

**Eradication and Surveillance of *Caulerpa taxifolia* within
Agua Hedionda Lagoon, Carlsbad, California
Fourth Year Status Report**

Fall 2003 through Fall 2004

Prepared for:

Steering Committee of the Southern California *Caulerpa* Action Team

- ? California Regional Water Quality Control Board – San Diego Region (SDRWQCB)
- ? California Regional Water Quality Control Board – Santa Ana Region (SARWQCB)
- ? California Department of Fish and Game (CDFG)
- ? National Marine Fisheries Service (NOAA-NMFS)
- ? U.S. Department of Agriculture (USDA)

Prepared by:

Rachel Woodfield, Merkel & Associates, Inc.
Keith Merkel, Merkel & Associates, Inc.

March 2005



TABLE OF CONTENTS

Executive Summary	1
Introduction	2
Eradication Program- Fourth Year: Fall 2003 through Fall 2004.....	5
Methods	5
Results	6
Fall 2003	6
Winter 2003.....	6
Spring 2004	6
Summer 2004	6
Fall 2004.....	7
Treatment Efficacy	9
Eradication Status	9
Status of the Lagoon and Coordination With Lagoon Users	10
Eradication Costs	11
Future Actions in the Eradication Program	11
References	12

FIGURES

Figure 1. <i>Caulerpa taxifolia</i> discovered since June 2000 at Agua Hedionda Lagoon	4
Figure 2. Transects surveyed for <i>Caulerpa taxifolia</i> during fourth year of the eradication effort .	8
Figure 3. Areal coverage of <i>Caulerpa taxifolia</i> in Agua Hedionda Lagoon in square meters.	9

Eradication and Surveillance of *Caulerpa taxifolia* within Agua Hedionda Lagoon, Carlsbad, California Fourth Year Status Report

Fall 2003 through Fall 2004

EXECUTIVE SUMMARY

On June 12, 2000 the first known infestation in the Western Hemisphere of the invasive strain of the tropical marine alga, *Caulerpa taxifolia*, was discovered in Agua Hedionda Lagoon, in Carlsbad, California. This document reports the results of the fourth year of the eradication program undertaken by the Southern California *Caulerpa* Action Team (SCCAT). Merkel & Associates has been contracted to conduct the eradication under the oversight of the SCCAT, a broad-based task force assembled from federal and state resource and regulatory agencies, exotic species experts, and marine resource scientists.

During the fourth year, covering fall 2003 to the end of fall 2004, there was no *C. taxifolia* found in the lagoon. Survey work involved three full surveys of the entire lagoon, conducted in fall 2003, summer 2004, and fall 2004. Assessments of the efficacy of the surveys using artificial *Caulerpa* found the surveys to be between 35 and 83% effective. Efficacy was dictated by water clarity and the amount of eelgrass occurring in the surveyed areas.

The fourth year of monitoring is marked by the completion of seven consecutive surveys with no *C. taxifolia* being found. None has been discovered since September 11, 2002, during the summer survey of 2002 (Year 2). The goal of the current phase of the eradication is to continue conducting surveys throughout the lagoon. The eradication effort will be completed following three years of negative surveys conducted during the high growth seasons. If no *C. taxifolia* is found during surveys conducted in the fifth year, 2005, eradication of *C. taxifolia* from Agua Hedionda Lagoon will be declared by SCCAT.

In the first year of the program, approximately \$1.1 million was spent on eradication at Agua Hedionda Lagoon. In the second year, approximately \$0.8 million was spent, with surveillance expenses being considerably more than treatment. During the third and fourth year, approximately \$0.6 million was spent annually at Agua Hedionda Lagoon, covering primarily expenses for surveillance. A total of approximately \$3.1 million has been spent at the site since June 2000.

INTRODUCTION

The highly invasive Mediterranean strain of the tropical marine alga *Caulerpa taxifolia* was discovered in Agua Hedionda Lagoon, Carlsbad, California in June 2000 (Figure 1). Its discovery represented the first known occurrence of this strain within the Western Hemisphere and is believed to pose a major threat to coastal ecosystems and recreational and commercial uses dependent upon coastal resources. While the species was also identified at a second site in California (Huntington Harbour, Orange County), the Agua Hedionda Lagoon infestation is the larger of the two known infestations. It is likely that *C. taxifolia* had been in the lagoon for at least four years prior to its discovery. It is not known whether other infestations also exist elsewhere in the United States. The continued wide availability and use of this species by saltwater aquarists is cause for concern.

