THE CALIFORNIA DEPARTMENT OF FOOD AND AGRICULTURE
HYDRILLA ERADICATION PROGRAM
ANNUAL PROGRESS REPORT 2003

PROTECTING CALIFORNIA'S WATERWAYS

INTRODUCTION

The State of California recognizes hydrilla (*Hydrilla verticillata*) to be a serious, noxious aquatic weed that is a threat to the water resources of the state. Hydrilla can reduce water storage capacity of lakes, ponds, and reservoirs; impede movement in streams, canals, and drains; jam water control structures and choke hydroelectric generators; impede navigation; degrade fish and wildlife habitat; and endanger public health by reducing water flow and producing mosquito breeding habitat.

The California Department of Food and Agriculture (CDFA) is the lead agency in California for the eradication of hydrilla[1]. The CDFA conducts the Hydrilla Eradication Program with the specific goal of eradicating hydrilla from California in order to protect the state's water resources from this invasive, noxious weed. As the lead agency, the CDFA administers the Hydrilla Eradication Program, but does so in cooperation with the local county agricultural commissioners and other federal, state, county, and city agencies, Native American tribes, and private individuals and entities. In addition, the CDFA Hydrilla Eradication Program received financial support in 2003 from the California Department of Boating and Waterways, California Department of Water Resources, United States Department of the Interior-Bureau of Reclamation, United States Army Corps of Engineers-Eastman Lake, Yolo County Flood Control and Water Conservation District, Lake County Department of Agriculture, and Lake County Department of Public Works.

This report covers the progress of the CDFA Hydrilla Eradication Program in 2003. The report gives a brief history and overview of the program and describes each of the current, active projects in detail. Also, there is a section describing the CDFA's annual hydrilla survey of the Sacramento/San Joaquin River Delta.

HISTORY AND OVERVIEW OF THE PROGRAM

Hydrilla is an invasive, submersed, non-native aquatic plant that has been found in various places in the United States, including California. The dioecious[2] form of hydrilla was first identified in Florida in the 1960s, where it is believed to have been introduced in the 1950s. This infestation spread throughout the southeastern United States and Texas. It was first found in California in 1976 in a 31-acre man-made lake in Marysville,

[1] California Food and Agricultural Code, Sections 6048 and 7271.

[2] The dioecious form of hydrilla has flowers of one sex only on each genetic individual. Monoecious individuals have individual flowers with only staminate or pistillate parts, but these occur on the same plant. Dioecious plants often branch freely near the water surface, forming large submerged mats near the water surface. In contrast, monoecious plants tend to branch freely near the rooting point, producing many stolons and a forest of vertical shoots, which can fill the entire water column with plant material. The genetic or ecological significance of this apparent dimorphism is unknown.

Yuba County. The monoecious form was first detected in the Potomac River, near Washington, D.C. in the 1980s. It has since spread into a number of the southern states, into Washington State, and was first found in California in 1993 at an aquatic nursery in Visalia, Tulare County.

In 1977, after the first California hydrilla find, the California Legislature mandated[3] that the CDFA Secretary initiate a survey and detection program for hydrilla, and to eradicate hydrilla wherever feasible[4]. In 1985, after hydrilla was found in Redding, near the Sacramento River, the Governor of the State of California declared a "State of Emergency" to eradicate hydrilla[5]. In 1994, the CDFA Secretary declared an "emergency situation" in regard to the hydrilla infestation discovered in that year in Clear Lake[6]. Similar declarations have been issued for most of the current hydrilla infestations[7].

Hydrilla has been introduced into California 28 separate times, in 17 counties[8]. Of these 28 separate hydrilla introductions, the Hydrilla Eradication Program has eradicated hydrilla from 19 introduction sites in the following 12 counties: Los Angeles, Monterey, Riverside, San Bernardino, San Diego, San Francisco, Santa Barbara, Shasta, Sonoma, Sutter, Tulare and Yuba (Table 1). The Hydrilla Eradication Program is currently eradicating hydrilla from nine locations in the following eight counties: Calaveras, Imperial, Lake, Madera, Mariposa, Shasta, Tulare, and Yuba (Table 1). In addition, these eight counties are currently under eradication[9].

Every year, program crews survey[10] all known infested locations, and high-risk lakes[11], ponds, reservoirs, streams, canals, and other water bodies in the state. High-risk areas include the Sacramento/San Joaquin River Delta, other high recreational-use water bodies, and waterways within quarantine zones[12]. Surveys generally start when the water temperature climbs above 10 degrees C[13] in the spring (and when water-flows in

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[3] California Food and Agricultural Code Article 9, Section 6048.

[4] A Hydrilla Science Advisory Panel was convened after each hydrilla outbreak. These panels have always found hydrilla eradication to be feasible.

[5] "Proclamation of a State of Emergency," issued by Governor George Deukmejian, October 23, 1985; terminated October 23, 1989.

[6] "Proclamation of a Project Regarding the Eradication of Hydrilla," issued by CDFA Secretary Henry Voss, August 12, 1994.

[7] Calaveras, Madera, Mariposa, Shasta, and Tulare counties.

[8] The CDFA considers hydrilla infestations to be separate introductions if they appear more than two or three years apart.

[9] California Code of Regulations, Title 3, Division 4, Sections 3281 and 3410; California Code of Regulations, Section 3962; CDFA Plant Quarantine Manual, Section 3410.

[10] Surveys are conducted by two methods, visual search of the water column and physical samples. Trained biologists and support staff conduct visual searches to locate individual plants or mats that are visible in the water column or on the water surface. The crews conduct the visual searches from boats, canoes, or kayaks; by wading in shallow streams and lakesides; and by swimming using sight buoys and face masks, depending upon the circumstances. Because visual searches from the surface are sometimes hampered by poor visibility, the program occasionally contracts divers for underwater surveys. Physical samples are taken using a modified grappling hook, usually thrown from a boat or canoe. Personnel trained in identifying hydrilla carefully examine the retrieved plant material. In either case, visual searches or bottom samples, if hydrilla is found, the number of plants or size of the infestation is recorded along with the physical location (by using a global positioning system technology and measured from known landmarks). Representative specimens from new locations are sent to the CDFA Plant Pest Diagnostic Center, Botany Laboratory for confirmation.

[11] High-risk lakes, streams, etc. are those within five miles of Clear Lake, one mile either side of the Sacramento River near the Riverview Golf Course, three miles of the Yuba canal, and one mile of Bear Creek, the west fork of the Chowchilla River, and the Springville ponds.

[12] Quarantine zones are established by declaration of the CDFA Secretary and are areas within eradication areas that have restrictions as to water use, access, or the intensity of survey.

[13] C = Centigrade.

rivers and creeks have diminished to a safe level), and end when water temperatures fall below 10 degrees C in the fall. The Hydrilla Eradication Program also follows up on all reports from the public on potential new infestations. No new hydrilla-infested sites were found in 2003. The last new hydrilla infestation was detected in Yuba County in 1997 (Table 1).

The Hydrilla Eradication Program uses an integrated pest management approach to eradicating hydrilla. In 2003, the Program used (alone or in combination) the following eradication methods: manual removal, biological control, and aquatic herbicides. The aquatic herbicides of choice were copper ethylenediamine liquid formulation[14] (applied at one ppm[15] and fluridone slow release pellet formulation[16] applied at 90 to 150 ppb[17], depending upon the size of the water body, and a small amount of fluridone liquid formulation[18]. In the past, the Program has also used water draw down hydrosoil and drying, followed by soil fumigation; large and small scale dredging, and lining and burying, as eradication methods (see Program's Best Management Practices, Appendix I).

All known, infested sites are intensively treated and surveyed for a minimum of three years after the last hydrilla detection, followed by another three years of intensive survey in order to determine if hydrilla has been eradicated from the site. After six years of negative detection, the CDFA considers hydrilla eradicated from a site.

