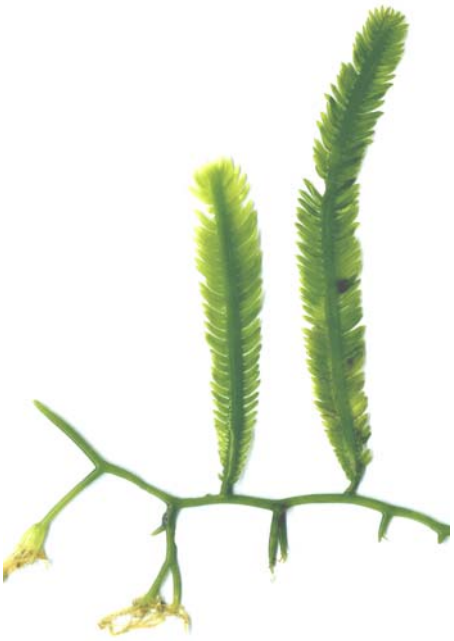
Eradication and Surveillance of *Caulerpa taxifolia* within Huntington Harbour, Huntington Beach, California Status Report

Prepared for:

Steering Committee of the Southern California *Caulerpa* Action Team

- California Regional Water Quality Control Board – San Diego Region
- California Regional Water Quality Control Board – Santa Ana Region
- California Department of Fish and Game
- National Marine Fisheries Service
- U.S. Department of Agriculture –Agricultural Research Service



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INTRODUCTION

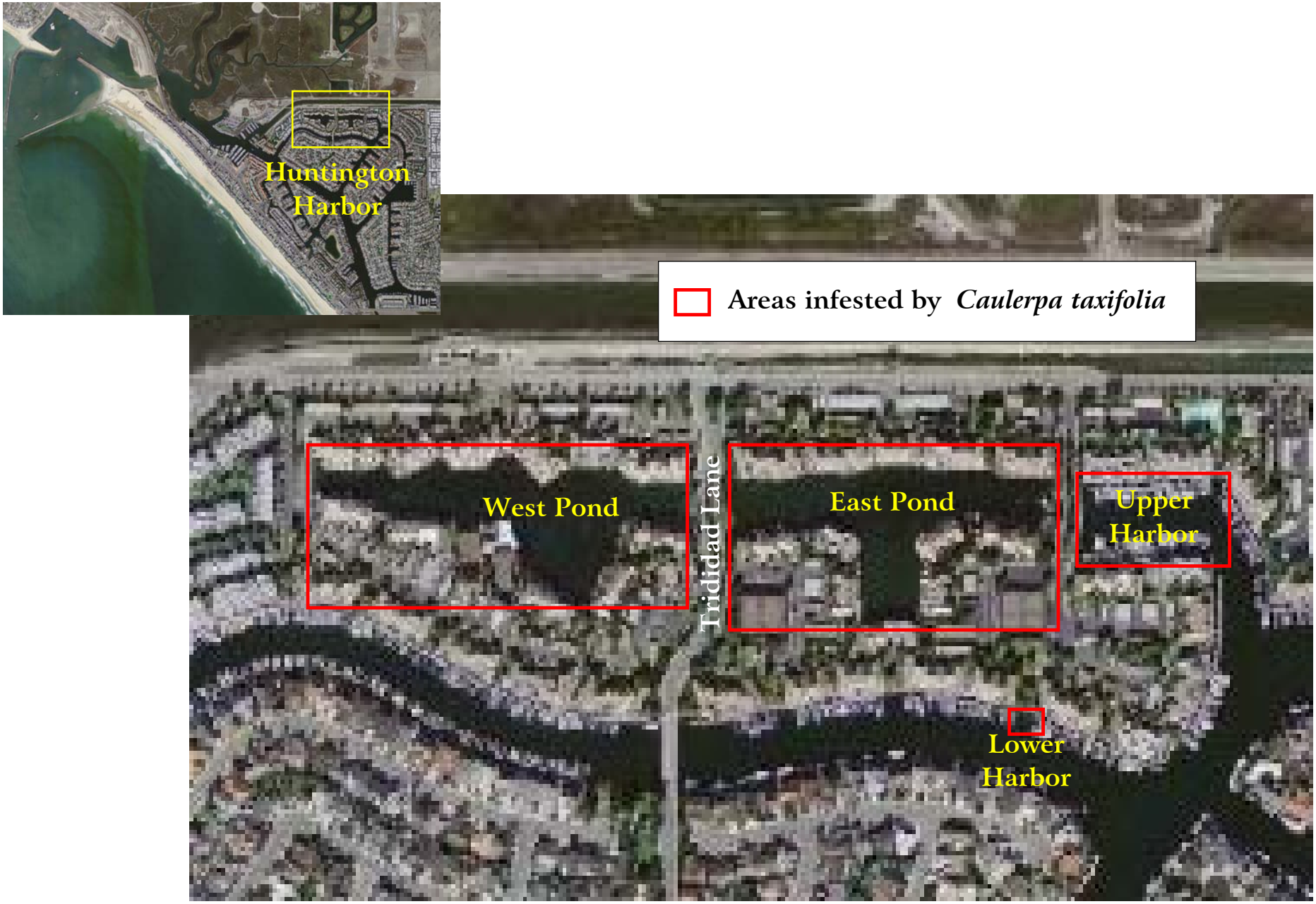
In 1984, an invasive, aquarium-raised strain of the seaweed *Caulerpa taxifolia* was first noted growing as a small patch in the Mediterranean Sea. Although the native strain occurs naturally in tropical waters, an aquarium strain of *C. taxifolia* had been cultivated for use in saltwater aquariums, becoming notably cold-tolerant and easy to cultivate. The small Mediterranean patch likely resulted from the disposal of aquarium water into the sea. Due to the rapid and aggressive growth habits of this strain of *C. taxifolia*, the patch of seaweed quickly spread and grew to form extensive meadows that displaced expanses of native habitat in much of the coastal northwestern Mediterranean, covering as much as 13,000 hectares (32,000 acres) of seafloor by 2001 (Meinesz et al. 2001). The aquarium strain of *C. taxifolia* has also been released into several water bodies in Australia in recent years.