In the United States, the Mediterranean strain of *Caulerpa taxifolia* has been banned from importation and interstate commerce since 1999 through the Federal Noxious Weed Act. Legislation banning the transport, sale, and possession of nine potentially invasive species of *Caulerpa*, including *C. taxifolia*, was enacted in the State of California in September 2001. Earlier in 2001, the City of San Diego adopted an ordinance with similar restrictions applicable to the entire genus of *Caulerpa*.

Since the discovery of *C. taxifolia* in Agua Hedionda Lagoon in June 2000, eradication, surveillance, public outreach efforts, eradication research, and legislative efforts have been initiated and are on-going. The primary goal of the Southern California *Caulerpa* Action Team (SCCAT), which is made up of resource managers, marine resource and pest control scientists, permitting agencies, marine biological consultants, land-owners and environmental stakeholder representatives, has been the eradication of the known infestations.

Tremendous progress was made during the first two years of the eradication program. From the date of discovery (June 2000) until the end of the Summer 2001 survey, the eradication effort at Agua Hedionda Lagoon primarily involved the treatment of all detected *C. taxifolia*. The amount of *C. taxifolia* present in the lagoon at the time of discovery was estimated to be 1,047 m² (Merkel & Associates, 2001a). By the end of the second year of eradication efforts at Agua Hedionda Lagoon the amount of *C. taxifolia* discovered had been reduced to 0.4 m² (Merkel & Associates, 2003). The location of all *C. taxifolia* discovered since the beginning of the eradication effort is indicated in Figure 1.

During the third year, there was no *C. taxifolia* detected over the course of four lagoon-wide surveys (Merkel & Associates, 2004). In response to concerns that funding for future surveillance could be exhausted prior to completion of the eradication program, SCCAT adopted a survey plan for the fourth year that involved conducting surveys only in the high growth seasons of summer and fall.

In order to simplify annual reporting and to synchronize reports with calendar years, the fourth year report will include the results of an extra survey quarter. This document provides a synopsis of the fourth year's efforts and costs, and reports on the status of the lagoon and the progress toward the final goal of full eradication of *Caulerpa taxifolia* from Agua Hedionda

Lagoon. This will cover quarterly sampling conducted in Fall 2003, Summer 2004, and Fall 2004. Please refer to the Year 1, Year 2, and Year 3 reports for details on survey and treatment actions completed during those years.



Caulerpa taxifolia discovered since June 2000
Agua Hedionda Lagoon, Carlsbad, CA
Last find: September 2002

Figure
1

ERADICATION PROGRAM- FOURTH YEAR: FALL 2003 THROUGH FALL 2004

Following the intensive summer 2001 survey and treatment season, a systematic quarterly survey program was undertaken to search for additional patches of *C. taxifolia*. During the second year of the program surveys were conducted lagoon-wide, covering the west, central, and east basin of Agua Hedionda Lagoon. During the third year, surveys were still conducted quarterly, however the winter and spring surveys were reduced to focused surveys of high-risk areas in the lagoon. During the fourth year, surveys were only conducted during summer and fall surveys. These surveys covered all basins of the lagoon.

METHODS

All surveys during the fourth year used the laid-transect line method. This method employs the use of SCUBA divers swimming along transects lines deployed by a small boat using differential GPS. The divers use a guide-line to maintain their spacing at 1 meter apart, and vary their swimming speed based on visibility and density of eelgrass. Having tested a variety of other survey methods, including towed divers, towed cameras, and laser line scan, it appears that the most effective approach to conducting intensive surveys that can locate very small fronds of *C. taxifolia*, even within dense eelgrass beds, is the current method employed. This survey intensity is defined as an eradication level survey in which divers are used to make visual searches to ensure 100% viewing of the study area (NMFS, 2002).

Survey staff were trained and prepared to respond to new discoveries. If *C. taxifolia* were to be found by divers, its location would be recorded by dGPS and the patch assessed by a biologist. The dimensions and, if possible, the number of fronds, number and length of thalli, and typical frond lengths would be recorded for each patch located. The patch would be marked by colored pin-flags to be left in place during treatment in order to relocate the treated *C. taxifolia* at a later date if necessary for efficacy investigations. The *C. taxifolia* would be contained within 24 hours with a PVC tarp and treated with solid chlorine pucks, as outlined in the Revised Eradication Plan for *Caulerpa taxifolia* in California (Merkel & Associates, 2001b).

