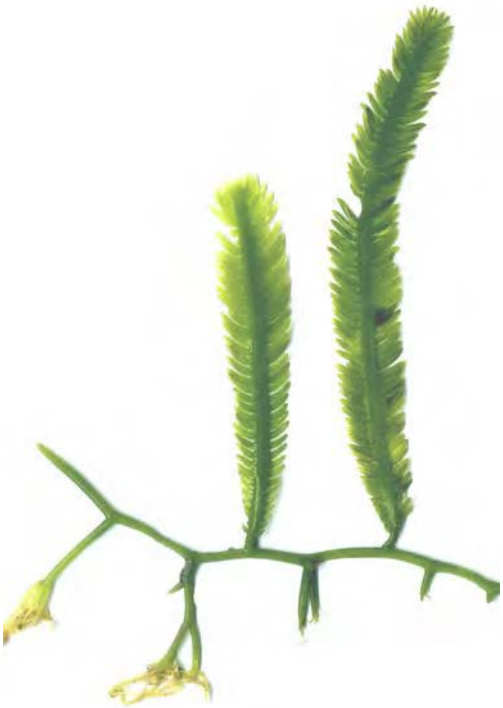
Eradication and Surveillance of *Caulerpa taxifolia* within Agua Hedionda Lagoon, Carlsbad, California
Fifth Year Status Report

January to December 2005

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)



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

January to December 2005

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 fifth 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 fifth year, survey work involved two full surveys of the entire lagoon, conducted in summer and fall 2005. No *C. taxifolia* was found in the lagoon, marking the completion of three and a half years of surveys with none being found. *Caulerpa taxifolia* was last detected on September 11, 2002 (Year 2).

The SCCAT Technical Subcommittee has established two criteria for successful eradication of the *C. taxifolia* infestation at Agua Hedionda Lagoon: 1) the containment and lethal treatment of *C. taxifolia* at the infestation site, and 2) the demonstrated absence of *C. taxifolia* from the infestation site.

Treatment efficacy assessments performed in both the field and laboratory indicate that the treatment approach used was lethal to *C. taxifolia* and that Criterion 1 has been met at Agua Hedionda Lagoon.

The second criterion is addressed by the intensive, long-term surveillance for undetected *C. taxifolia* in the lagoon. Seven full surveys of the entire lagoon have been conducted over the course of three years with no *C. taxifolia* detected, with two additional surveys that focused only on previously infested areas also detecting no *C. taxifolia* (conducted in winter 2002 and spring 2003). The confidence in these survey results was quantified by the Survey Efficacy Assessment Program, involving the placement of patches of artificial *Caulerpa* during each of the surveys. The results of the consecutive assessments of the surveys ultimately allowed for the estimation of the eradication certainty: the certainty that all real *C. taxifolia* existing at Agua Hedionda Lagoon has been found and eradication achieved. The assessments determined that there is a 97.71% certainty that eradication has been achieved at Agua Hedionda Lagoon, assuming the worst conditions (small patch size and low visibility), and a 99.86% certainty if the average conditions are assumed. These results indicate that Criterion 2 has also been met at Agua Hedionda Lagoon.

A recommendation that eradication be declared at Agua Hedionda Lagoon is in preparation and will be submitted to the California Department of Fish and Game by the SCCAT Steering Committee for consideration. The final determination on the status of the eradication will be made by the California Department of Fish and Game after reviewing the collected data.

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 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.

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 m^2 (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 m^2 (Merkel & Associates, 2003). The last discovery of *C. taxifolia* at Agua Hedionda Lagoon was on September 11, 2002. 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. No *C. taxifolia* was detected during the fourth year surveys, conducted in summer and fall.

A similar schedule was maintained in the fifth year of the program. This document provides a synopsis of the fifth 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. Please refer to the Year 1, Year 2, Year 3, and Year 4 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

Merkel & Associates, Inc.

FIFTH YEAR SURVEILLANCE - JANUARY TO DECEMBER 2005

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 and fifth year, surveys were only conducted during summer and fall surveys. These surveys covered all basins of the lagoon.

