 60% efficacy goal cannot be achieved, or if *C. prolifera* is discovered during the third to sixth pass, additional surveys will be necessary to ensure no *C. prolifera* remains to spread further within the infestation management area. That possibility is reflected in the schedule in Figure 3 but is not included in the cost estimate in Table 1.

Removal of benthic barriers is an integral part of the eradication. Test holes will be made in the barriers at a time agreed on by SCCAT, assumed in this case to be seven months after the start of barrier installation and following at least one complete resurvey with no *C. prolifera* found (Figure 3). If inspection of the holes during the next two surveys (and potentially lab assay of the sediment) reveal no regrowth, the tarps could be removed in month 13 after the start of barrier installation. The sixth resurvey would serve as a verification survey after the barriers were removed. It is estimated that barriers could be removed for approximately half of the installation cost. This estimate is based on the fact that supplies do not need to be purchased for removal. Moreover, while removal can be a demanding task, less time is needed because installation requires special planning and underwater navigation to get barriers oriented properly. Thus, the estimated cost to remove barriers would be $125,000 (Table 1).

SURVEY COSTS FOR SURROUNDING AREAS

Coronado Cays

The entirety of the Coronado Cays should be surveyed at least one time at the eradication level (100% coverage). Given that there is no penetration connecting the water area across Grand Caribe Causeway, if no *C. prolifera* is identified in the southern portion of the Coronado Cays, that area would require no further investigation. However, it would be prudent to survey the northern Coronado Cays again at some point after treatment of all known *C. prolifera* and prior to any determination that *C. prolifera* has been declared eradicated. The costs to survey within these additional areas used the same estimated costs per hectare to survey under docks and within the channels as provided above for the infestation action area. Refer to Figure 2 for the relative locations of the infestation action area, north Coronado

Cays, and south Coronado Cays. The surveys would be performed by a team of approximately five to seven *Caulerpa* Certified divers in the same manner as in the infestation site.

South San Diego Bay

Like the need to survey all the Coronado Cays, at some point it is critical to survey the remainder of South San Diego Bay at the high intensity level (50%) to ensure that *C. prolifera* does not exist beyond the limits of the Coronado Cays. The surveys would be performed again as detailed in the RREP, with the modification of spacing the dive team further apart from each other along each transect to inspect 50% of the bottom. If those surveys are performed at 50% coverage, it is estimated that 4.05 hectares can be surveyed per day at a cost of $9,927 per day. It is anticipated that up to 250 hectares would be selected for surveillance beyond the Coronado Cays extending into south San Diego Bay.

COST SUMMARY

Table 1 provides estimates based on the descriptions above. The eradication costs are based on the placement of 3,471 square meters of barrier using the known distribution of *C. prolifera* in October 2023. There are considerable uncertainties in the execution of the eradication including timing of funding (delay will result in additional survey needed prior to barrier placement to delineate current boundaries after spread), weather delays, discovery of additional *C. prolifera* in the infestation area prior to barrier placement, or repeated discovery of new growth during the six surveys necessitating additional resurvey work.

Table 1. Table showing the required actions, cost per unit of those actions, the estimated units to achieve eradication, and the costs to complete the eradication effort and surrounding survey work.

Action	Cost per Unit	Anticipated Units	Cost
Eradication			
Application of benthic barriers over 3,471 square meters of seafloor	$250,000	1	$250,000
Resurvey and treatment in 8.64-hectare survey management area	$94,960	6*	$569,760
Removal of benthic barriers from 3,471 square meters of seafloor	$125,000	1	$125,000
Survey of Surrounding Areas			
Survey entire Coronado Cays	$272,926	1	$272,926
Survey north Coronado Cays	$154,862	1	$154,862
High-intensity survey 250 hectares	$615,474	1	$615,474
Total			$1,988,022

*any discovery of *C. prolifera* during the third to sixth survey may trigger the need for additional surveys.

INITIAL ACTIONS

The eradication of *C. prolifera* from the Coronado Cays requires immediate attention to minimize further spread and increase the probability of successful eradication. Critical to initiate are the application of benthic barriers and the first two surveys of the 8.64-hectare infestation action area to find and treat remaining *C. prolifera*. These actions will be performed in an iterative manner with initial application of benthic barriers, followed immediately by a follow-up survey. It is anticipated that the first survey following treatment will identify additional areas where minor additional application of benthic barriers would be necessary. After this secondary treatment, a second resurvey roughly a month later will find and treat additional *C. prolifera* that may have sprouted from fragments. This timing will allow any missed *C. prolifera* to reach a detectible size while not being so large as to cause significant loss of containment. The actual timing of the treatment and survey events will be dependent upon the timing of funding, winter storms, and results of initial efforts. The SCCAT Steering Committee will oversee and direct the eradication team in the timing of events.