During each quarterly survey, assessments were made of the efficacy of the survey methodology. This was achieved through the placement of artificial *C. taxifolia* in the lagoon during the survey. These efficacy trials were generally conducted twice during each survey, once in Snug Harbor, which is relatively clear and supports dense eelgrass, and one further east off of Bristol Cove, in an area with only sparse eelgrass and often poor visibility. The amount of plants found by the team was analyzed based on water clarity, plant size, and density of eelgrass in the survey area. These trials allowed for a rough assessment of the confidence in the results of the survey for real *C. taxifolia*. They also allowed for the calculation of the number of additional surveys that would be needed to achieve an acceptable level of confidence that all *C. taxifolia* present in the lagoon had been found. A full discussion of this efficacy program is detailed in *Caulerpa taxifolia* in Southern California: Results from Survey Efficacy Trials (M&A 2004).

Water temperature was monitored over the year in the infested portion of the east basin of Agua Hedionda Lagoon. Data were collected hourly by deployed loggers manufactured by Onset ®, with an accuracy of ± 0.2 °C (± 0.3 °F).

RESULTS

The results of each of the quarterly surveys conducted at Agua Hedionda Lagoon are discussed below. Figure 2 displays the lines surveyed during each quarter of the fourth year.

Fall 2003

The Fall 2003 survey effort was conducted from September 23 to November 26, 2003. All basins of the lagoon were surveyed using the laid line methodology with divers at 1-meter spacing (Figure 2).

No *C. taxifolia* was found in the lagoon during this survey.

A survey efficacy trial was conducted during this period in Snug Harbor. During this trial 75% of the artificial *C. taxifolia* placed in the study area was found by the survey team. The results of this trial suggest that 4 additional negative surveys at this efficacy level would be necessary to be 99% certain that no single *C. taxifolia* patch remains (M&A 2004a).

An additional element of the efficacy assessment included placing out larger artificial patches of *Caulerpa*, in order to determine the minimum sized plant that would be detected 100% of the time. Trials with round patches sized 0.3m, 0.5m, and 1m wide found that the 1m patch was the smallest patch size found 100% of the time. More detailed results of these efficacy trials can be found in the reports attached in Appendix A of this report.

Water temperature data for Fall 2003 were collected only from September to November, with December data not available. The mean water temperature during that time period was 19.5°C (67.1°F), ranging between 16.9 and 22.7°C (62.5-72.8°F).

Winter 2003

No survey work was conducted during this time period. The mean water temperature during the winter 2003 season was 15.3°C (59.6°F), ranging between 11.9 and 20.8°C (53.5-69.5°F).

Spring 2004

No survey work was conducted during this time period. Water temperature data collected during this period remain in the logging unit at time of this report preparation.

Summer 2004

The Summer 2004 survey was conducted from July 7 to September 7, 2004. The entire lagoon was surveyed using the laid line methodology with divers at 1-meter spacing (Figure 2).

No *C. taxifolia* was found in the lagoon during this survey.

Survey efficacy trials were conducted during this period in Snug Harbor and off of Bristol Cove. In Snug Harbor, 83% of the artificial *C. taxifolia* placed in the study area was found by the survey team. Off of Bristol Cove, visibility was commonly very low, resulting in an efficacy of 35% of the artificial *C. taxifolia* being found. The additional element of the efficacy assessment that included placing out larger artificial patches of *Caulerpa* found that during both trials the 1m patch was the smallest patch size found 100% of the time.

Water temperature data collected during this period remain in the logging unit at time of this report preparation.

Fall 2004

The Fall 2004 survey effort was conducted from September 21 to November 30, 2004. All basins of the lagoon were surveyed using the laid line methodology with divers at 1-meter spacing (Figure 2).

No *C. taxifolia* was found in the lagoon during this survey.

A survey efficacy trial was conducted during this period in Snug Harbor. During this trial 63% of the artificial *C. taxifolia* placed in the study area was found by the survey team. The minimum sized plant that was detected 100% of the time was 1-m wide.

Water temperature data collected during this period remain in the logging unit at time of this report preparation.



— Fall 2003
— Summer 2004
— Fall 2004



Transects Surveyed for *Caulerpa taxifolia* During Year 4 of the Eradication Effort
Fall 2003 - Fall 2004
Agua Hedionda Lagoon, Carlsbad, CA

Figure
2

TREATMENT EFFICACY

An assessment investigating the efficacy of the treatment methodology of tarping and chlorinating was initiated in April 2002. Openings were cut into selected tarps of various ages and monitored for regrowth of *C. taxifolia*. Since that time no regrowth of *C. taxifolia* has been observed in any of the study plots. Each plot continues to be monitored both for *C. taxifolia* regrowth and for recovery of native species to the exposed bottom. A separate report on this project will be prepared after completion of the study in 2006.