METHODS

All surveys during the fifth 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 patches 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 survey, assessments were made of the efficacy of the survey methodology. This was achieved through the placement of synthetic *Caulerpa* in the lagoon during the survey. These efficacy trials were conducted twice during each survey, once in Snug Harbor, which is relatively clear and typically 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. Extraordinary rain events during the winter of 2004-2005 and subsequent red tides in summer 2005 are believed to have significantly reduced the amount eelgrass habitat in Agua Hedionda Lagoon. Thus, the summer and fall 2005 efficacy trials were performed with all patches of synthetic *Caulerpa* being placed on bare bottom.

By testing the team's ability to find synthetic patches of *Caulerpa*, confidence in the results of each survey could be quantitatively estimated. The survey efficacy assessments addressed the questions: (1) what are the relationships between important environmental variables and survey efficacy, and (2) how do the estimates of survey efficacy during each survey event translate to eradication certainty? A full discussion of this efficacy program is detailed in *Caulerpa taxifolia Survey Efficacy Assessment at Agua Hedionda Lagoon and Huntington Harbour* (M&A 2006).

RESULTS

The results of the surveys conducted at Agua Hedionda Lagoon during the fifth year of the eradication program are discussed below. Surveys were limited to summer and fall months when conditions for the growth of *C. taxifolia* were most favorable.

Summer 2005

The Summer 2005 survey effort was conducted from June 10 to October 6, 2005. The completion of the summer survey was delayed during July and again in August when survey work had to be temporarily suspended due to the extremely heavy red tide that persisted along the coast of southern California that summer.

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 and off of Bristol Cove. In Snug Harbor, 66% of the synthetic *Caulerpa* placed in the study area was found by the survey team. Off of Bristol Cove, visibility was commonly very low, resulting in 52% of the synthetic *Caulerpa* being found.

A second element of the efficacy assessment included the placement of larger synthetic patches of *Caulerpa* in the survey area, sized 0.3m, 0.5m, and 1m wide, in order to determine the minimum sized plant that would be detected 100% of the time. The results for these larger patches at Snug Harbor were 60%, 90%, and 100%, respectively. The results for 0.3-m, 0.5-m, and 1-m wide patches at Bristol Cover were 70%, 90%, and 100%, respectively, suggesting that the 1-m patch was the smallest patch size that would always be detected, regardless of environmental conditions.

Fall 2005

The Fall 2005 survey effort was conducted from October 7 to December 22, 2005. 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 and off of Bristol Cove. In Snug Harbor, the survey team found 58% of the synthetic *Caulerpa* placed in the study area. Off of Bristol Cove, 48% of the synthetic *Caulerpa* was found.

The results for the 0.3-m, 0.5-m, and 1-m wide patches at Snug Harbor were 80%, 60%, and 90%, respectively. The results for 0.3-m, 0.5-m, and 1-m wide patches at Bristol Cover were 80%, 100%, and 100%, respectively. These results represent the only time a 1-m patch was not detected by the survey team. Over the entire length of the survey efficacy assessment program, out of ninety 1-m patches that were placed, eighty-nine were detected. Based on this very high find rate of 99%, and the high find rate for the 0.5-m patches (87%), it is still assumed that a 1-m patch of *C. taxifolia* would always be detected, regardless of environmental conditions.

Transects surveyed for *Caulerpa taxifolia* during Year 5 of the eradication effort
January - December 2005
Agua Hedionda Lagoon, Carlsbad, CA

Figure 2

Merkel & Associates, Inc.

TREATMENT EFFICACY

An assessment investigating the efficacy of the treatment methodology of tarping and chlorinating was initiated in April 2002. Round 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. The monitoring for both *C. taxifolia* regrowth and for recovery of native species to the exposed bottom continued in the fifth year in April and October 2005. The data collected over three and a half years indicate that the treatment methodology that was used in the eradication effort was effective. They also suggest that once the treatment tarps are removed there will be a recovery of eelgrass and invertebrate infauna. A separate report on the treatment efficacy and biotic recovery will be prepared following the completion of the study in 2006.