In June 2000, this seaweed was discovered growing in Agua Hedionda Lagoon in Carlsbad in San Diego County, where it was quickly spreading to cover large areas, displacing the native seagrass beds found there. Because the invasive strain of this seaweed does not exist naturally in the wild in the United States, it is believed that the seaweed must have been released from a saltwater aquarium. The resulting press coverage of the infestation brought to light a second infestation in the SeaGate Lagoons of Huntington Harbour in Huntington Beach in Orange County. This infestation is also believed to have resulted from the release of saltwater aquarium material into the lagoons. *Caulerpa taxifolia* was found not only in both SeaGate Lagoons, but also in two locations in the main harbor, immediately adjacent to drains that empty lagoon water into the harbor. Genetic studies have determined both California infestations to be identical to the strain invading the Mediterranean Sea (Jousson et al. 2000).

Since the discovery of *C. taxifolia* in California 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 two known infestations: Huntington Harbour and Agua Hedionda Lagoon.

INFESTATION AREAS

The Huntington Harbour *C. taxifolia* infestations were discovered in the northern portion of the harbor, primarily in the water bodies known as SeaGate Lagoons. The “lagoons” consist of two man-made ponds located on Trinidad Lane in the City of Huntington Beach (Figure 1). The ponds contain harbor water, but are non-tidal. Water level is maintained by pumps that fill the east pond with water from the harbor, which drains into the west pond, and then back out into Huntington Harbour. The ponds are enclosed on all sides by concrete bulkheads, with residential condominium patios forming the “banks” of the ponds. The ponds range from three to six feet



***Caulerpa taxifolia* infestation areas in Huntington Harbour - 2000**
Huntington Beach, CA

Figure 1

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in depth, with an approximately one-foot thick soft sediment layer over harder sediment beneath. There are no boats in the ponds with the exception of several pedal-boats.

The pumping mechanisms and grating at all drains generally restrict the immigration of large fish into the ponds from the outer harbor, suggesting that the majority of the larger fish know to live in the ponds were intentionally placed there. This has been confirmed by reports from numerous local residents who regard many of these animals as pets or claim to have released marine life into the ponds themselves.

In addition, *C. taxifolia* was discovered growing at two locations where outflow pipes drain the east pond back into the harbor. These sites are referred to at the north and south harbor sites (Figure 1). These areas reach a maximum depth of approximately -17 ft Mean Lower Low Water (MLLW).