If funding were secured quickly, barrier installation could begin in December 2023 as described in Adaptive Management Memorandum #1 for the RREP, with the first two surveillance and treatment events being completed by March 2024.

Additional future actions will include the continued surveillance of the infestation action area until eradication has been achieved and surveys of adjacent areas in the Coronado Cays and south San Diego Bay have been performed. Funding opportunities will be sought to implement all of these actions as well as any additional actions as deemed necessary by SCCAT to achieve eradication, prevent additional infestation and distribution of Caulerpa species, and declare eradication of *C. prolifera* from San Diego Bay.

SCHEDULE

Figure 3 lays out a schedule for the treatment and surveillance necessary for the eradication work, starting with the installation of the benthic barriers. The eradication surveillance timeline assumes a scenario where additional *C. prolifera* is found and treated during the first two surveys and is not found during the third to sixth. The repeated survey and retreatment would be extended as indicated in Figure 3 if *C. prolifera* was found during surveys three to six or if the measured efficiency was not as assumed. Figure 4 provides a simplified eradication probability matrix assuming a fixed per survey efficacy. A proposed timeline for cutting test holes in the barriers, removing the barriers, and examining the infestation area an additional time (survey six) is proposed. However, this element of the eradication has not been fully strategized and will be detailed in a future adaptive management memo.

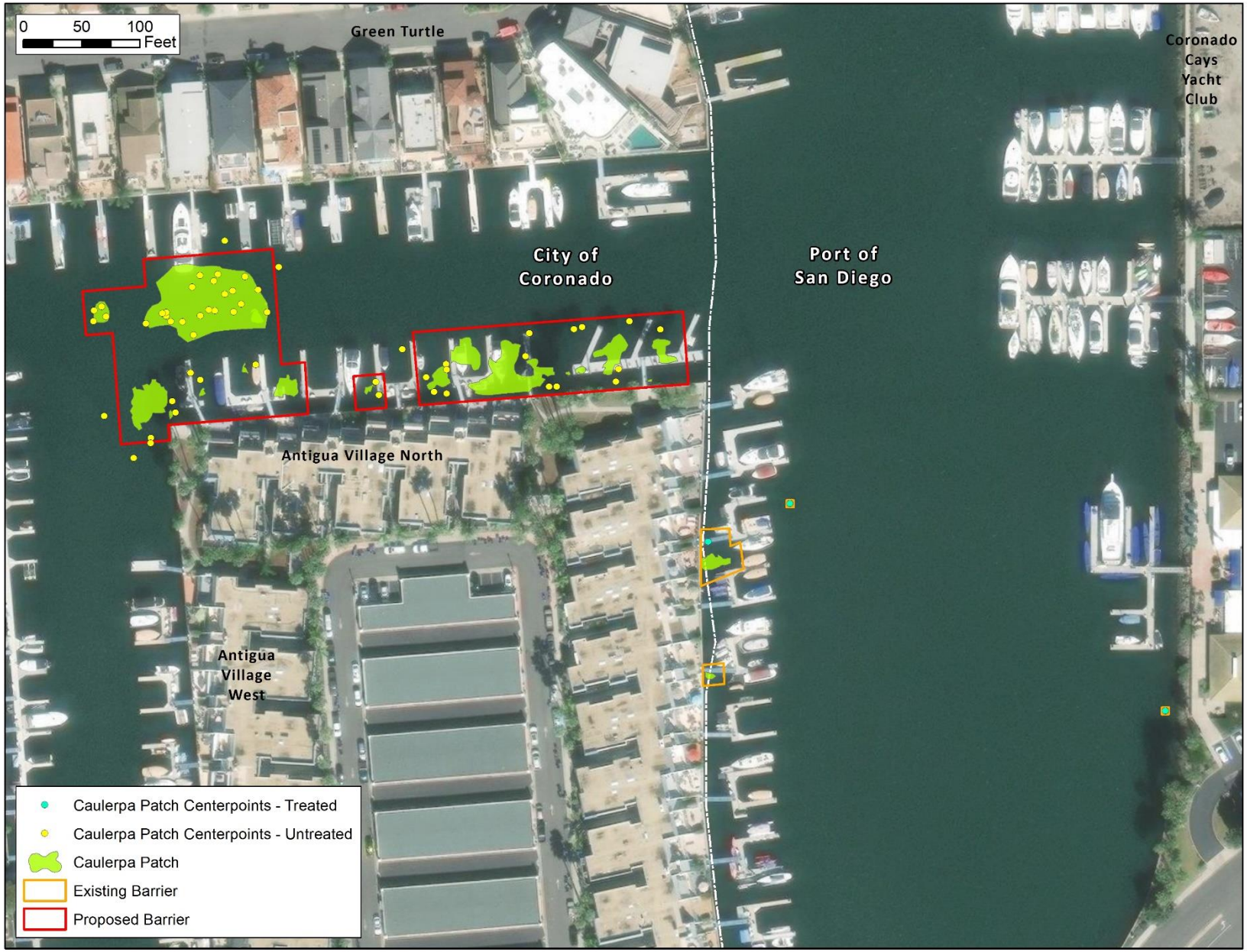
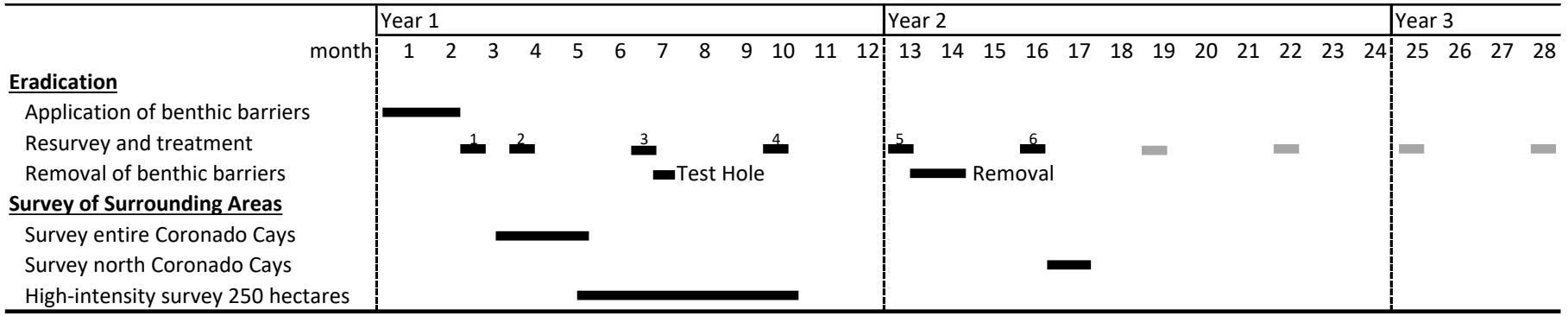