ERADICATION STATUS

The completion of the Fall 2004 survey marked the seventh complete survey of Agua Hedionda Lagoon with no *C. taxifolia* found. It was estimated that 1,047 m² of *C. taxifolia* was present lagoon-wide at the start of the eradication effort in summer 2000. This amount declined steadily throughout the eradication effort, with only 0.4 m² found lagoon-wide in summer 2002. The encouraging results seen during the second monitoring year persisted throughout the third and fourth year, with no *C. taxifolia* found during any of the surveys.

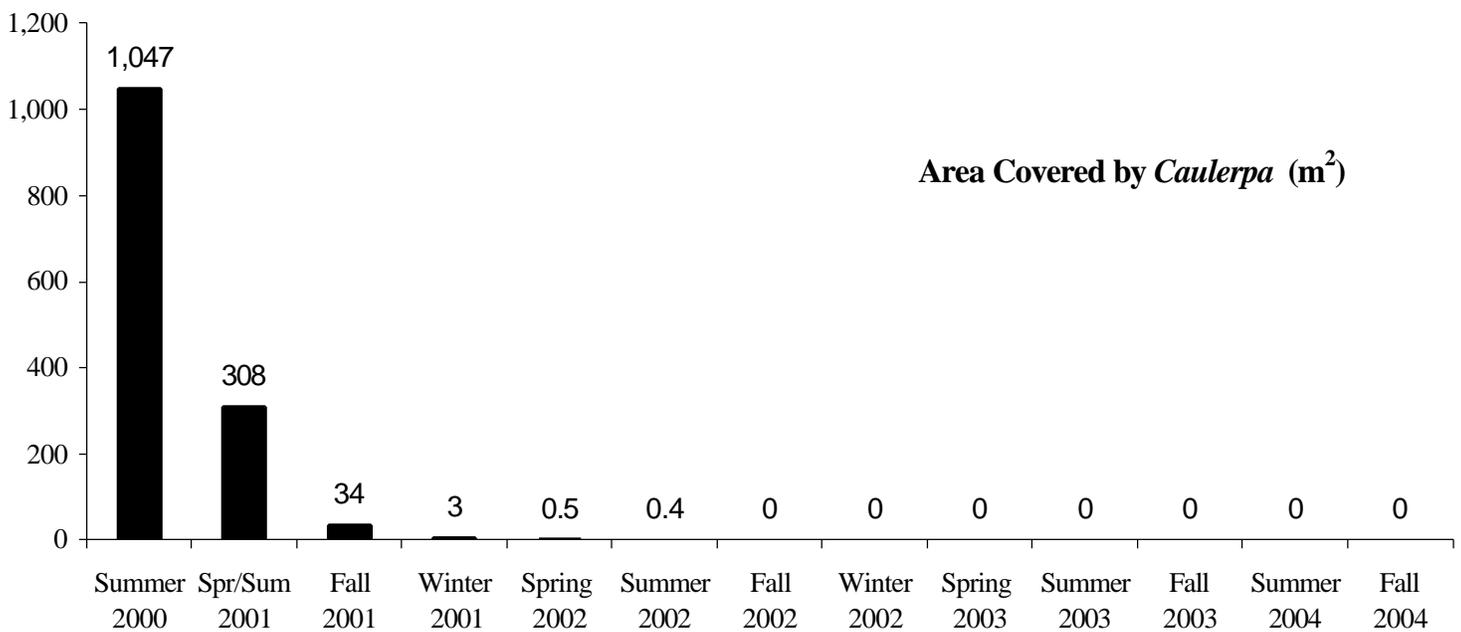


Figure 3. Areal coverage of *Caulerpa taxifolia* in Agua Hedionda Lagoon in square meters.

The SCCAT Technical Subcommittee has developed a timeline for declaration of eradication based on both the biology of *C. taxifolia* and the capabilities and efficacy of the survey team. The proposed schedule involves conducting surveys for a minimum of two growing seasons (summer and fall) following the last find of *C. taxifolia*. If no *C. taxifolia* is found during each consecutive survey, surveys during the next season would be expected to find any patches previously missed, due to patch expansion facilitated by the favorable growing conditions that exist for much of the year in the lagoon. Once surveys have been conducted over three full growing seasons with no *C. taxifolia* found, then eradication would be declared. Following this timeline, there are two full surveys (the third full growing season) remaining to be conducted: Summer 2005 and Fall 2005.

STATUS OF THE LAGOON AND COORDINATION WITH LAGOON USERS

During the fourth year, activities on the lagoon continued to be coordinated through the Interim Management Plan (Plan), a document drafted and adopted by the SCCAT, the Agua Hedionda Lagoon User Representatives, and the City of Carlsbad. This plan partitioned the lagoon into management units and established safety guidelines for both the eradication crew and recreational users of the lagoon. To coordinate the activities of all users, informational signage at access points around the lagoon was posted with regular activity updates, and a recorded phone message with schedule updates was maintained. This Plan allowed the survey work to be conducted more safely and efficiently than before the adoption of the plan. The City of Carlsbad and SCCAT review the Plan several times annually to assess its efficacy and consider modifications.