The infestation of *C. taxifolia* at the Huntington Harbour sites was distinctly different than that observed in Agua Hedionda Lagoon. Rather than growing in discrete, dense patches, the infestation generally consisted of hundreds of small plants scattered over a wide area, making measurement of the actual areal coverage of *C. taxifolia* on the bottom difficult. In many cases, fragments of *C. taxifolia* were drifting loose on the bottom, further spread and fragmented by benthic species of fish (primarily round stingrays [*Urobatis halleri]* and various species of goby). A measurement was therefore made of the area of bottom "affected", including all rooted *C. taxifolia*, drifting fragments, and bare areas in between. The actual biomass of *C. taxifolia* discovered in Huntington Harbour was considerably less than that observed at Agua Hedionda Lagoon, and distributed over a much smaller area. The estimation of the total affected area in Huntington Harbour at the time of first assessment in Fall/Winter 2000 was 7,890m^2, distributed over a 1.1-hectare (2.6-acre) area in both ponds and the affected open harbor areas.

Detailed discussions of the extent of the infestation in each area, the treatment response, and the results of follow-up surveys are presented in the following sections.

East Pond

The most extensive infestation of *C. taxifolia* was discovered growing in the east pond. Due to the scattered distribution of the plants and fragments, the eradication response focused on treating the entire affected area. A treatment approach involving the placement of tarps over the affected areas had been effectively developed for use at the Agua Hedionda Lagoon infestation site, as outlined in the *Revised Eradication Plan for Caulerpa taxifolia in California* (Merkel & Associates, 2001). This approach was also applied at the Huntington Harbour infestation site, with treatment efforts consisting of covering *C. taxifolia* with heavy black PVC tarps under which a solid, pelleted chlorine formulation was placed, which provided full containment of *C. taxifolia* while minimizing the water quality impacts of the treatment on the surrounding waters. All work was conducted by a team of SCUBA divers. In order to contain the *C. taxifolia* and small fragments scattered over an estimated 6,704m^2 of the east pond, treatment tarps were placed over much of the western and southern portion of the pond and secured with sandbags and rebar (Figure 2). Initial placement of treatment tarps in the east pond was conducted from October 2000 to February 2001 (fall/winter 2000).

Infested/tarped area fall/winter 2000

Infested/tarped area summer 2001

Infested/tarped area fall 2001

Infested/tarped area summer 2002

Infested/tarped area fall 2002

Path of underground pond drain

Locations of *Caulerpa taxifolia* infestation and treatment in Huntington Harbour
Huntington Beach, CA

Figure 2

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Following the completion of initial survey and treatment efforts, a systematic quarterly survey program was undertaken to search for additional patches of *C. taxifolia*. The transect methodology employed was designed with the goal of surveying 100% of the infested area. A lead SCUBA diver followed a transect line with three to six additional divers, spaced 1 meter apart, positioned next to the lead diver, perpendicular to the transect line. Each diver scanned the bottom area within 0.5 m to either side of their line of travel. If a diver encountered *C. taxifolia,* the rest of the crew was signaled to stop, and the position marked with a float and recorded with a differential global positioning system (dGPS)(±50cm accuracy). In the east pond, the transects were established by the lead diver, who used the bulkhead walls as a guide. The outer diver in the line dragged a blunt object through the mud at the outside of the search area. The created 'drag-line' was then used to establish the transect line of the next survey route. This method was followed until the entire pond had been surveyed. Later in the program, the transect lines were placed by a boat using dGPS.