Figure 1. The above figure shows a potential barrier arrangement that covers all of the larger *C. prolifera* beds and most of the small patches. Additional small barriers not shown or hand picking would be used to treat any small patches not shown to be covered by the large barriers shown above in red. Proposed barrier area is 3,471 square meters.

Figure 2. The above figure shows the infestation action area (green), north Coronado Cays (red), and south Coronado Cays (blue). Areas in white are the dock areas used to help partition costs between dock areas and open water.



* Assumes resurvey 1 and 2 find *C. prolifera* and resurveys 3-6 do not.

Potential additional resurvey events needed if additional *C. prolifera* found during surveys 3-6

Figure 3. Schedule for *Caulerpa prolifera* eradication efforts, and survey of surrounding areas, in Coronado Cays, San Diego Bay.

Efficacy (Per Survey)	Survey Number 1	2	3	4	5	6
20.0%	20.0%	36.0%	48.8%	59.0%	67.2%	73.8%
30.0%	30.0%	51.0%	65.7%	76.0%	83.2%	88.2%
40.0%	40.0%	64.0%	78.4%	87.0%	92.2%	95.3%
50.0%	50.0%	75.0%	87.5%	93.8%	96.9%	98.4%
60.0%	60.0%	84.0%	93.6%	97.4%	99.0%	99.6%
70.0%	70.0%	91.0%	97.3%	99.2%	99.8%	99.9%
80.0%	80.0%	96.0%	99.2%	99.8%	100.0%	100.0%
90.0%	90.0%	99.0%	99.9%	100.0%	100.0%	100.0%

Figure 4. The above figure provides a simplified matrix of eradication probability based on the number of surveillance events and the per survey efficacy assuming a constant efficacy across surveys. Actual eradication probability can be determined based on the measured survey efficacy for each survey event as they occur. Shaded cells are those cells where the per survey efficacy and the number of repeated surveys results in a greater than 95% eradication probability.

REFERENCES

[SCCAT] Southern California *Caulerpa* Action Team. 2023. Adaptive Management Memorandum #1 for the Rapid Response and Eradication Plan for the Invasive Green Alga *Caulerpa prolifera* in San Diego Bay, November 2023.

[SCCAT]. 2023. Rapid Response and Eradication Plan for the Invasive Green Alga *Caulerpa prolifera* in San Diego Bay, September 2023.