In addition to surveying and treating for hydrilla, the Hydrilla Eradication Program monitors aquatic herbicide concentrations in water after applications in order to confirm that the beneficial use of the state's waters are protected. This monitoring is done as a CDFA policy, and also to comply with the National Pollution Discharge Elimination System (NPDES) General Permit issued by the State Water Resources Control Board. The NPDES is a provision of the Clean Water Act to regulate and protect "waters of the United States" from pollution caused by point sources. This system was extended to aquatic pesticide applications by the United States Court of Appeals for the Ninth Circuit in its decision in *Headwaters, Inc. et al. v Talent Irrigation District*, March 12, 2001. To comply with the NPDES General Permit, the Hydrilla Eradication Program monitors fluridone water concentrations in Clear Lake and in the Riverview Golf Course Ponds in Shasta County, and monitors for copper water concentrations in Clear Lake and in Bear Creek in Calaveras County (see next section of this report). The Hydrilla Eradication Program also does monitoring upon request from the public in regards to the beneficial use of treated water. This report includes the results of the monitoring in response to requests from the public. The monitoring done in support of the NPDES General Permit will be published in a separate report.

The status of all current and historical sites in the Hydrilla Eradication Program is summarized in Table 1 and Plate 1.

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[14] Komeen® brand, Griffin Corporation.

[15] One ppm = one part per million = one milligram per liter.

[16] Sonar® SRP brand, SePRO Corporation.

[17] One ppb = one part per billion = one microgram per liter.

[18] Sonar® AS brand, SePRO Corporation.

ACTIVE, ON-GOING PROJECTS IN DETAIL

SHASTA COUNTY

The Shasta County Hydrilla Eradication Project (Shasta Project) is a cooperative effort between the CDFA and the Shasta County Department of Agriculture. The Shasta Project began in 1985 after hydrilla[19] was detected in seven ponds located next to the Sacramento River. Due to the close proximity of the river and the potential threat to California water systems, the Governor of California issued a "Proclamation of Emergency" to facilitate eradication efforts. An additional four infested ponds were found in 1986. The CDFA convened a Scientific Advisory Panel in 1986, which recommended a survey, treatment, and public education program (Stocker, R.K. and L.W.J. Anderson *et. al.* 1986). Based on these recommendations, Shasta Project crews chemically treated and filled in with soil four of these 11 ponds. Shasta Project biologists also treated the remaining seven ponds with herbicides for several years. By 1994, surveys showed that only a few scattered plants remained in one of the original 11 ponds (Swimming Pond at Shea's Pond). Shasta Project personnel found no plants in this pond in 1996, which was the year the final applications of fluridone slow-release pellets were made. No hydrilla was detected in this pond from 1997 through 2000, and the CDFA considers hydrilla to be eradicated from these original 11 ponds. However, in 1994, hydrilla was detected in two interconnected ponds in Anderson River Park (Plate 2), and in 1996 hydrilla was detected in a pond system in the Riverview Golf Course in Redding (Plate 3). A treatment program consisting of aquatic herbicides and hand removal of plants was initiated.

Survey of Anderson River Park Ponds

No hydrilla was detected in the three-acre pond in 2003. In fact, no hydrilla has been detected in this pond since 1994 (Table 2). No hydrilla has been detected in the 10-acre pond since 1999. In 2003, both ponds were surveyed seven times between June 2 and November 10. If no hydrilla is detected in either pond next season, the Shasta Project intends to declare both Anderson Ponds eradicated in Fall 2004. (No treatments have been made to either pond since 2001, when the area in the 10-acre pond, where the plants were found in 1999, was treated with fluridone slow release pellets).

Survey of Riverview Golf Course Ponds

The Riverview Golf Course infestation consists of four ponds, all connected by water flow. The most upstream pond, which is approximately 30 surface acres in size and is adjacent to the golf course, is fed from a small creek off the Sacramento River. The next three ponds are on the golf course, and are approximately six, one, and two acres, respectively, in surface area. Water returns to the Sacramento River along a small stream leading from the two-acre pond to the levee. The two-acre pond and small stream often go partially or completely dry in the late summer. When Shasta Project crews first surveyed these ponds in 1996, they found the 30-acre pond to be infested in the lower 15 acres where the infestation ranged from scattered single plants to small clumps, the six-acre pond to be moderately to heavily infested, and the two small ponds to be heavily infested (Table 2).

[19] All occurrences of hydrilla in Shasta County have been of the dioecious form.

In 2003, all four ponds were surveyed. The first, Rother's Pond was surveyed 12 times between June 2 and November 6 by boat and/or canoe and by shoreline survey. The water temperature at the time of the first survey was approximately 26 degrees C, and at the time of the final survey approximately 18 degrees C. One hydrilla plant was detected on June 2 by boat survey. This was a four-inch plant fragment retrieved from the bottom by a modified grappling hook toss, and showed symptoms of a previous fluridone treatment (Table 2); this compares to plants detected in eight different locations in 2002. The six-acre, one-acre, and two-acre ponds were surveyed 12 times between May 12 and November 6. No hydrilla was found in the three smaller ponds (Table 2), as compared to 10 plants and 75 tubers in 2002.

Treatment of Riverview Golf Course Ponds

Because hydrilla was found in Rother's Pond in 2002 and 2003, it was treated with three applications of fluridone slow release pellets at 50 ppb[20] each. Applications were made on May 12, June 7, and September 8. Because hydrilla plants or tubers were detected in two of the three smaller ponds in 2002, project crews applied fluridone slow release pellets to these ponds three times at 30 ppb each in 2003, on the same dates that Rother's Pond was treated.

Environmental Monitoring of Riverview Golf Course Ponds[21]

Starting in May and for most of the treatment season, the Riverview Golf Course pumped irrigation water from the Sacramento River in order to avoid using fluridone treated water from Rother's Pond[22]. Project crews monitored fluridone residue levels in water using an ELISA[23] test. The first water analysis was done in June in order to assure the golf course superintendent that unacceptable levels of fluridone were not leaking into the holding pond from which the golf course is irrigated. Fluridone residues were 2.4 ppb, below the label maximum allowed for "newly planted grass" of five ppb (SePRO Corporation 2002b). In the fall, the golf course switched back to pumping irrigation water from Rother's Pond after water analysis confirmed the fluridone level was below five ppb.

Survey Inside and Outside the Quarantine Zone[24]

Shasta Project biologists believe that hydrilla has appeared in the Redding area on three separate occasions (1985, 1994, and 1996) and are concerned that it might appear again. Accordingly, they maintain an intensive survey program inside and outside the quarantine zone. The quarantine zone is a corridor one mile wide on either side of the

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[20] Rother's Pond is large enough to qualify for a higher total seasonal application rate (150 ppb) than the smaller ponds (90 ppb), as per the Sonar® SRP label.

[21] Not including monitoring done in compliance with the National Pollution Discharge Elimination System. See separate report for this information.

[22] In 1996, the golf course superintendent was concerned that fluridone treated irrigation water might injure the turf or ornamentals on the course. For this reason, Rother's Pond was not treated with fluridone in 1996 in order to avoid any possibility of phytotoxicity. The golf club developed an alternate water source in 1997, and fluridone has been applied to the pond since 1997.

[23] ELISA = enzyme lined immuno-assay. The specific test used was the FasTEST® by SePRO Corporation (Netherland, M.D., D. R. Honnell *et. al*. 2002, SePRO 2002a).

[24] Hydrilla infested counties are "Eradication areas" by California Code of Regulations, Section 3962. "Quarantine zones" are reduced areas within "Eradication areas" and are the specific water bodies in the county where there are restrictions as to water access or use, as per California Code of Regulations, Section 3410.