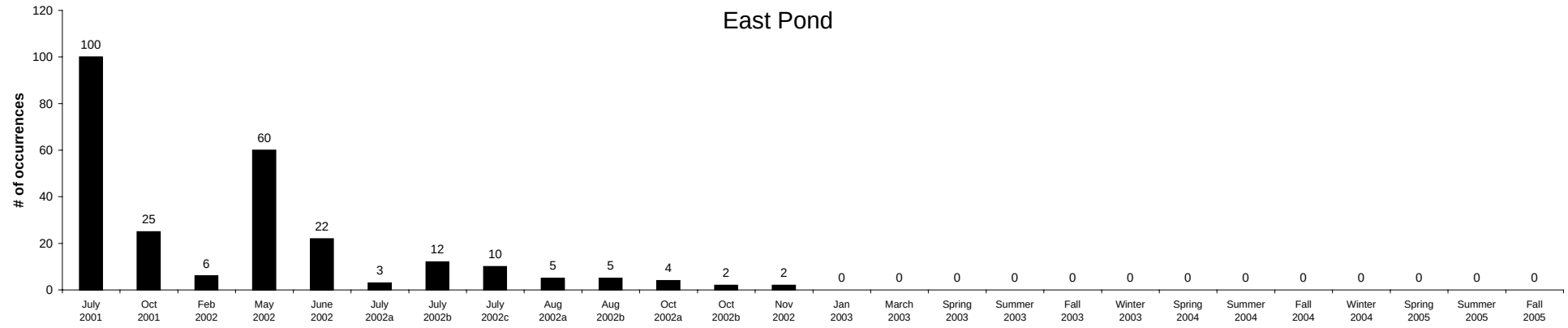
As the water temperature rose in spring and summer 2001 following the initial treatment, additional patches of *C. taxifolia* emerged from the sediment in the east pond and additional tarps were placed to treat them (Figure 2). Follow-up surveys were repeated regularly to search for additional patches that may have arisen or grown to a larger, more detectable size. Observations by the survey team suggested that the burrowing and bolting behavior of the large population of round stingrays and gobies that occupied the east pond may have facilitated the spread of small fragments of *C. taxifolia*. Additionally, chronic high turbidity in the east pond severely limited visibility for the SCUBA survey team, increasing the possibility that small patches or fragments of *C. taxifolia* would go undetected until they grew to a larger size. As a result, surveys were conducted more frequently than quarterly during 2001 and 2002, with any detected occurrences quickly removed or tarped.

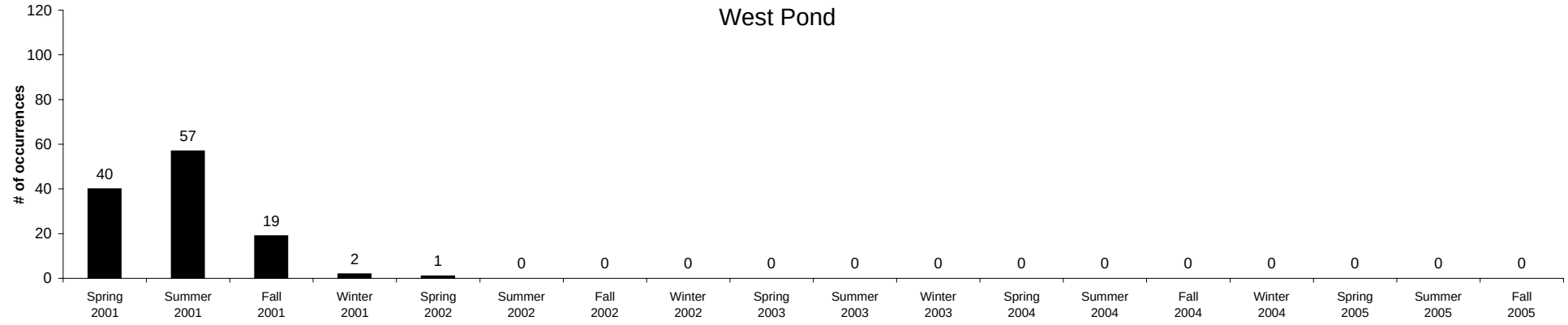
All treatment tarps were left in place to discourage regrowth of any material that may have not been treated by the chlorine. A thick layer of sediment quickly settled onto the tarps, in effect providing additional substrate for the establishment of fragments of *C. taxifolia*. Initially these fragments were collected by hand as they were found, however *C. taxifolia* often regrew in these areas, suggesting that rhizoid material (root-like structures of *C. taxifolia*) remaining in the sediment was leading to regrowth. Therefore an approach of placing new tarps on top of existing tarps, where necessary, was adopted in summer 2002. This proved extremely effective at preventing new growth and few additional occurrences were found subsequently. Surveys in the east pond were therefore reduced to quarterly intervals starting in spring 2003, when it appeared that significant strides had been made toward controlling *C. taxifolia* in the east pond.