Southern California Caulerpa Action Team

Rapid Response and Eradication Plan for the Invasive Green Alga *Caulerpa prolifera* in San Diego Bay

Adaptive Management Memorandum #3 (May 2024)

May 10, 2024

SUMMARY OF KEY POINTS

- An Eradication Plan was drafted in September 2023 after the initial discovery of *Caulerpa prolifera* in San Diego Bay.
- This memo describes additional *C. prolifera* discovered east of the Coronado Cays in the San Diego Bay National Wildlife Refuge.
- The planned response to the new discovery is similar to that of the Coronado Cays, with modifications to better control the escape of live fragments during and after barrier placement.
- The implementation schedule is updated to reflect work already completed and upcoming treatment and survey efforts.

INTRODUCTION

In September 2023, the Southern California *Caulerpa* Action Team (SCCAT) adopted a Rapid Response and Eradication Plan for the Invasive Green Alga *Caulerpa prolifera* in San Diego Bay (Eradication Plan) describing the concern with the discovery of *C. prolifera* in San Diego Bay. The Eradication Plan provided a general approach to mapping and removing *C. prolifera*. Adaptive management memoranda have been regularly prepared as new data, funding, or insight become available, and then attached as addenda to the September 2023 Eradication Plan. This third memorandum discusses the discovery of additional *C. prolifera* in south San Diego Bay and the proposed response to the find.

SURVEY IN SOUTH SAN DIEGO BAY

The U.S. Fish and Wildlife Service (USFWS) has provided rapid response funding for the survey of high priority areas at risk of infestation from the known location of *C. prolifera* in the Coronado Cays. There is a specific threat to eelgrass beds and habitats within the San Diego Bay National Wildlife Refuge (SDBNWR) immediately adjacent to the infestation area. The SDBNWR and adjacent waters are being surveyed by the eradication team, made up of certified *Caulerpa* divers from Merkel & Associates (M&A) and Marine Taxonomic Services (MTS). During surveys in April 2024 the dive team discovered a small infestation of *C. prolifera* roughly 580 meters east of the Coronado Cays infestation, within the SDBNWR (Figure 1). It was made up of nine small patches ranging in size from 6 centimeters to 3 meters in width. The total coverage of *C. prolifera* was approximately 15 square meters (Figure 2), distributed over a roughly 962 square meter (0.24 acre) area of seafloor, considered the eradication area.

RESPONSE PLAN

The planned response to isolate and eliminate the April *C. prolifera* infestation found in SDBNWR follows the methods outlined in the Eradication Plan. Divers will first systematically re-survey the infested area and collect any loose fragments, place them in a fine mesh bag, and bring them to the surface for disposal. Once the infestation area survey is complete, divers will place benthic barriers over the patches of *C. prolifera*. Barriers will overlap 0.6 meter along the long sides and approximately 1 meter on the short ends and will be secured to the bottom with rebar pins and sandbags. Following placement, the surrounding area will be re-inspected by the dive team for any fragments of *C. prolifera*. The re-inspections will be continued until SCCAT has adequate confidence that existing fragments have been found based on efficacy assessments and/or consistently declining find numbers.

Observations at the Coronado Cays treatment area suggest that small fragments may have been displaced during the barrier placement process or, in limited instances, escaped through perforations built into the barriers to allow the escape of decomposition gasses and better ensure the barriers remain in place. Modifications to the treatment approach in the SDBNWR may include placement of a water permeable mesh over the *C. prolifera* prior to barrier placement to secure the algal material and minimize its displacement into the water column as the barriers are placed. The mesh would be removed at the same time as the barrier removal at the end of the eradication process. Additionally, the perforations that allow off-gassing will be sealed and smaller slit punctures made to continue to allow gas from decay to escape but more securely contain fragments of *C. prolifera* under the barrier.

For the distribution of *C. prolifera* in the SDBNWR as of April 19, treatment will involve placement of barriers over an approximately 215 square meter treatment area within the eradication area (Figure 3). The survey of the SDBNWR has not been completed at this time, therefore it is likely that additional *C. prolifera* will be discovered. This memorandum will apply to responses to additional finds in south San Diego Bay. For planning purposes SCCAT will be anticipating the possibility that up to 1.24 hectares (0.5 acre) could potentially need to be contained with barriers, if a large source patch is discovered.

The treatment of the discovered *C. prolifera* in south San Diego Bay will be covered by a Regional General Permit 63 verification from the U.S. Army Corps of Engineers through a new application. The California Coastal Commission plans to issue an emergency permit to cover the treatment work.

It is anticipated that the treatment could be completed roughly in the same timeframe as the Coronado Cays infestation treatment. At that time both infestation areas would be scheduled to have a series of quarterly follow-up surveys to find and treat any regrowth, as described in the Eradication Plan.