ERADICATION STATUS

The completion of the Fall 2005 survey marked the third year of surveys of Agua Hedionda Lagoon with no *C. taxifolia* found. It was estimated that 1,047 m^2 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 m^2 found lagoon-wide in summer 2002. No *C. taxifolia* has been detected since that date.

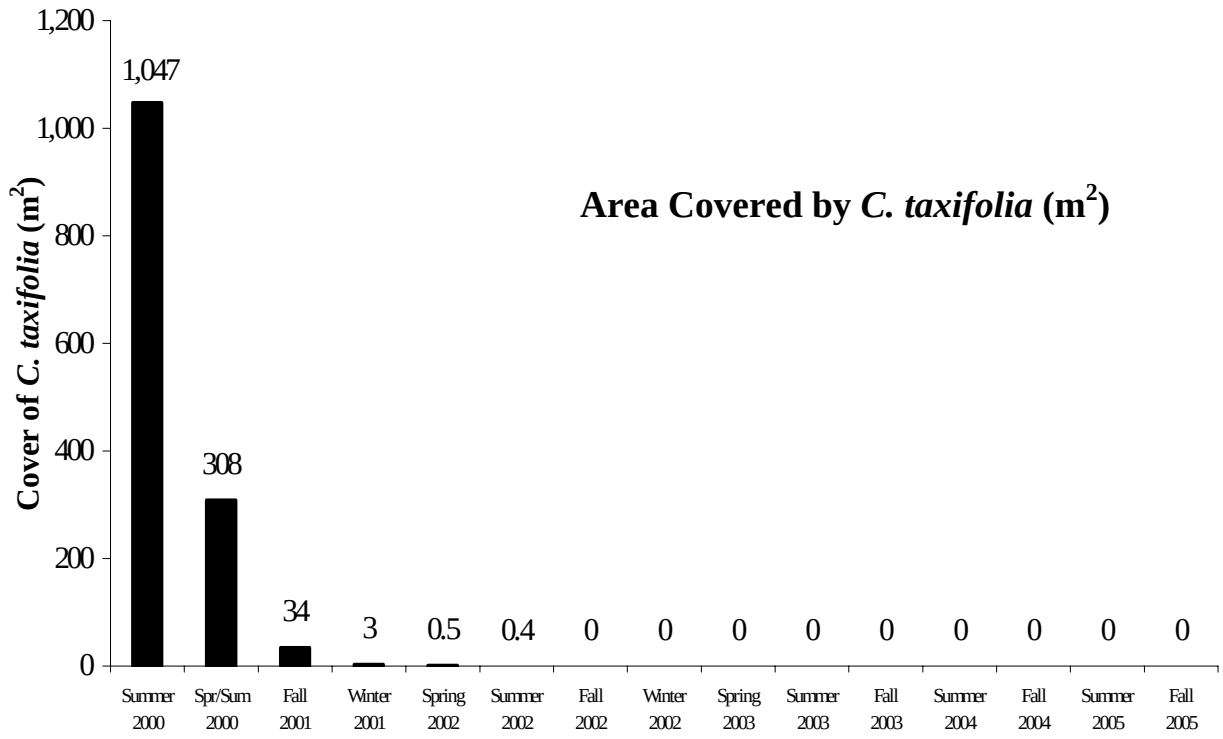


Figure 3. Areal coverage of *Caulerpa taxifolia* in Agua Hedionda Lagoon in square meters.

The SCCAT Technical Subcommittee has established two criteria for successful eradication of the *C. taxifolia* infestation at Agua Hedionda Lagoon: 1) the containment and lethal treatment of *C. taxifolia* at the infestation site, and 2) the demonstrated absence of *C. taxifolia* from the infestation site.

The treatment efficacy assessment mentioned above, in addition to evaluations of the treatment efficacy that have been performed in the laboratory, indicate that the treatment approach used was lethal to *C. taxifolia* and that Criterion 1 has been met at Agua Hedionda Lagoon.