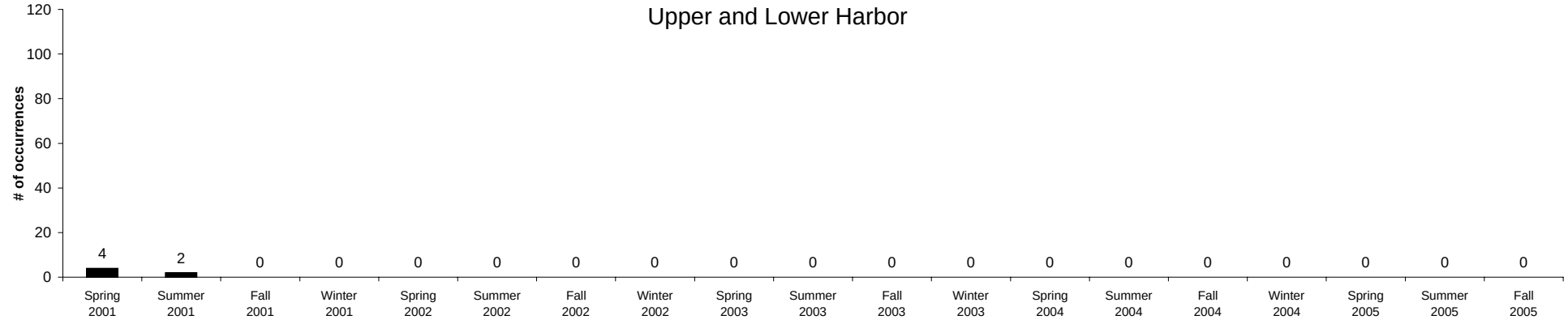
The progress of the eradication effort was tracked by the number of new plants or fragments detected during a given survey. Figure 3 presents the number of occurrences found during each survey. By fall 2002, intensive surveys were finding only a few small plants remaining, with the last occurrence detected on November 19, 2002. Follow-up surveys continued over the next three years. There have been thirteen additional surveys of the east pond since that time, with no *C. taxifolia* detected. The final survey (fall 2005) was conducted in December 2005.

West Pond

The west pond receives water from the east pond through a culvert under Trinidad Lane (Figure 2). The infestation of *C. taxifolia* in the west pond may have resulted the drifting of fragments







Number of new occurrences of *Caulerpa taxifolia* detected in follow-up surveys
Infestation Areas: East Pond, West Pond, Upper and Lower Harbor
2001-2005

Figure 3

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from the east to the west pond. Likely due to reduced turbidity (allowing increased light penetration) and to a lower abundance of benthic fish species, *C. taxifolia* in the west pond was distributed in more discrete patches. This made mapping and treatment less problematic than in the east pond. The infestation was detected in eight areas affecting approximately 1,094 m^2 of bottom within the west pond, which were tarped over a period extending from February to April 2001 (winter 2000)(Figure 2).

The follow-up monitoring program described above was initiated in the west pond spring 2001, using the same methodology. As anticipated, new occurrences were detected as the water temperature increased, and two additional areas in the west pond were tarped in August 2001 (Figure 2). Additional quarterly surveys found a small number of new occurrences over the next three quarters, generally associated with the edge of an existing tarp and likely the result of a fragment or buried plant material that had not been contained under the original tarp. These occurrences were treated with additional small tarps and chlorine.

The last occurrence of *C. taxifolia* was detected in the west pond in May 2002 (Figure 3). Quarterly surveys continued over the next three years. Thirteen additional consecutive quarterly surveys of the west pond have failed to detect any persisting or new *C. taxifolia*. The final survey (fall 2005) was conducted in December 2005.

Upper and Lower Harbor

It was initially believed that *C. taxifolia* was restricted to the east and west ponds (SeaGate Lagoons). However, an October 2000 investigation of areas of the main harbor "upstream" of the east pond, as well as portions of the main harbor where water drained from the east and west ponds, revealed two additional areas of infestation described below (Figure 1). There is a skimmer located in the east pond that drains to the two harbor locations found to be infested with *C. taxifolia* (Figure 2). It is possible that water containing fragments of *C. taxifolia* passed out of the east pond into the harbor through this skimmer. It is also possible that the infestation originated in the upper harbor area and was then pumped up into the east pond, then spread to the west pond. The exact origin and pathways of spread throughout the Huntington Harbour site will likely never be determined.

The lower harbor infestation site is located immediately at the outflow of an underground drain that conveys skimmed water from the east pond to the lower harbor site (Figure 1). A small patch of *C. taxifolia* (~0.1m^2) was discovered in October 2000, growing approximately 2 meters from the drain outlet, at a depth of approximately -6 ft MLLW. A single treatment tarp and chlorine was immediately placed over the patch.