SCHEDULE

Figure 4 provides an updated schedule for the treatment and surveillance necessary for the eradication work, reflective of the new discovery in south San Diego Bay and the extended treatment time needed for the Coronado Cays infestation.

Figure 1. This locator map shows the position of the *Caulerpa prolifera* infestation in south San Diego Bay as of May 2024.

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Figure 2. The above figure shows the 15 square meters of *Caulerpa prolifera* discovered in the San Diego Bay National Wildlife Refuge in April 2024.

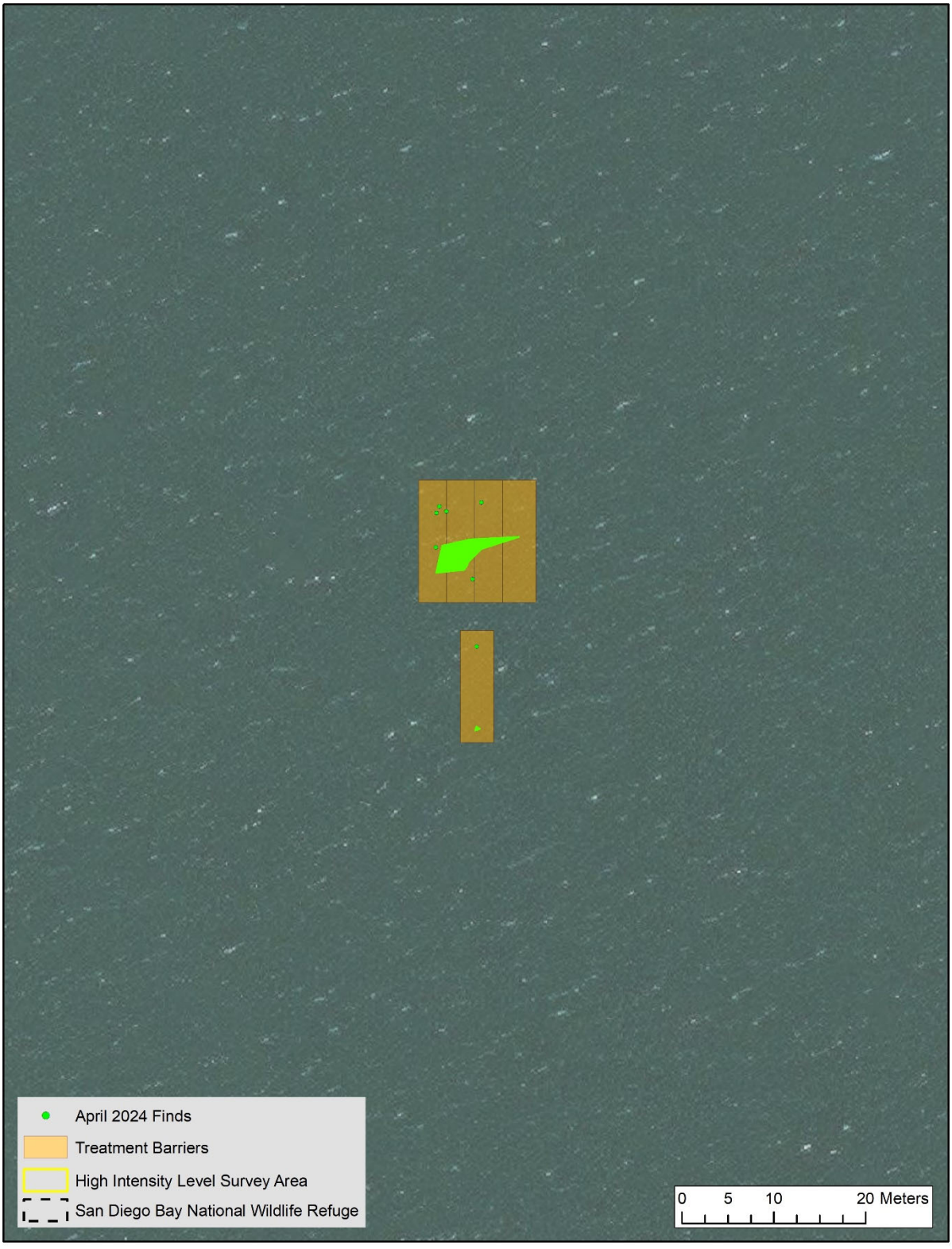
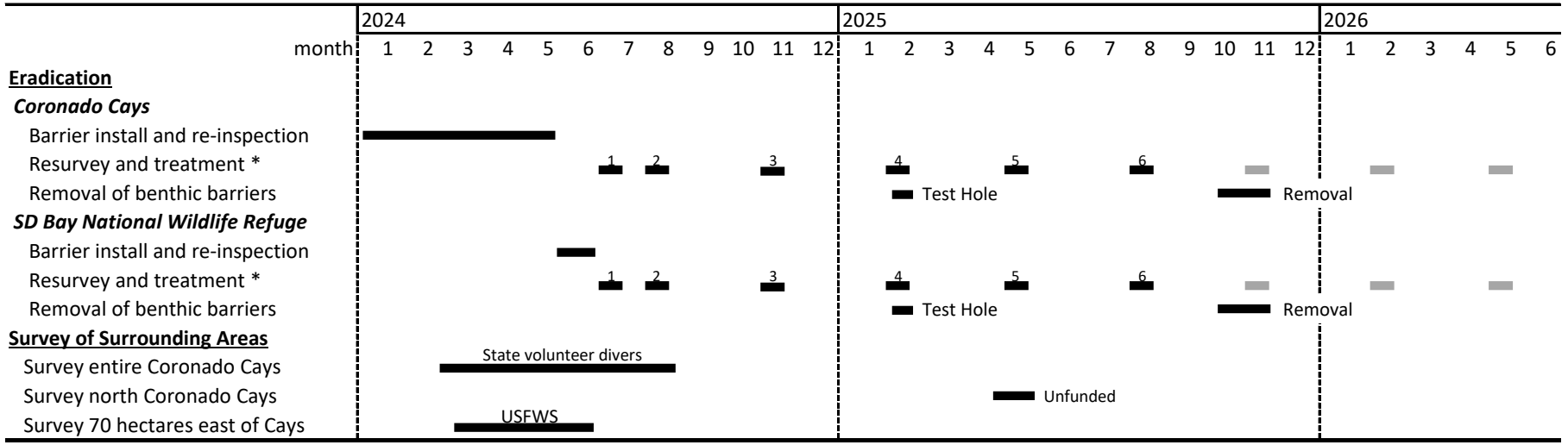