Sacramento River from the Redding Civic Center to the Red Bluff Diversion Dam. This zone includes 18 ponds, four creeks, and a section of the Sacramento River (Appendix II). In 2003 these ponds, creeks and section of river were all surveyed at least twice (the creeks are surveyed between one-half mile above and one-half mile below road crossings, and the river is surveyed at 13 access points). No hydrilla was detected.

Outside the quarantine zone, Shasta Project personnel routinely survey another 25 ponds, lakes, and creeks (Appendix II). In 2003, all areas were surveyed at least once. No hydrilla was detected.

Public Information and Awareness

Project biologists made their presentations to the public about the Shasta County Hydrilla Eradication Project. Project crews distributed approximately 200 hydrilla brochures to bait shops, marinas, and recreation areas around Lake Shasta in the towns of Redding and Anderson, including the Coleman Fish Hatchery, in 2003.

LAKE COUNTY

The Clear Lake Project is a cooperative effort of the CDFA, the Lake County Department of Agriculture, and the Lake County Department of Public Works. Clear Lake is the largest freshwater, natural lake completely within California's borders[25]. Clear Lake is almost 21 miles long and eight miles wide, has a surface acreage of approximately 43,000 acres, and has approximately 100 miles of shoreline (Plate 4). Clear Lake is located approximately 90 miles north of San Francisco. The lake is relatively shallow, with an average depth of approximately 26 feet. Because it is relatively shallow, and has winds most afternoons, Clear Lake is not highly stratified, even in late summer. Water temperatures range from mid to high 30 degrees C in the summer to five to 10 degrees C in the winter. These temperatures are ideal for hydrilla germination and growth from mid-May until mid-October, especially the monoecious form that is found in Clear Lake.

Hydrilla was first found in Clear Lake on August 1, 1994 during a routine detection survey conducted by personnel from the CDFA and the Lake County Department of Agriculture. The CDFA and Lake County biologists responded rapidly and applied copper aquatic herbicide to some infested areas within two weeks of the first detection. In addition, the CDFA, with the cooperation of the Lake County Agricultural Commissioner, put Lake County under quarantine[26]. The CDFA and Lake County biologists conducted the initial delimiting survey in 1994 and found that 175 to 200 surface acres along the shoreline of the upper arm of Clear Lake were infested. Infestation levels varied from a few scattered plants to dense populations. In addition, in both 1994 and 1995, thousands of hydrilla fragments were visible at some of the boat ramps at the upper end of the lake. The CDFA also convened a Scientific

[25] Clear Lake is a popular fishing and water sports recreational lake. Clear Lake has often been described as the "Bass Capital of the West." The Lake is host to a number of bass tournaments throughout the year. There are also catfish, crappie, and bluegill in the lake.

[26] Because of the heavy recreational use of the lake, and the high risk that contaminated recreational equipment, clothing, or vehicles could spread hydrilla plant fragments, tubers, or turions around the Lake, or out of the Lake to nearby ponds, lakes, and streams (particularly Cache Creek), the CDFA and Lake County restricted movement of watercraft, motors, trailers, fishing gear, and other vehicles and equipment until they were inspected and cleaned of aquatic vegetation at the boat docks and ramps. These restrictions are still in place.

Advisory Panel in 1994 (Stocker, R.K. and L.W.J. Anderson *et. al.* 1994), which recommended a survey, treatment, and public education program.

Clear Lake Project personnel divided the lake's shoreline into 85 (originally 80) management units in order to better track and plan the eradication effort (Plate 4). These management units were based upon landmarks for ease of identification; they are not equal in length. These management units also vary in width toward the center of the lake but are usually about 500 feet wide toward the center of the lake. In 2003, all of these management units were surveyed and mapped using global positioning system/global information system technology to increase accuracy of herbicide treatments, and to better coordinate aquatic vegetation management activities with the Lake County Integrated Aquatic Vegetation Management Program[27].

Survey of Clear Lake

Surveys within Clear Lake constitute approximately 50 percent of the Clear Lake Project's field activities. In 2003, project crews conducted 620 surveys of the management units for an average of 7.8 surveys per unit. The first survey in 2003 was on May 1, and the last on November 12. The water temperature at the time of the first survey was 21.4 degrees C and at the time of the last survey was 15 degrees C. Only one hydrilla plant was detected in 2003. This was a rooted plant detected by a modified grappling hook from a boat survey on June 25 in management unit number 25 (Table 3). The number of plant finds has continued to decrease every year since the plant population has been low enough to count discrete finds (Plate 5, Table 3). The number of management units in which hydrilla was detected has also decreased from a maximum of 54 in 1998 to one in 2003 (Table 3)[28].

Clear Lake Project crews survey deep-water sections of the lake in mid to late summer every year. Mid to late summer was chosen because if any hydrilla plants were growing in the deeper water sections of the lake, they would have reached near the water surface by this time, and be fairly easy to detect. In 2003, project crews made three deep-water surveys, consisting of approximately 100 total hours of time. No hydrilla has ever been detected in deep-water sections of the lake.

In 2002, the Lake County Department of Public Works contracted with ReMetrix LLC to do an aquatic vegetation survey of Clear Lake. These results became available in 2003 (ReMetrix LLC 2003a). In this survey, ReMetrix biologists took 747 vegetation points in the lake, along a grid, and identified the aquatic weeds that were pulled up using a double-sided rake as a sampling device. Sampling was done between August 22 and September 23, 2002. No hydrilla was detected at any point. Though ReMetrix's survey was less thorough than CDFA's, ReMetrix's data supports the CDFA's conclusion that the level of hydrilla in the lake is very low.

Treatments of Clear Lake

In 2003, the CDFA continued to use aquatic herbicides (copper ethylenediamine and fluridone) as the eradication method of choice in Clear Lake (Plate 6). No small-scale

[27] The Clear Lake Integrated Aquatic Vegetation Management Program is a permit system to allow the public to conduct weed control operations in Clear Lake. The program is operated by the Lake County Department of Public Works.

[28] This does not mean that hydrilla has been eradicated from the management units. It is very possible that new plants are emerging from tubers in the treated units, but that the fluridone herbicide treatments are suppressing their growth.

dredging or other eradication methods were used. For the reason that only one hydrilla plant was detected in 2003, only one copper ethylenediamine herbicide treatment was made this year, on July 7, to a total of five acres. This represents a substantial decrease in copper herbicide use, both in terms of pounds of active ingredient used and acres treated, since the program began (Table 4)[29]. Visual observation and surveys indicated no mature hydrilla plants were growing in the treated area after application.

The Clear Lake Project's use of fluridone has also decreased in the last two years (Table 5). This decrease is a result of the fewer plants detected in the last three years[30]. In 2003, Project treatment crews applied the first fluridone slow release pellets on May 29, and the last on September 10. In 2003, the number of pounds of fluridone active ingredient applied in the slow release pellet formulation was 32 percent less than in 2001, the year of peak use. The number of acres treated with fluridone slow release pellets in 2003 was 13 percent less than in 2002. In 2003, no fluridone aqueous formulation was used. Visual observations and surveys indicated that the fluridone slow release pellets gave complete control of hydrilla in treated areas.

Starting in 2000, some management units have been hydrilla free for over three years and are no longer actively treated, though surveys continue. In 2003, there were 13 previously infested, which are apparently hydrilla free and are no longer treated, though surveys continue[31].