The first version of the Plan originally adopted in June 2002 included the following restrictions on the lagoon relating to the control of *C. taxifolia*: a ban on anchoring and fishing throughout the east basin, a prohibition of wake height by boats in excess of 0.3 m (12 inches) when measured from the undisturbed water surface to the top of crest, and continued exclusion of all unauthorized vessels from most of Snug Harbor, the most infested area of the lagoon.

As promised by the SCCAT, these restrictions were reviewed regularly in the context of the progress of eradication efforts. In November of 2002, SCCAT recommended the re-opening of the eastern portion of the east basin to fishing, given that after two years of survey, no *C. taxifolia* had ever been found there. The following year, in May 2003, SCCAT also recommended that the previously closed area in Snug Harbor be opened to passive use vessels (non-motorized vessels). In fall of 2003, SCCAT further recommended that Snug Harbor be returned to its original use as the operational area for the vessels of Carlsbad Watersports, located in Snug Harbor. The Carlsbad City Council approved and adopted each of these changes, which were implemented throughout the fourth year. The only remaining restriction is the prohibition of anchoring in the east basin, except in the passive use area. SCCAT will continue to regularly revisit the Plan with the goal of eventually recommending the complete return to pre-*C. taxifolia* uses.

ERADICATION COSTS

During the fourth year of the eradication program at Agua Hedionda Lagoon, Merkel & Associates performed many tasks, including SCCAT coordination and presentations, outreach, surveillance and mapping, maintenance of *C. taxifolia* stock from Agua Hedionda Lagoon, collection and management of data relating to efficacy of treatment and survey efforts, reporting, and a variety of other tasks, as assigned. The vast majority of the funds expended were for the surveillance work. During the fourth year (October 2003 to December 2004), approximately \$626,000 was expended on the above-described work. This funding was provided by the State Water Resources Control Board (through Cleanup and Abatement Account funds and an EPA 319h Water Quality Implementation Project grant), NOAA Fisheries, the California Coastal Conservancy (Southern California Wetlands Recovery Project grant), the Agua Hedionda Lagoon Foundation, Cabrillo Power LLC, and the National Fish and Wildlife Foundation. Since June 2000, eradication efforts at Agua Hedionda Lagoon have cost approximately \$3.1 million.

Additional costs of eradication not accounted for above include the contributions of all active SCCAT members including the California Department of Fish and Game, NOAA Fisheries, the San Diego and Santa Ana Regional Water Quality Control Boards, U.S. Department of Agriculture, UC Davis, University of California Cooperative Extension, the City of Carlsbad, Agua Hedionda Lagoon Foundation, and Cabrillo Power LLC.

FUTURE ACTIONS IN THE ERADICATION PROGRAM

Continued intensive surveys seeking the detection of any new patches arising from small, previously undetected fragments will be the focus during the fifth monitoring year (2005). There will be a Summer 2005 and Fall 2005 survey conducted in the fifth monitoring year. If *C. taxifolia* is encountered in either of these surveys, the timetable to eradication success will be reset, with the three years of follow-up surveys re-initiated following the treatment of the discovered *C. taxifolia*.

Funding for this project has been provided in part by the U.S. EPA pursuant to Assistance Agreement No. C9-9768201-0 and any amendments thereto which has been awarded to the State Water Resources Control Board (SWRCB) for the implementation of California's Nonpoint Source Pollution Control Program. The contents of this document do not necessarily reflect the views and policies of the USEPA or the SWRCB, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

REFERENCES

- Merkel & Associates. 2004a. *Caulerpa taxifolia* in Southern California: Results from Survey Efficacy Trials. Report prepared for Southern California *Caulerpa* Action Team.
- Merkel & Associates. 2004. Third Year Status Report – Eradication and Surveillance of *Caulerpa taxifolia* within Agua Hedionda Lagoon, Carlsbad, California. Report prepared for Southern California *Caulerpa* Action Team.
- Merkel & Associates. 2003. Second Year Status Report – Eradication and Surveillance of *Caulerpa taxifolia* within Agua Hedionda Lagoon, Carlsbad, California. Report prepared for Southern California *Caulerpa* Action Team.
- Merkel & Associates. 2001a. One Year Status Report – Eradication and Surveillance of *Caulerpa taxifolia* within Agua Hedionda Lagoon, Carlsbad, California. Report prepared for Southern California *Caulerpa* Action Team.
- Merkel & Associates. 2001b. Revised eradication plan for *Caulerpa taxifolia* in California. Prepared for Southern California *Caulerpa* Action Team.
- Woodfield, R. and Mooney, R. 2002. Field Response to Infestations of *Caulerpa taxifolia* in Southern California. California and the World Ocean 2002 Proceedings. In press.