Figure 3. The above figure shows the proposed barrier placement over the *Caulerpa prolifera* discovered in the San Diego Bay National Wildlife Refuge in April 2024.



* Assumes resurvey 1 and 2 find *C. prolifera* and resurveys 3-6 do not.

Potential additional resurvey events needed if additional *C. prolifera* found during surveys 3-6

Figure 4. Schedule for *Caulerpa prolifera* eradication efforts, and survey of surrounding areas, in South San Diego Bay.

Southern California Caulerpa Action Team

Rapid Response and Eradication Plan for the Invasive Green Alga *Caulerpa prolifera* in San Diego Bay

Adaptive Management Memorandum #4 (May 2024)

May 31, 2024

SUMMARY OF KEY POINTS

- An Eradication Plan was drafted in September 2023 after the initial discovery of *Caulerpa prolifera* in San Diego Bay.
- This memorandum provides the methods for a pilot study to evaluate the efficacy of the initial barriers installed as part of the *C. prolifera* eradication program at Antigua Village East in the Coronado Cays.
- This study will involve creating small openings, or test plots, to observe the conditions beneath the barriers for a three-month period.
- The study will be immediately discontinued, and the plots sealed and covered, if there is any sign of *C. prolifera* remaining under the barriers, whether alive or dead.

INTRODUCTION

In September 2023, the Southern California *Caulerpa* Action Team (SCCAT) adopted a Rapid Response and Eradication Plan for the Invasive Green Alga *Caulerpa prolifera* in San Diego Bay (Eradication Plan) describing the concern with the discovery of *C. prolifera* in San Diego Bay. The Eradication Plan provided a general approach to mapping and removing *C. prolifera*. Adaptive management memoranda have been regularly prepared as new data, funding, or insight become available, and then attached as addenda to the September 2023 Eradication Plan. This fourth memoranda describes the methodology to study the effectiveness of barriers installed in the Antigua Village East area as part of the *C. prolifera* eradication program in the Coronado Cays.

The Coronado Cays is a residential community located in South San Diego Bay where *C. prolifera* was discovered in October 2023. On October 9, 2023, benthic barriers were installed over the *C. prolifera* at Antigua Village East and have now been in place for nearly eight months (Figure 1). Since the installation of the barriers, a series of surveys directly over the barriers and the surrounding area have been conducted to search for remaining *C. prolifera* in the infested area. As there have been no additional findings of *C. prolifera* within the vicinity of these barriers in recent surveys, it is of interest to evaluate the status of the treated *C. prolifera* beneath the barriers, without removing them entirely. To investigate the effectiveness of the barriers, small openings (test plots) will be cut in the barriers in Antigua Village East to observe the condition of the seafloor, including any observations of mobile invertebrates, eelgrass growth, and other algae.