Environmental Monitoring of Clear Lake[32]

In August, Clear Lake personnel were approached by a Lake County grape grower who was planting a new vineyard near the lake and who was concerned that irrigating his new vines from Clear Lake might cause damage to the vines from the herbicides used by the project. On August 7, project personnel took a water sample from near the intake for the new vineyard and sent it to SePRO Corporation for analysis by ELISA. As soon as the results were available, Clear Lake Project personnel visited the grower to inform

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[29] This herbicide is applied on an as-needed basis to achieve rapid destruction of biomass in areas where plants or plant fragments are found. A five-acre area around each plant find is treated with copper ethylenediamine herbicide at one-ppm copper within a few days of any find. The decrease in use is a consequence of both the decreasing numbers of hydrilla finds in the lake, and the increased use of fluridone slow release pellets. However, copper ethylenediamine, because it is a contact herbicide, is still the herbicide of choice for rapid dissolution of large plants and mats, and in certain other situations, such as where water might be used for irrigation or where it is not practical to obtain the long contact time required by fluridone.

[30] Fluridone slow release pellets have the advantage that they give residual control because they release the active ingredient slowly into the water column. In addition, fluridone slow release pellets are easy to apply and their use concentrates the fluridone near the water: hydrosoil boundary where it controls plants from newly germinated tubers. In general, the Clear Lake Project treatment crews apply fluridone slow release pellets on a two-week schedule, once applications begin in the spring. The treatment zone is a five-acre area around the location of each plant find that has occurred in the previous three years. If there are a number of plant finds within the management unit, so that there is extensive overlap, then the entire management unit is treated. The standard treatment is seven applications at 20 ppb (calculated to a maximum depth of six feet only) applied on a two-week schedule for a yearly maximum of 140 ppb. The number of applications is decreased to six (120 ppb yearly maximum) in management units in which hydrilla has not been detected the previous year. The number of applications are further decreased to five (100 ppb yearly maximum) in management units in which hydrilla has not been detected in the previous two years (Plate 5). After hydrilla has not been detected for the previous three years, herbicide treatments to that unit cease, but intensive survey continues.

[31] The CDFA Hydrilla Eradication Program prohibits the use of mechanical harvesters in areas in which hydrilla has been detected in the previous six years. The prohibited area is a circle of a one-quarter mile radius around each find. The reason for this prohibition is that even the best mechanical harvesters produce numerous plant fragments that could potentially become established thereby spreading the hydrilla infestation.

[32] Not including monitoring done in compliance with the National Pollution Discharge Elimination System. See separate report for this information.

him of the results and to address any further concerns he may have had. The results were that fluridone residues were not detected (detection limit of one ppb). The grower irrigated his new vineyard from the lake and did not report any problems.

In September, following another request from the public, a water sample was taken from management unit 50 (Lily Cove) and sent to SePRO Corporation for analysis by ELISA. This water sample was taken seven days after the seventh of seven applications at 20 ppb each to this management unit. The results were that fluridone residues were not detected (detection limit of one ppb).

Surveys Outside of the Quarantine Zone

As the number of hydrilla plants has fallen in Clear Lake, the Clear Lake Project crews dedicate more time to surveying surrounding lakes, ponds, streams and other water bodies in order to detect any hydrilla infestations in the incipient stage and prevent re-infestation of Clear Lake itself. These surveys are conducted because of the possibility that boats, trailers, or other equipment originating from Clear Lake might transport hydrilla fragments, tubers, or turions to these nearby lakes and reservoirs. In 2003, project crews surveyed numerous water bodies in the Clear Lake area including Indian Valley Reservoir, Highland Spring Reservoir, Lake Pillsbury, Blue Lakes, and Thurston Lake. In addition, major reservoirs and lakes in Colusa, Mendocino, Napa, Sonoma[33] counties and Cache Creek in Yolo County were also surveyed for a complete list of surveyed areas, see Appendix III). No hydrilla has been detected during these surveys.

Public Information and Awareness

Public information and awareness is an essential component of the Clear Lake Project. Recreational fishermen, guides and outfitters, fishing tournament organizers, sailors and boaters, and other recreational users of Clear Lake need to know how to prevent the spread of hydrilla in the lake and from Clear Lake to other lakes, streams, ponds and reservoirs. Since public access to the lake is not being restricted, this aspect of the Clear Lake Project must be maintained throughout the duration of the project.

In 2003, Clear Lake Project personnel distributed Notices of Intent and informational pamphlets to homeowners and businesses with lakefront property. These Notices of Intent and pamphlets were sent prior to initiation of aquatic herbicide applications. In addition, Clear Lake Project personnel distributed approximately 1,200 informational pamphlets to businesses and government agencies around Clear Lake. The Clear Lake Project aquatic herbicide treatment schedule was also posted on the Lake County Department of Public Works website[34].

In 2003, Clear Lake Hydrilla Eradication Project personnel made six presentations to the public about the project. For instance, the project was highlighted in a presentation given at the *Pesticides and Health Conference* sponsored by Big Valley Rancheria in Lakeport in February. The project was also highlighted in two presentations at the Western Aquatic Plant Management Society conference in Sacramento in March; a

[33] During the week of October 27, Spring Lake in Sonoma County was surveyed and two small patches of water hyacinth were found. The Sonoma County Department of Agriculture and the California Department of Boating and Waterways were appraised.
[34] http://watershed.co.lake.ca.us

poster was presented at the Invasive Plants in Natural and Managed Systems[35] conference in Florida on November 5. In December, Clear Lake Project biologists and the Lake County Aquatic Vegetation Manager reviewed the Clear Lake Hydrilla Eradication Project and the Lake County aquatic vegetation control permitting process with the Hinthil Environmental Resources Consortium[36]. In addition, several informal discussions of the project occurred at other events during the year.

YUBA COUNTY

Yuba County has had three distinct infestations: Lake Ellis, Shakey's Pond, and Oregon House. The first two infestations have been eradicated. The first infestation was in Lake Ellis, a 31-acre ornamental lake in the center of Marysville. Hydrilla was found in Lake Ellis in 1976, the first occurrence of hydrilla found in California. The hydrilla was identified as the dioecious form. In 1979, the lake was drawn down, the hydrosoil removed, and the infested areas treated with metam-sodium. Six plants re-appeared in 1980 in one small location. Project biologists then treated the entire lake with endothall and copper ethylenediamine complex with special attention paid to the infested location. By 1981, the lake was free of hydrilla and eradication was declared in 1984. The second infestation was discovered in 1990 in Shakey's Pond, which may have become infested as a result of carrying aquatic plant material to it from Lake Ellis. Hand removal and aquatic herbicide treatments reduced the number of plants until only one plant was found in 1996, when the pond received three treatments of fluridone. No plants have been found in the pond since 1996, and this infestation is also considered eradicated.

Oregon House: The On-Going Eradication Project

On August 7, 1997, a third infestation of hydrilla was detected in Yuba County near Oregon House (Plate 7). A visitor to a nearby winery suspected that hydrilla had infested one of the ponds on the winery and reported this suspicion to the Yuba County Department of Agriculture. Yuba County biologists investigated, found hydrilla, and sent a sample to the CDFA Plant Pest Diagnostics Lab for confirmation. The CDFA's Plant Pest Diagnostics Lab confirmed the specimen to be hydrilla. Scientists at the United States Department of Agriculture, Agricultural Research Service (USDA-ARS) Exotic and Invasive Weed Unit then confirmed it to be the monoecious form of hydrilla.

The Oregon House Hydrilla Eradication Project (Oregon House Project), which is a cooperative effort between the CDFA and the Yuba County Department of Agriculture, was started after this first detection. Biologists conducted delimitation surveys at the winery and found that a total of five ponds and an ornamental fountain[37] were infested (Elizabeth, Luban, Swan, Ditch, and Tank ponds with surface areas of 3.1, 3.0, 2.7, 0.2, and 0.15 acres, respectively, and average depths ranging from nine to 13 feet) (Plate 8). The Ditch and Tank ponds were, and still are, used to irrigate the vineyard. Project crews then conducted delimitation surveys within the three-mile quarantine zone (around the known infested ponds) and detected additional infestations on three private

[35] Invasive Plants in Natural and Managed Systems/Seventh International Conference on the Ecology and Management of Alien Plant Invasions, sponsored by the Weed Science Society of America and the Ecology Society of America.