APPENDIX A

***Caulerpa taxifolia* Survey Efficacy Assessment**
Agua Hedionda Lagoon, Carlsbad, California
Summary of Results
Trial: Fall 2003

Merkel & Associates, Inc.
October 2003

INTRODUCTION

The success of the *Caulerpa taxifolia* eradication effort under way at Agua Hedionda Lagoon relies heavily upon a quality surveillance protocol. A protocol was developed to quantitatively test the efficacy of surveillance techniques presently used to search for *C. taxifolia* in eelgrass beds and on bare substrate (Merkel & Associates, 2002). This protocol involves the placement of artificial *Caulerpa taxifolia* in the area to be surveyed. The artificial plants are of variable patch sizes, allowing for an analysis of detectability based on patch size, as well as by habitat type.

The eradication effort has entered a phase where detection of remaining small patches of *C. taxifolia* is the key focus of the survey work. This efficacy assessment provides a meaningful way to assess the statistical certainty associated with surveys. It provides a means of predicting the amount of material missed during a given survey and a way of reporting accuracy levels from each survey. This is extremely important when negative surveys (those where no *C. taxifolia* is found) begin to occur and the statistical probability of *C. taxifolia* being missed must be quantified and recognized.

Efficacy trials are now conducted quarterly, at a minimum. This summary report provides the recovery results of the trial conducted at Agua Hedionda Lagoon during the Fall 2003 survey.

METHODS AND MATERIALS

The study site is located within Agua Hedionda Lagoon in Carlsbad, California. This trial was conducted within an 8-acre area of Snug Harbor, located in the western portion of the east basin of the lagoon. On October 15, 2003, M&A biologists Robert Mooney and James Reeves placed plastic reproductions of *Caulerpa taxifolia* on the bottom of Snug Harbor. The plants were divided into three patch size classes: 1 frond, 5 fronds evenly spaced on a 10-cm stolon, and 10 fronds evenly spaced on a 20-cm stolon. Ten of each size class were haphazardly placed in eelgrass beds within the study area. Another ten of each size class were placed on bare bottom within the study area. In total, 60 artificial plants were placed: 30 in eelgrass and 30 on bare bottom. Each plant was weighted with lead and tagged with a uniquely numbered code.

An additional experiment was added to this efficacy trial. In order to determine the minimum sized plant that would be detected 100% of the time, larger size classes have been experimented with. In prior trials, less than 100% of larger patches sizes (0.3 and 0.5 m) were found. During this trial, the experiment was repeated, with ten of each sized ring placed in the study area, with no preference given to eelgrass or bare bottom. Additionally, an even larger size class was created with patches 1 m in diameter. Ten of these were also placed in the study area. Figure 1 shows the size classes used in the trial.

The SCUBA dive crew surveyed the study area from October 16-23, 2003 as part of the Fall 2003 survey. The eradication program surveys are currently implemented by positioning weighted transect lines along the lagoon bottom. With the aid of a geographical positioning system, parallel transects were placed 10 m apart. A SCUBA diver followed the survey line with four more divers out to his side, spaced one meter

apart. This distance was maintained by the five divers by holding a line with one meter markers on it. At the end of the line the divers turned around and returned up the other side of the transect line. This method assures that after swimming both sides of adjacent transect lines, the space between lines has been surveyed with each diver viewing a 1-m wide swath of lagoon bottom. Transect lines were placed repeatedly in a pattern that ensured 100% coverage of the lagoon area.

As the survey proceeded, the amount of artificial *Caulerpa* recovered by the survey team was recorded. Divers collected any artificial *Caulerpa* encountered and returned it to the support vessel upon completion of each transect line. The codes on the collected *Caulerpa* were used to confirm whether it was found in eelgrass or bare bottom. Divers measured horizontal visibility at the bottom several times daily during the survey, using a black and white barred stick held horizontally and used in a manner similar to a secchi disk.

RESULTS

Visibility during the six-day survey ranged from good to excellent. Daily horizontal visibility ranged from 0.6 m-1.5 m. Visibility varied over the course of each day based on wind and tidal conditions.

The results of the 1, 5, and 10-frond trial are reported separately in order to allow for comparison to previously conducted trials.