The second criterion is addressed by the intensive, long-term surveillance for undetected *C. taxifolia* in the lagoon. Seven full surveys of the entire lagoon have been conducted with no *C. taxifolia* detected, with two additional surveys that focused only on previously infested areas also detecting no *C. taxifolia* (conducted in winter 2002 and spring 2003). To illustrate the exhaustive coverage of the survey work, all transects that have been surveyed by divers since the last discovery of *C. taxifolia* in September 2002 are presented in Figure 4.

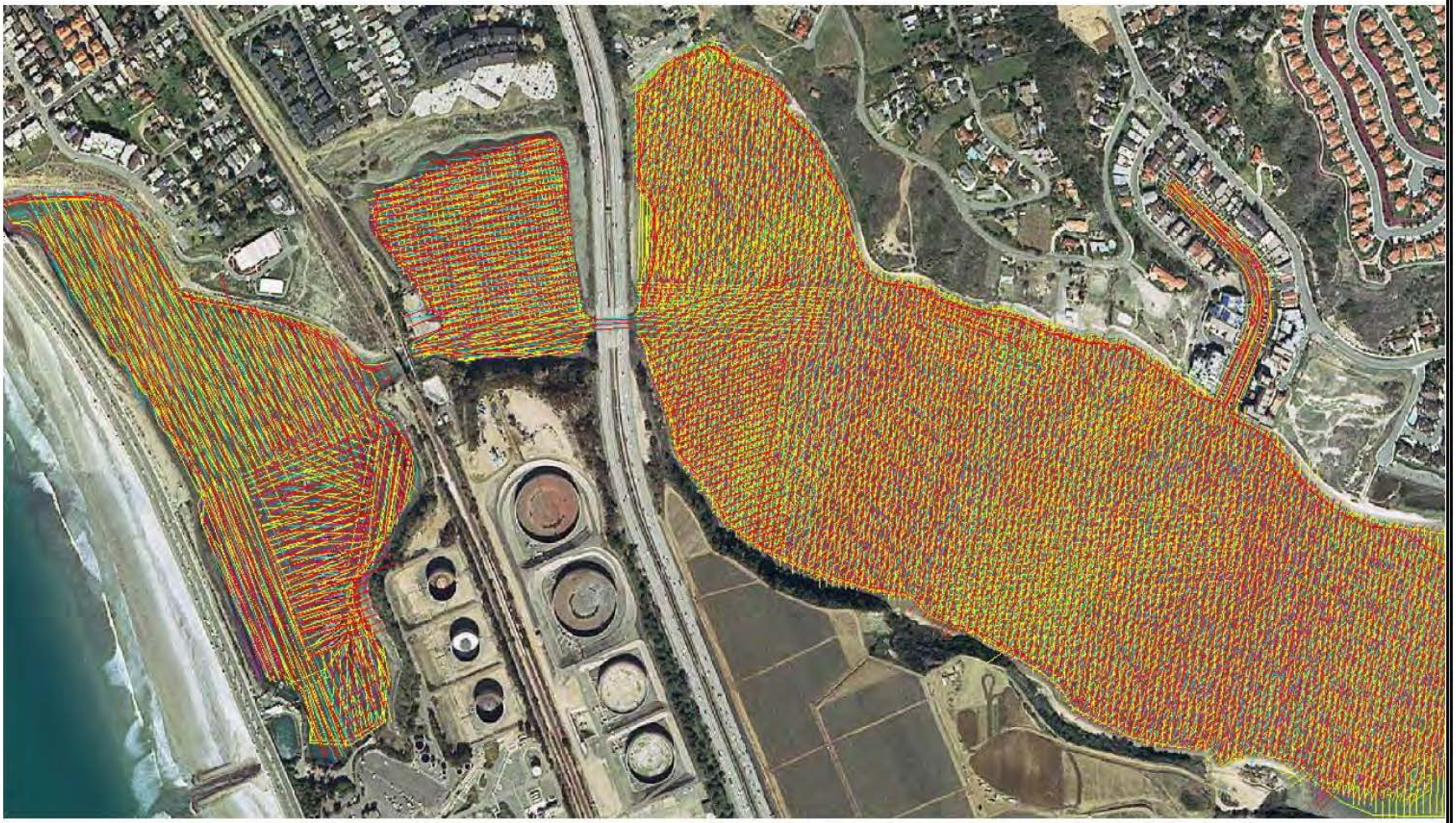
The evaluation of our confidence in these survey results was quantified by the Survey Efficacy Assessment Program mentioned above, involving the placement of patches of artificial *Caulerpa* during each of the surveys. Confidence in the results of each survey for live *C. taxifolia* was quantitatively estimated based on the amount of artificial *Caulerpa* found by the survey divers. The results of the consecutive assessments of the surveys ultimately allowed for an the estimation of the eradication certainty, the certainty that all real *C. taxifolia* existing at the two sites had been found and that eradication had been achieved. The assessments determined that there is a 97.71% certainty that eradication has been achieved at Agua Hedionda Lagoon, assuming the worst conditions (small patch size and low visibility), and a 99.86% certainty if the average conditions are assumed. These results indicate that Criterion 2 has also been met at both sites with a high degree of certainty.