The objective of the investigation is to determine how effective the barriers are at developing a continuous reducing beneath the tarps such that anaerobic bacterial decay can reduce the *C. prolifera* to non-viable conditions. Given that the present treatment is ongoing, it is premature to initiate complete barrier removals. However, it is valuable to explore the effectiveness of the barriers being placed particularly considering the context of the barriers having small vents to allow for off-gassing. This study is intended to advance this effort.

Figure 1. Vicinity map showing the location of Antigua Village East in the Coronado Cays, San Diego, California.

OBSERVATION PLAN

The plan to observe the efficacy of *C. prolifera* treatment under the barriers will involve the creation of test plots in the treatment barriers. The test plots will consist of 1/16th square meter openings that will be cut in the treatment barriers in Antigua Village East. The test plots will be located within the beds of *C. prolifera* that were previously mapped prior to barrier placement. The larger of the two barriers will have three test plots and the smaller barrier will have two test plots (Figure 2).

Once the locations of the test plots have been identified on the barriers, divers will cut a $1/16^{th}$ square meter opening such that a flap is created to view underneath the barrier. The flap will be weighted open against the barrier with a sandbag. Divers will then take photos and record observations of vegetation, invertebrates, and sediment condition of each test plot. If there is any evidence of material with *C. prolifera* structure, whether dead or alive, all flaps will immediately be closed, and a 1.5 square meter barrier will be secured on top of each test plot. Although the thalli may appear dead, repeated field observations have found new growth sprouting from the remaining dead structure. The plots will only remain open if there is no sign at all of C. prolifera. If the barriers have been in place a sufficient amount of time, it would be anticipated that only anoxic sediment would remain under the barrier.

The test plots will remain open for regular observation and to allow the environmental conditions of the newly created openings to equilibrate to those outside the barrier. The objective of keeping the flap open is to observe if there is a reemergence of *C. prolifera*, eelgrass, and or change in epibenthic invertebrate occupation. If at any point *C. prolifera* is observed to be growing in a test plot, the flap will immediately be closed, and a 1.5 square meter barrier will be secured on top of the test plot.

The test plots will be further monitored 3, 7, 14, 30, 45, 60, and 90 days following the opening and inspection of the test plots. A brief memorandum with photos and summary observations of each monitoring event will be provided following the completion of the final 90-day survey. If at any point during the study there is evidence of regrowth of *C. prolifera* the SCCAT will be notified promptly.