	# found / # placed on-site, % found			
	1 frond	5 frond	10 frond	TOTAL
In Eelgrass	5/10, 50%	6/10, 60%	8/10, 80%	19/30, 63%
On Bare Bottom	7/10, 70%	10/10, 100%	9/10, 90%	26/30, 87%
TOTAL COMBINED	12/20, 60%	16/20, 80%	17/20, 85%	45/60, 75%

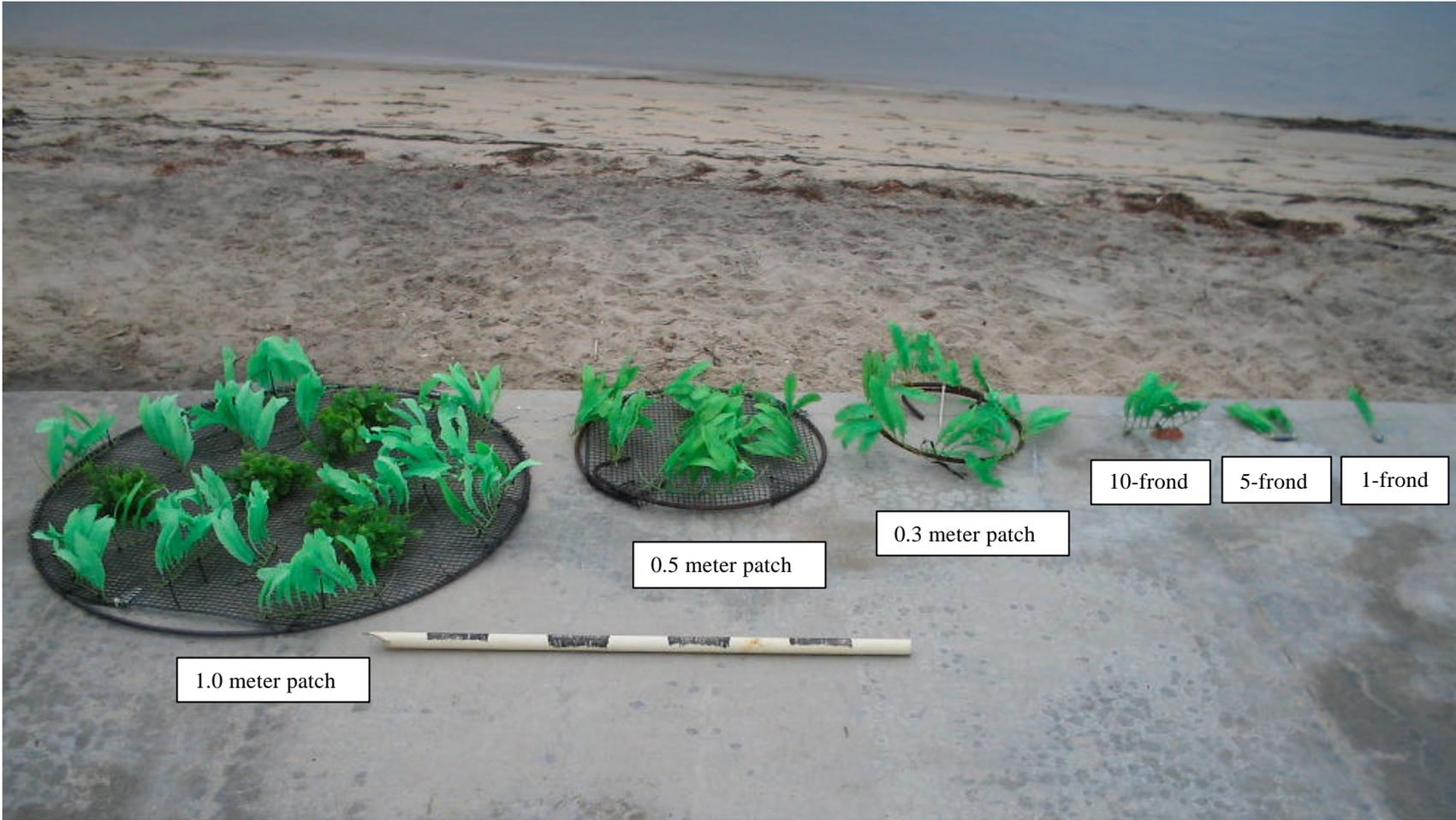
The additional trial with larger patches resulted in ten of ten 0.3 m patches being found, nine of ten 0.5 m patches being found, and ten of ten 1.0 m patches being found.

DISCUSSION

The overall survey efficacy of 75% is considerably higher than in most recent previous trials at Agua Hedionda Lagoon. Divers conducting similar trials in Snug Harbor in July 2003 found 55% of the artificial *Caulerpa* and found 52% in September 2003. The improved efficacy likely resulted from the favorable visibility conditions during the survey. Based on calculations presented in the original report prepared on survey efficacy (Merkel 2003), four surveys at the 75% efficacy level would be required to be greater than 99% certain that no single patch remained. Findings in the previous trials suggested that between four and seven surveys would be needed, based on observed efficacy levels.