[36] This consortium is made of representatives from the six Pomo tribes of Native Americans that live near Clear Lake (Big Valley Rancheria, Elem Indian Colony, Habematolel Pomo of Upper Lake, Middletown Rancheria, Robinson Rancheria, and Scott's Valley Band of Pomo Indians).

[37] The infested water lilies in the ornamental fountain were removed, the hydrilla plants and tubers destroyed, and the water lilies repotted and returned.

properties, the Spiers 1, 2, and 3 ponds (3.8, 0.5, 0.4 acres) and the Clouse and Ronen ponds (1.9, and 0.1 acres) (Plate 8). The two smaller Spiers ponds were used for rearing catfish. Another 40 ponds were surveyed and found not to be infested.

In 2000, project survey crews, during routine surveys, detected three additional infested ponds. These were Reservoir 23 (0.25 surface acres), Davis (0.37 acres), and Citron (0.22 acres) ponds (Plate 8). Reservoir 23 is also used for irrigation at the winery.

Survey of Ponds Within the Quarantine Zone

On October 1, 2003, during a routine survey of Spiers 5 Pond, hydrilla was detected for the first time in this pond (Table 6). This pond has been surveyed multiple times per year since the beginning of the project with no hydrilla being found. The find consisted of a single plant at the upper end of the pond, near the inlet. It is speculated that the plant may have flowed down through the small creek from Spiers 1.

Of the infested ponds in 2003, the Oregon House Project biologist first detected hydrilla on May 15 in Spiers 1 and Citron ponds (Table 6). In subsequent 2003 surveys, hydrilla was detected in Tank Pond and Reservoir 23 on July 7, Luban Pond on July 14, and again in Spiers 1 and Citron ponds on July 15. In addition, hydrilla was detected in Clouse and Ronen ponds on July 15. Ronen pond has had no hydrilla since 1999, but one plant was found this year. Hydrilla was found in Ames Basin on July 22 and again in Ditch Pond on that date. Ditch Pond also had observable plants on September 5 (Table 6).

Beacon Pond that was drained of water in January 2002 and all debris and hydrilla was swept out of this gunite lined pond. No hydrilla has been found since that time, for two full seasons. Spiers 2 and 3 are still dry (they do have small quantities of water, inches deep, probably from seepage) and continue to have no hydrilla. No plants were found in Davis, Swan or Elizabeth ponds in 2002 or 2003 (Table 6).

Treatment of Ponds Within the Quarantine Zone

In 2003, the three irrigation ponds, Ditch Pond, Tank Pond and Reservoir 23, were treated with copper ethylenediamine at one ppm on July 7, July 22 and September 5. The eight non-irrigation, infested ponds were treated three times with fluridone slow release pellets at 30 ppb[38]. The first applications began in mid-May, the second in mid-July and the final in late September. Spiers 5 Pond was treated with fluridone slow release pellets at 30 ppb in early October, after finding a plant there for the first time.

The fluridone treatments have been very effective in suppressing hydrilla. In treated ponds, when hydrilla is found, only single plants are found and they exhibit chlorosis from the treatments. In addition, no hydrilla was found in Elizabeth, Swan and Davis ponds, all of which are being treated with fluridone.

The Yuba County Water District Canal

While surveying the Oregon House area in 1997, the CDFA and Yuba County biologists found that the lowest 3.1 miles of an 18-mile irrigation canal, owned by the Yuba County

[38] Ronan Pond was treated once at 60 ppb and a second time at 30 ppb, starting after the first hydrilla find.

Water District (YCWD), was infested with hydrilla (Plate 8). In addition, two other small water impoundments, which are fed from the canal, were also found to be infested (Ames, 0.01 acres and Beacon, 0.02 acres). The canal is in operation between April and October. For the reason that the irrigation canal is the headwaters of the entire infestation, eradication of the hydrilla in the canal is pivotal to the success of the entire Oregon House Project, including eradication from the ponds.

In 1997, 1998, and 1999, several eradication methods were tried in the canal, with varied results[39]. Starting in 2000, Oregon House Project biologists have used a flowing-water copper application method with good results. After a successful preliminary test in mid-summer 2000, they have used electric pumps at three stations one mile apart to meter copper ethylenediamine herbicide into the flowing water of the canal for six hours. The rate of metering of copper ethylenediamine complex decreased from station to station to maintain a one-ppm concentration of copper in the water. Visual observations in 2000 showed that this method proved to be very effective in controlling the hydrilla top growth and the method was adopted. Also in 2000, project biologists started raking[40] the canal, which has proven in the last three years to be very effective, though labor intensive and time consuming. In 2001, an acetic acid treatment was tried with promising results (Spencer, D and G. Ksander, 2001). However, despite several attempts, it has not been possible to repeat this treatment due to inclement weather. Acetic acid will be tried again in the spring of 2004 if the weather permits.

Survey of the Yuba Water District Canal

In September 1998, Dr. David Spencer and Greg Ksander (USDA-ARS Exotic and Invasive Weed Unit) made their first estimate of the tuber distribution in the canal by counting the number of hydrilla tubers in core samples from the canal bottom (Table 7). In 2003, their tuber core samples reflected a density of one tuber per square meter, versus 316 tubers per square meter in 1998, a 99.7 percent reduction. For a full description of the Dr. Spencer and Greg Ksander's method and results, see Appendix IV.

The visual survey of plant density conducted in previous years was not conducted in 2003 (Plate 9), but is scheduled to be repeated in the fall of 2004.

Treatment of the Yuba County Water District Canal

In 2003, the project biologist continued to combine raking and physical removal of individual plants with the flowing-water copper herbicide treatments. The project

[39] In October 1998, the YCWD used a backhoe on tracks to reshape the canal, and move some of the infested hydrosoil up onto the dirt road that parallels the canal. Based on visual observations the next spring, this operation was partially effective in reducing the hydrilla population. In addition, in October 1999, after the irrigation season, the bottom of the infested section of the canal was treated with diuron. The diuron had little impact on the re-growth of the hydrilla next spring. In 1999, they also tried suction dredging with a small pump and screens, but found dredging to be difficult and extremely slow due to the nature of the hydrosoil-compacted clay embedded with rocks. In 1997, 1998, and 1999, the water in the canal was pooled with sandbags and sprayed with copper ethylenediamine (or a tank mix of copper and diquat herbicides for increased efficacy) to control the hydrilla. However, this would disrupt water delivery to YCWD customers whose complaints to the YCWD made it difficult to maintain a four-week treatment schedule. In addition, this technique left the sides of the canal untreated. For these reasons, this method was only partially effective and hydrilla regrowth was rapid, especially during the summer.

[40] The rake method is simply to use a garden rake to sift the sediment in the canal bottom and sides to remove any hydrilla plants, tubers, roots, and root crowns. Screens are placed downstream of the raking operation to catch any floating hydrilla fragments.

biologist removed over a thousand small new forming tubers, many of which were still attached to the root crowns, from the areas that were raked. It is believed, based on visual observation, that the chemical treatments combined with raking of the few dense areas of hydrilla allowed for almost no tuber recruitment to the tuber bank in 2003. Five metered copper herbicide applications were made; the first was made in early June and the last was made on September 18 (Plate 8 for application locations). The copper application rate was one ppm. In mid-October, the water district discharged the canal.

The CDFA biologist noted that this year, as compared to last, the percentage of plants with attached old tubers, when physically removed, was much lower than last year. Also, in the areas of dense hydrilla, many more had formed new root crowns from stolon growth from older plants, than last year. These differences may have been in part to the copper treatments exhausting carbohydrates in the tubers and the later start at physical removal.