A much larger area of infestation was also discovered in October 2000 at the upper harbor site, which is much deeper than the ponds (up to -17 ft MLLW) (Figure 1). The infestation was sparsely distributed, growing as small plants, with few fragments noted. Treatment of the detected *C. taxifolia* began immediately, with the placement of treatment tarps and smaller treatment tubs and chlorine over an affected area of approximately 93m^2. The intial treatment was completed by November 2000 (Figure 2).

Follow-up surveys of the infested upper and lower harbor sites were initiated in spring 2001. *Caulerpa taxifolia* was never again detected at the lower harbor site (Figure 3). Additional

occurrences were detected at the upper harbor site in two follow-up surveys and were promptly treated. The last occurrence of *C. taxifolia* was detected in the harbor in July 2001. Seventeen additional consecutive quarterly surveys have failed to detect any persisting or new *C. taxifolia* in the infested harbor areas. The final survey (fall 2005) was conducted in December 2005.

REMAINDER OF HUNTINGTON HARBOUR

Although initial surveillance conducted in 2000 indicated that the infestation was restricted to the east and west ponds (SeaGate Lagoons) and the small areas in the northern portion of Huntington Harbour discussed above, two harbor-wide surveys of the remaining areas of the entirety of Huntington Harbour were conducted by teams of SCUBA divers. These full surveys of the entire harbor were conducted in 2001 and again in 2005. *Caulerpa taxifolia* was not detected elsewhere in the harbor during these surveys.

ERADICATION STATUS

The completion of the Fall 2005 survey marked the third year of surveys of the Huntington Harbour infestations sites with no *C. taxifolia* found. None has been detected since November 2002.

A program to assess the survey dive team's ability to locate *C. taxifolia* in the often murky water of the infestation sites was developed at Agua Hedionda Lagoon. Patches of artificial *Caulerpa* of various small sizes were randomly placed at Agua Hedionda Lagoon during each of the regular follow-up surveys to test the dive team. Confidence in the results of each survey for live *C. taxifolia* could then be quantitatively estimated based on the proportionate amount of known quantities of artificial *Caulerpa* found by the divers. Based on the tremendously useful data collected by this program at Agua Hedionda Lagoon, a similar program was implemented at the Huntington Harbour infestations sites in summer 2003 and continued through the last quarterly survey in fall 2005.

The survey efficacy assessment trials at Huntington Harbour resulted in a combined return of 400 out of 500 (80%) patches of synthetic *Caulerpa* over the course of seventeen trials. Individual trial results ranged from 68% to 87% success at detecting the synthetic *Caulerpa.* A full discussion of this efficacy assessment program is detailed in *Caulerpa taxifolia Survey Efficacy Assessment at Agua Hedionda Lagoon and Huntington Harbour* (M&A 2006). The results of the consecutive assessments of the efficacy of the surveys ultimately allowed for an estimation of the eradication certainty that all real *C. taxifolia* existing in the Huntington Harbour infestation areas had been found. This estimation was calculated as of December 2005 to be 99.86% (M&A 2006).

A recommendation that *C. taxifolia* be declared eradicated from Huntington Harbour 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 Huntington Harbour, 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 infested areas. The tarps were left

in place to this point to discourage regrowth of any material that may have not been treated by the chlorine. This removal work will likely be conducted in late summer and fall 2006.

Although success has been achieved in Huntington Harbour, the threat of a repeated introduction is ever-present. Funds have been set aside to conduct one full survey of the east and west ponds and affected harbor areas in late 2007 in order to detect any new infestations that may have established from new introductions.

ERADICATION COSTS

The funding for the *C. taxifolia* eradication program at Huntington Harbour has been provided by the Santa Ana Regional Water Quality Control Board. Since August 2000, eradication efforts at the Huntington Harbour infestation sites have cost approximately $660,000. Additional funding was provided for the harbor-wide surveys in 2001 and 2005 by the California Department of Fish and Game, NOAA's National Marine Fisheries Service, and by the State Water Resources Control Board (Proposition 13 Watershed Protection Program Grant).

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's National Marine Fisheries Service, the San Diego and Santa Ana Regional Water Quality Control Boards, and U.S. Department of Agriculture- Agricultural Research Service.

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