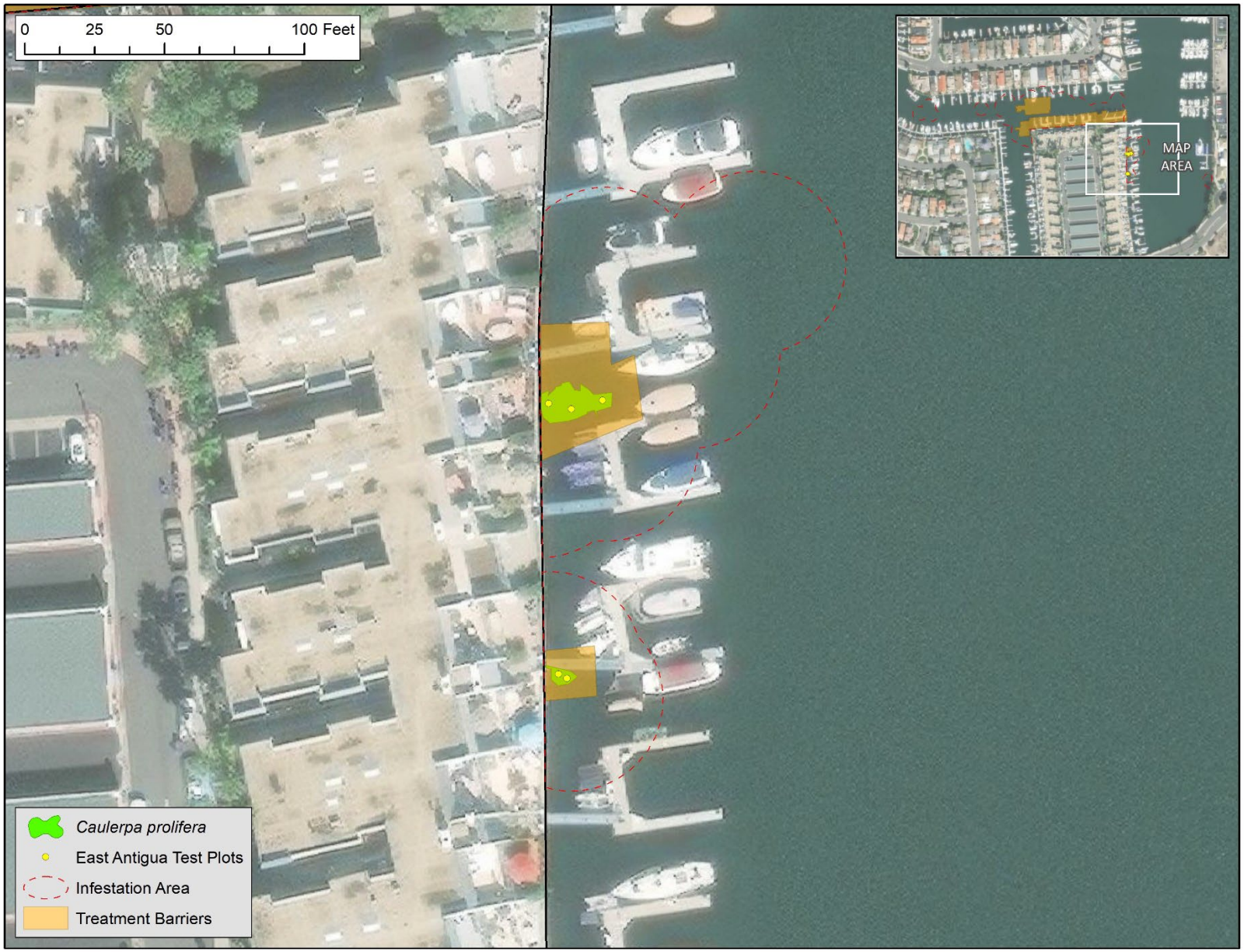


Figure 2. The above figure shows the location of the planned test plots at Antigua Village East.

Southern California Caulerpa Action Team

Rapid Response and Eradication Plan for the Invasive Green Alga *Caulerpa prolifera* in San Diego Bay

Adaptive Management Memorandum #5 (October 2024)

October 31, 2024

SUMMARY OF KEY POINTS

- This memo provides methods associated with a modification to add rock salt during the treatment process to eradicate *C. prolifera* in Antigua Village, Coronado and the San Diego Bay National Wildlife Refuge.

INTRODUCTION

This memo is written to add the application of salt to the barrier containment methodology to eradicate the infestation of *Caulerpa prolifera* in the Antigua Village area of the Coronado Cays and the San Diego Bay National Wildlife Refuge. The current methodology consists of the placement of a benthic barrier over any *C. prolifera* discovered that cannot be easily picked by hand. The benthic barrier metholology is described in prior Adaptive Management Memoranda and the Rapid Response Plan. The application of salt can speed the process of killing C. prolifera contained under the benthic barriers through osmotic shock (Glasby et al. 2005).

METHODS

Any occurrence of *C. prolifera* is first mapped in accordance with SCCAT (2023a). For small occurrences, generally smaller than 30 centimeters across, an inverted, shallow-plastic bin is placed over the *C. prolifera* and a sandbag is placed on top of the bin to secure it to the seafloor. For larger occurrences of *C. prolifera*, a plastic benthic barrier is unrolled over the *C. prolifera* patch. The edges are sealed to the seafloor with a combination of rebar and sandbags. The *C. prolifera* is left to die through lack of sunlight and increased biological oxygen demand.

For patches encountered that require bins or barriers moving forward, the SCCAT would like to have the ability to add rock salt over the *C. prolifera* prior to placing the barrier. In the instances where bins are used, rock salt would be applied to the seafloor immediately over the *C. prolifera* and then the bin would be placed over the top. In instances where flexible plastic benthic barriers are used, a mesh with a mesh size of no larger than 1 centimeter will first be placed over the *C. prolifera*. This mesh is intended to provide a means to prevent any fragments from being able to migrate due to surrounding water turbulence created during the application of the salt or the solid barrier. Following application of

the mesh, the salt would be placed and then the impermeable barrier would be placed over the top of the treated area.

The application of salt will be performed at an amount necessary to reach or exceed the saturation point of salt (NaCl) in water. At 25C saturation occurs at 357 mg/ml. Assuming a water column of approximately 2.5 cm under a barrier, it would take approximately 8.9 kg/m^2. Applications in Glasby et al. (2005) were 50 kg/m^2. Glasby et al. (2005) worked in an open system with no barrier over the tested C. taxifolia. Thus, it is proposed that applications between 8.9 and 50 kg/m^2 be performed when placing barriers over *C. prolifera* patches. The actual application amount would be at the discretion of the SCCAT in consultation with regulatory agencies.

REFERENCES

Glasby, T. M., Creese, R. G., & Gibson, P. T. (2005). Experimental use of salt to control the invasive marine alga *Caulerpa taxifolia* in New South Wales, Australia. *Biological Conservation, 122*(4), 573–580. https://doi.org/10.1016/j.biocon.2004.09.007

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