The addition of the larger 1-m patches was intended to determine if the survey conditions and methodology would allow the dive team to find 100% of large patches of *Caulerpa*. The minimum size that can be found 100% of the time is critical to the development of eradication criteria for this program. The results of this trial suggest that the minimum size that would be detected 100% of the time is 1 meter, however the 100% recovery of the 0.3-m patches shows that smaller patches would also be likely to be effectively found. This additional investigation will be repeated in upcoming trials to explore this topic further.

Figure 1. Size classes of artificial *Caulerpa* used in the Fall 2003 survey efficacy trial.



***Caulerpa taxifolia* Survey Efficacy Assessments**
Agua Hedionda Lagoon, Carlsbad, California
Summary of Results

Trials: Summer 2004a, Summer 2004b, Fall 2004a, Fall 2004b
Merkel & Associates, Inc.

The results reported here are from summer and fall 2004 surveys conducted at Agua Hedionda Lagoon. The background and methodology for the survey efficacy program are detailed in all previous quarterly reports. These and future results will be presented in this summary format.

SUMMER 2004a – Snug Harbor

Visibility during the five-day survey conducted in Snug Harbor in early August was excellent. Each day horizontal visibility ranged from 2 to 2.5 m.

The results of the 1, 5, and 10-frond trial and the larger patch trial were:

	# found / # placed on-site, % found			
	1 frond	5 frond	10 frond	TOTAL
In Eelgrass	7/10, 70%	6/10, 60%	8/10, 80%	21/30, 70%
On Bare Bottom	10/10, 60%	10/10, 60%	9/10, 50%	29/30, 97%
TOTAL COMBINED	17/20, 85%	16/20, 80%	17/20, 85%	50/60, 83%

	0.3 meter	0.5 meter	1.0 meter
LARGE PATCHES	9/10, 90%	10/10, 100%	10/10, 100%

SUMMER 2004b – Bristol

Visibility during the four-day survey conducted later in August off of Bristol Cove was very poor, with occasional periods of good visibility. Each day horizontal visibility ranged from 0 to 1 m, with occasional periods up to 2 m.

The results of the 1, 5, and 10-frond trial and the larger patch trial were:

	# found / # placed on-site, % found			
	1 frond	5 frond	10 frond	TOTAL
In Eelgrass	3/10, 30%	2/10, 20%	3/10, 30%	8/30, 27%
On Bare Bottom	3/10, 60%	4/10, 40%	6/10, 60%	13/30, 43%
TOTAL COMBINED	6/20, 30%	6/20, 30%	9/20, 45%	21/60, 35%

	0.3 meter	0.5 meter	1.0 meter
LARGE PATCHES	6/10, 60%	8/10, 80%	10/10, 100%

FALL 2004a – Snug Harbor

Visibility during the three-day survey conducted in early October 2004 in Snug Harbor ranged from 0.3 to to 1.5 m. The results of the 1, 5, and 10-frond trial and the larger patch trial were:

	# found / # placed on-site, % found			
	1 frond	5 frond	10 frond	TOTAL
In Eelgrass	4/10, 40%	5/10, 50%	7/10, 70%	16/30, 53%
On Bare Bottom	5/10, 50%	8/10, 80%	9/10, 90%	22/30, 40%
TOTAL COMBINED	9/20, 45%	13/20, 65%	16/20, 80%	38/60, 63%

	0.3 meter	0.5 meter	1.0 meter
LARGE PATCHES	8/10, 80%	9/10, 90%	10/10, 100%

FALL 2004b – Bristol

Visibility during the three-day survey conducted off of Bristol Cove in mid-November 2004 was very poor, ranging from 0.3 to 1.0 m. Time constraints limited the efficacy assessment to the placement of 30 plants, with no discrimination of bottom type. The results of the 1, 5, and 10-frond trial and the larger patch trial were:

	# found / # placed on-site, % found			
	1 frond	5 frond	10 frond	TOTAL
SMALL PLANTS	5/10, 50%	4/10, 40%	7/10, 70%	16/30, 53%

	0.3 meter	0.5 meter	1.0 meter
LARGE PATCHES	6/10, 60%	8/10, 80%	10/10, 100%

Figure 1. Survey areas for the Summer and Fall 2004 survey efficacy trials.



Figure 2. Size classes of artificial *Caulerpa* used in the Summer and Fall 2004 survey efficacy trials.