CALAVERAS COUNTY

It is believed that there have been two separate infestations of dioecious hydrilla in Calaveras County, based on their geographic and hydrologic separation. The first infestation was detected in May 1988, consisting of ponded areas in Bear Creek and three isolated ponds between the towns of Burson and Wallace (Plate 10). The Calaveras County Hydrilla Eradication Project (Calaveras Project), a cooperative effort between the CDFA and the Calaveras County Department of Agriculture, began soon thereafter. The CDFA convened a Scientific Advisory Panel that made recommendations as to the survey, treatment, and public education in the Calaveras County area (Stocker. R.K. and L.W.J. Anderson *et. al.* 1988). The Bear Creek drainage infestations are of particular concern because Bear Creek enters the Sacramento/San Joaquin River Delta at Disappointment Slough in San Joaquin County, only about 26 miles downstream from the lowest infested area on the creek, the Hesseltine ponded area.

Later in 1988, the CDFA and Calaveras County survey crews discovered the other infestation, two ponds located near Mokelumne Hill (Plate 11). The two Mokelumne Hill ponds are located about 30 miles from the Bear Creek area and are 0.45 and 0.15 acres in size and are used for watering cattle. Another seven cattle watering ponds surround them. The Mokelumne Hill infestation has been particularly troublesome because it has been difficult to eliminate the tuber bank. No hydrilla plants have been found in the smaller of the previously infested pond since 1998, but plants were detected in the larger pond in 2002 and 2003.

Survey and Treatment of the Bear Creek Drainage

Due to the Calaveras Project's efforts, most of the originally infested ponds and ponded areas in the Bear Creek drainage project are approaching eradication. Calaveras Project crews have not detected any hydrilla plants upstream of the Perock and Baker ponded areas (Management Units 3 and 5) of Bear Creek since 1996 (Plate 10). They have not detected any hydrilla plants in either unit 3 or unit 5 since 1998. Nonetheless, in 2003, project crews surveyed all of these units between one and five times.

In contrast to the above ponded areas approaching eradication, the Hesseltine ponded area (Unit 1) is still active because of hydrilla finds in 2001, 2002, and 2003. Unit 1 is an

approximate 10-acre pond located approximately one mile downstream from Unit 3. In 2003, project survey crews detected three hydrilla plants in Unit 1, near a previously infested area of the pond (Plate 10). No tubers were detected. This compares to 10 plants, 33 tubers, and 13 turions in 2001, and five plant mats, 18 single plants and 19 plant fragments in 2002. In 2003, the first survey was conducted on May 21 (water temperature 24 degrees C) and the last on November 18 (water temperature 10 degrees C). A total of 10 surveys were made.

Since the first hydrilla find in Unit 1 in 1996, Calaveras Project personnel have treated all infested areas in this drainage with various combinations of physical removal and applications of copper ethylenediamine and/or fluridone herbicide. In 2003, project survey and treatment crews found and removed three plants by hand, carefully removing as much of the plant and root crown as possible. No tubers were found. Project crews then treated the infested areas with copper ethylenediamine herbicide at one ppm within a few days of detection. The copper treatments were followed by eight applications of fluridone (both slow release pellets and liquid formulation) totaling 90 ppb.

Survey and Treatment of Mokelumne Hill

Calaveras Project survey crews surveyed each of the two previously infested ponds 10 times in 2003, and each of the near-by ponds at least twice. The first survey was on May 21, when the water temperature was 17 degrees C. The last survey was on November 17, when the water temperature was six degrees C. In total, 22 hydrilla plants were detected in pond three, the pond found infested in 2002 (Plate 11). Unlike the 2002 finds, most in 2003 were single plants, and were detected and removed before growing to the surface and branching out. Project treatment crews hand removed all plants when detected, carefully removing as much plant material, including root crowns and tubers, as possible. In total, 22 plants and two tubers were removed. The infested pond was treated twice with copper aquatic herbicide at 0.4 ppm and three times with fluridone liquid for a total rate of 90 ppb.

Surveys Outside of the Quarantine Zone

Calaveras Project personnel surveyed the following water bodies in 2003: Lake Comanche, four ponds in the Lake Comanche Recreation Area, Lake Wallace, Bear Creek from the Calaveras/San Joaquin County line west four miles to the Highway 88 and Highway 12 split, all access points along Bear Creek from the Highway 88 and Highway 12 split west 22 miles to Thornton Road in Stockton (surveyed twice), four golf course ponds at Lockeford Springs Golf Course, and two ponds at Bezley Ranch. No hydrilla was detected.

Public Information and Awareness

In 2003, Project biologists made one presentation and training to the public about the project. Brochures were also distributed at the Calaveras County Agricultural Commissioner's office.

MADERA AND MARIPOSA COUNTIES

In June 1989, the CDFA and Madera County Agriculture Department personnel, during a routine survey of aquatic sites in the county, detected dioecious hydrilla in Eastman

Lake. Eastman Lake is a 1,800-acre reservoir that belongs to the United States Army Corps of Engineers (USACE) and is used for flood control, irrigation, recreation and wildlife. The survey crews found scattered patches of hydrilla along the northern section of the lake and along the eastern and southeastern shoreline, amounting to 100 infested acres.

During an extensive survey of all known water bodies in the vicinity of Eastman Lake, survey crews detected hydrilla upstream of the lake in the west fork of the Chowchilla River. After a thorough survey, the crew determined that approximately 26 miles of the river were infested. Plant density ranged from sites with single plants to sites with dense patches (Plate 12).

The CDFA, Madera County Department of Agriculture, Mariposa County Department of Agriculture, and USACE initiated the Madera and Mariposa Counties Hydrilla Eradication Project (Madera/Mariposa Project) in 1989, right after the first detections were made. The CDFA, with the cooperation of the Madera County Department of Agriculture and Mariposa County Department of Agriculture, and USACE issued a quarantine for all of Eastman Lake and for the infested portions of the Chowchilla River. Both the lake and the river were then placed under quarantine and closed to recreational use. Survey crews have not detected hydrilla in Eastman Lake since 1993. As a result, quarantine restrictions have been progressively lifted so that today only the uppermost section near the inlet remains under quarantine, where fishing is prohibited. The west fork of the Chowchilla River remains under quarantine, and fishing is prohibited in all management units[41].

Survey of Eastman Lake

Hydrilla plants and tubers were detected upstream of Eastman Lake in the west fork of the Chowchilla River as recently as 2002 (Table 8); surveys of Eastman Lake continue, and will continue until the hydrilla is declared eradicated in the Chowchilla River. In 2003, survey crews surveyed Eastman Lake by boat and canoe four times. The first survey was on May 23, when the water temperature was 26 degrees C. The last survey was on November 5, when the water temperature was 16 degrees C.

Because of continuing drought in the area, the USACE once again reduced the water level of the lake to near minimum pool (466 foot elevation), once again exposing the sites of the original hydrilla finds to drying. No hydrilla was detected in the lake or at the exposed original sites. No herbicide treatments were made.

Survey and Treatment of the Chowchilla River

In 2003, project survey crews conducted between one and five surveys of each management unit along the river. The first survey was on May 23, when the water temperature in the river was 22 degrees C. The last survey was on November 5, when the water temperature was 11 degrees C. For the first time since the project began, no hydrilla plants or tubers were detected in any of the 38 management units (Table 8). However, these results should be interpreted with caution. Drought continued in this area in 2003. The lack of water could be masking the hydrilla population by forcing the

[41] In 1989, project leaders divided the river into 38 management units for tracking of survey and eradication activities: The units followed the original property lines and are not the same length or area.

tubers to remain dormant in the dry soil and artificially reducing the survey counts. Alternatively, the tubers could be expiring in the dry soil. The effects of the drought, and the true hydrilla population will not be known until wet years return.