A recommendation that eradication be declared at Agua Hedionda Lagoon is in preparation and will be submitted to the California Department of Fish and Game by the SCCAT Steering Committee for consideration. The final determination on the status of the eradication will be made by the California Department of Fish and Game after reviewing the collected data.

ONGOING ERADICATION PROGRAM WORK

Although it is recommended that *C. taxifolia* be declared eradicated from Agua Hedionda Lagoon, there are remaining work elements that will be undertaken through the end of 2007. A major remaining task is the removal of treatment materials from the lagoon. The tarps were left in place to this point to discourage regrowth of any material that may have not been treated by the chlorine. Based on the studies outlined above, removal of the treatment tarps will not result in regrowth of *C. taxifolia*. Removal of the tarps will facilitate a full recovery of the flora and fauna present prior to the introduction of *C. taxifolia*. This work will be conducted in late summer and fall 2006.

Although success has been achieved in Agua Hedionda Lagoon, the threat of a repeated introduction is ever-present. Funds have been set aside to conduct one full survey of the lagoon in late 2007 in order to detect any new infestations that may have developed from new introductions.



Transects surveyed for *Caulerpa taxifolia* since the last detection in September 2002
Fall 2002, Winter 2002, Spring 2003, Summer 2003, Fall 2003, Summer 2004, Fall 2004, Summer 2005 and Fall 2005
Agua Hedionda Lagoon, Carlsbad, CA

Figure 4

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COORDINATION WITH LAGOON USERS

During the fifth year of the eradication program, 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 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.

These restrictions were regularly reviewed by SCCAT 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 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 plan was extended for an additional year in April 2005, with a new expiration of June 30, 2006. The only remaining restriction was the prohibition of anchoring in the east basin, the limitation of fishing to the passive use area, and the closure of zones to facilitate eradication activities. It is anticipated that zone closures will be needed to carry out the additional work elements outlined above in 2006 and 2007. SCCAT will continue to revisit the Plan annually with the goal of eventually recommending the complete return to pre-*C. taxifolia* uses.

ERADICATION COSTS

During the fifth year of the eradication program at Agua Hedionda Lagoon, Merkel & Associates performed many tasks, including SCCAT coordination and presentations, outreach, surveillance and mapping, 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 fifth year (January to December 2005), approximately $524,000 was expended on the above-described work. This funding was provided by the State Water Resources Control Board (through an EPA 319h Water Quality Implementation Project grant), the California Coastal Conservancy (through a Southern California Wetlands Recovery Project grant), and the Agua Hedionda Lagoon Foundation. Since June 2000, eradication efforts at Agua Hedionda Lagoon have cost approximately $3.34 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, National Marine Fisheries Service, the San Diego and Santa Ana Regional Water Quality Control Boards, U.S. Department of Agriculture, UC Davis, Agua Hedionda Lagoon Foundation, and Cabrillo Power I LLC.

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