Though no hydrilla was detected in 2003, project crews treated the two areas where hydrilla was detected in 2001 and 2002. In 2001, hydrilla plants were found in Management Unit 2 near Raymond Bridge, and in 2002, plants were found upstream in Management Unit 29 (Plate 12). Both areas were treated twice with fluridone slow release pellets for a total of 90 ppb. Treatment dates were July 8 and August 7.

Surveys Outside of the Quarantine Zone

Project survey crews surveyed the following water bodies in the Eastman Lake and Chowchilla River area in 2003: Hensley Lake, Berenda Reservoir, O'Neill Forebay, Chowchilla River and Santa Fe Avenue, and Chowchilla River at Avenue 19, Manzanita Lake, Corrine Lake, Yosemite Lakes Park, two ponds at Sugar Pine Christian Camp, Bass Lake, Millerton Lake, Pine Flat Lake, Woodward Lake. Surveys were conducted by boat and/or canoe. No hydrilla was detected.

TULARE COUNTY

There have been two separate infestations of hydrilla in Tulare County. In 1993, a Tulare County Department of Agriculture biologist detected monoecious hydrilla in three small ponds that belonged to an ornamental, wholesale nursery near Visalia. The CDFA and Tulare County biologists, with the cooperation of the owner, emptied the ponds to dry out the hydrosoil and dry out the tubers, and then fumigated the hydrosoil with metam-sodium to control the plant tubers. The ponds were never re-charged with water and remain dry to this day. The CDFA crews continued to survey these ponds for several years, but no hydrilla was ever found. The CDFA considers these ponds to be eradicated.

On October 7, 1996, dioecious hydrilla was detected in a fishing resort southwest of Springville in Tulare County (Plate 13). This resort is adjacent to the Tule River and is approximately two miles upstream from Lake Success[42]. The Tulare County Hydrilla Eradication Project (Tulare Project), which is a cooperative effort between the CDFA and the Tulare County Department of Agriculture, began soon thereafter.

Delimitation surveys by project crews determined that five ponds were infested on the resort and one pond was infested on an adjacent, downstream property. The infested ponds ranged in size from 0.02 acres to 10.8 acres with a total surface area of all ponds being 20 acres (Plate 13). The infestations in the ponds ranged from very dense to just a few scattered plants. Four other non-infested ponds were also on the resort's property. Additional ponds have been created since the initial hydrilla detection. Most of these are relatively small (less than 0.1 acre) and are used for fish breeding. There are now a total of 15 ponds on the resort property.

[42] Lake Success is a 2,450-acre reservoir managed by the USACE and is used primarily for flood control and agricultural purposes, although it is also popular for recreation.

Survey and Treatment of the Springville Ponds

Project crews surveyed all 15 ponds on the resort property and the one previously infested pond off the property between six and eight times in 2003. The first survey was on June 4, when the water temperature was 28 degrees C. The last survey was on December 3, when the water temperature was 11 degrees C. This is the second year in a row that no hydrilla was detected in any of the ponds (Table 9).

Since the project began, the eradication treatments used have included hand removal of plants, copper and fluridone herbicides, and small-scale dredging of tubers. In 2003, project crews applied fluridone liquid and fluridone slow release pellets to areas infested in 2001[43]. Project crews made two applications of each formulation, one on June 16 and the second on August 5. The rate of the pellet formulation was 15 ppb for each application; the rate of the liquid formulation was 30 ppb.

Surveys Outside of the Quarantine Zone

In 2003, Tulare Project crews surveyed the following water bodies in the area of the infested ponds: Lake Success, River View Golf Course ponds, Tule River, 25 surrounding private ponds, Lake Kaweah, Lake Isabella, Lake Ming, Kern River County Park ponds, Buena Vista Aquatic Recreation Area, and Lake Woollomes. Surveys were conducted by boat, canoe, and hiking. No hydrilla was detected.

IMPERIAL COUNTY

Imperial Irrigation District (IID) personnel first detected dioecious hydrilla in Imperial County in June 1977 in the All American Canal. The IID is a gravity-fed irrigation system that delivers water from the Colorado River via the All American Canal through a network of lateral canals, ponds, and other reservoirs to farmers' ditches, which in turn water the farms and fields of the Imperial Valley. Drainage canals (drains) then carry the runoff and seepage to the New and Alamo rivers. IID personnel conducted surveys in 1988 and found that the hydrilla infestation covered, to a greater or lesser degree of plant density, 320 canals extending approximately 600 miles, 32 ponds comprising 161 surface acres, and 79 privately owned delivery ditches.

The CDFA, IID, USDA-Animal and Plant Health Inspection Service, California Department of Fish and Game (CDFG), and Imperial County Department of Agriculture formed a cooperative agreement in 1981 to research and develop control and eradication methods for the IID. Between 1981 and 1984, the main control methods were mechanical removal of plant mats and mechanical dredging. In 1984, the IID received permission from the CDFG to stock the west side of the IID (the infested area) with triploid grass carp (*Ctenopharyngodon idella*) (TGC)[44]. The TGC has been the main

[43] Fluridone liquid is used where the pond bottom is heavy clay and organic sediment. Fluridone slow release pellets are used where the pond bottom is solid (granite).

[44] The biological control agent, the triploid grass carp (*Ctenopharyngodon idella*) (TGC) is used to consume hydrilla and other aquatic vegetation. When used in confined areas, and in adequate stocking rates, the TGC can suppress a population nearly to extinction. However, to prevent establishment of a wild population, the CDFG Code requires that only sterile fish be stocked. (TGC roe is put through a high-pressure treatment that gives each egg a triploid chromosome complement and makes the fish sterile). Nonetheless, the CDFG is concerned that the sterility might not be absolute, so they have tight restrictions on TGC use. According to the CDFG Code, the TGC cannot be deployed in any open water bodies that empty into natural waters of the state (CDFG Code, Sections 6440-6460). Therefore, all use of the TGC must

control and eradication method since, supplemented by hand removal of individual plants and mechanical dredging when necessary. The IID stocks the TGC on a yearly basis at a target rate of up to 100 fish per mile for canals and drains infested with aquatic vegetation, and up to 100 fish per acre for ponds infested with aquatic vegetation.

Survey and Treatment of the Imperial Irrigation District Canals and Waters

In 2003, IID weed control crews surveyed all canals, ponds, drains, and farmers' sides in the system for hydrilla and other aquatic vegetation. IID crews detected hydrilla in two locations, the Bryant canal (near Brawley) and the Wildcat drain (where hydrilla was also detected in 2001 and 2002) (Plate 14). This compares to four infested sites in 2001 and 2002 (Table 10).

In 2003, Imperial Project biologists manually removed the hydrilla plants from each infested location. The IID continues to employ the TGC for control of hydrilla and other aquatic vegetation. In 2003, the IID released 2,822 TGC into canals and waterways in the quarantine zone (Table 10)[45]. This is a slight increase in the number of TGC released compared to 2002.

SACRAMENTO/SAN JOAQUIN RIVER DELTA SURVEY

Each year since the mid-1980s, CDFA personnel have conducted a survey of the Sacramento/San Joaquin River Delta and the lower reaches of the tributary rivers for hydrilla[46]. Hydrilla tubers or plant fragments could be introduced into the Delta by natural or human vectors[47]. The annual survey is conducted in the fall of the year when hydrilla plants would be most visible as they reach the water surface and form dense mats. The presence of other aquatic weeds is also noted.

Survey of the Sacramento/San Joaquin River Delta

In 2003, CDFA crews, assisted by biologists from the San Joaquin County Department of Agriculture, surveyed the Delta from August 18 through August 29. Surveys consisted of a total of five boats or airboats and 12 surveyors. A total of 420 miles of Delta waterways were surveyed (Plate 15). Surveys were by visual inspection of the water column and by sampling submersed vegetation with modified grappling hooks. Survey teams monitored their progress and position using global positioning system technology. The following areas were surveyed: Suisun Bay, Middle River, Old River, Frank's Tract,

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be in areas that are contained with gates and screens, which severely restricts TGC use. Despite this limitation, the use of the TGC can be very effective in ponds and canals where the inlets and outlets can be screened to contain the fish.

[45] The IID also provided 1,500 TGC to the Mexicali Irrigation District for aquatic weed control.

[46] The Sacramento/San Joaquin River Delta is one of the most important sources of fresh water in the State of California. The Delta carries 47 percent of all the runoff water in the state. It provides water for residential, industrial, and agricultural uses in both the north and south state areas. The Delta supports approximately 120 fish species, approximately 750 plant and animal species, and is the largest wetland habitat in the western United States (CALFED Bay-Delta Program 2001). Any blockage of this water-flow by hydrilla would impede navigation, clog water control structures, imperil native plant, fish, and animal life and diversity; and raise the cost of water delivery to users. The annual CDFA hydrilla survey of the Delta was partially initiated in response to recommendations made by the Scientific Advisory Panel convened in 1988 to consider the hydrilla infestation in Calaveras County (Stocker, R.K. and L.W.J. Anderson *et. al.* 1988).

[47] Plant fragments, tubers, or turions from any active hydrilla infestation in California or elsewhere could potentially infest the Delta. Plant fragments, tubers, or turions could be carried into the Delta by direct hydraulic connection (water-flow) or by way of contaminated boats, boat trailers, boat motors, live wells, trucks, fishing gear, clothing, and other equipment. Of the active hydrilla eradication projects, the closest and most direct hydraulic connection to the Delta is the Hesseltine ponded area in Bear Creek in Calaveras County, which is about 26 miles upstream from Disappointment Slough near Stockton.

Potato Slough, White's Slough, Disappointment Slough, the Stockton Deepwater Channel, Victoria Channel, Grant Line Canal, Cache Creek, Bear Creek, the lower reaches of the Sacramento River and San Joaquin River. No hydrilla was detected. However, other non-native, aquatic pest plants, such as Brazilian waterweed (*Egeria densa*), water hyacinth (*Eichhornia crassipes*), fanwort (*Cabomba caroliniana*), and Eurasian watermilfoil (*Myriophyllum spicatum*) were detected, sometimes in large populations (Plate 15).

In 2003, as every year, CDFA and county personnel investigated every report from the public that hydrilla has been sighted in the Delta or any of its tributaries. None of these reports has resulted in a positive finding.

In 2003, the CDFA also cooperated with the California Department of Boating and Waterways (CDBW) in conducting a pilot project to detect, quantify, and map Brazilian waterweed, water hyacinth, and other aquatic weeds in the Delta using remote sensing. The methods used were a hyperspectral sensor system on an aircraft platform[48], hand-held sensors on boat platforms in the field, and hand-held hyperspectral sensors on lab/greenhouse grown plants (including hydrilla)[49]. For both aerial and hand-held systems, the electromagnetic spectrum between 400 and 2,500 nanometers (visible, near-infrared, and short-wave infrared) was divided into 126 bands. Field measurements were geo-referenced using the global positioning system[50]. Data analysis was done by the Center for Spatial Technologies and Remote Sensing at the University of California, Davis (Mulitsch, M. and S. Ustin 2003), and results were confirmed by the Boeing Company (Boeing Company 2003)[51]. Images were registered (geo-corrected) using United States Geological Survey orthophoto quads. Spatial resolution was 3-meter by 3-meter pixels. The aircraft based sensor proved promising for the detection, quantification, and mapping of water hyacinth and Brazilian waterweed. Though the aircraft based sensor data was not analyzed for hydrilla, based on the spectra of lab/greenhouse grown plants, the preliminary conclusion of the researchers is that it may be possible to resolve hydrilla from other submerged aquatic weeds (Plate 16), which would make large scale remote sensing surveys for hydrilla possible. The CDFA plans to cooperate with the CDBW to sponsor further research in the use of remote sensing, particularly hyperspectral imaging, for the detection, quantification, and mapping of hydrilla and other noxious and invasive aquatic weeds.

In summer 2003, the CDBW contracted with ReMetrix LLC to conduct aquatic vegetation surveys of their aquatic herbicide treatments for water hyacinth and Brazilian waterweed control in the Delta (ReMetrix LLC 2003b). A total of 18 sites were surveyed including Big Breaks, Connection Slough, Frank's Tract (several sites), Little Potato Slough, Middle River (two sites), Rhode Island, Pixley Slough, Sandmound Slough, Seven Mile Slough, Venice Cut, and White Slough. In these surveys, ReMetrix biologists took 1,316 aquatic vegetation samples with a double-sided rake. No hydrilla was detected at any point. Though ReMetrix's survey was less thorough than CDFA's,

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[48] The HyMap® system, HyVista Corporation. For more information, see Cocks, T., R. Jennsen, *et. al.* 1998.

[49] Field portable spectrometer by Analytical Spectral Devices.

[50] Trimble® Pro-XRS with less than one-meter accuracy.

[51] Initial data processing was done with HYCORR® software, HyVista Corporation. Subsequent data analysis was done by the Center for Spatial Technologies and Remote Sensing and by the Boeing Company using proprietary and public algorithms, including the ENVI (Environment for Visualizing Images) Hourglass® Spectral Angle Mapper, Research Systems Incorporated.

ReMetrix's data supports the CDFA's conclusion that there is no hydrilla in the Delta at this time.

SUMMARY AND CONCLUSIONS

The CDFA's Hydrilla Eradication Program has been a cooperative effort since the first discovery of hydrilla in Marysville in 1976. The Governor, Legislature, and the CDFA recognized the threat hydrilla posed for the State of California and quickly instituted the legal framework needed to eradicate this aquatic, noxious weed. With the operational and technical support of many cooperators, the CDFA Hydrilla Eradication Program has been operating successfully ever since.

From the beginning, the CDFA has used an integrated approach to hydrilla eradication. The CDFA has used physical methods (large-scale mechanical dredging, small-scale suction dredging, raking, manual removal, screening of outlets), biological methods (the triploid grass carp), cultural methods (draw down), chemical methods, and combinations of each. In each situation, the program has used the most appropriate method, or combination of methods, for that particular situation.

The CDFA is eradicating hydrilla from California. Many of the original, infested sites, such as Lake Ellis in Marysville and Lake Murray in San Diego, were eradicated several years ago. Many of the current infestations are approaching eradication. In 2003, only one hydrilla plant was found in Shasta County, and only one hydrilla plant was found in Clear Lake in Lake County. No hydrilla plants were found in the Springville ponds in Tulare County, and no hydrilla plants were detected in Eastman Lake or the Chowchilla River. Only two infested sites were detected in Imperial County. In addition, plant populations and tuber counts are decreasing in the Yuba County Water District Canal and associated ponds. A few plants continue to be detected in Calaveras County.

CDFA's survey crews continue to guard against new hydrilla introductions. The CDFA is dedicated to finding any new introductions in California in an early and relatively easy-to-eradicate growth stage. This is particularly true of the environmentally sensitive Sacramento/San Joaquin River Delta. In addition, the CDFA continues to work with cooperating agencies and researchers to develop new and more efficient survey technologies for hydrilla and other invasive plants.

In conclusion, the CDFA's Hydrilla Eradication Program is keeping California free of the establishment of the invasive, noxious aquatic weed, hydrilla.

COOPERATORS

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