Report of the Science Advisory Panel for the California Department of Food and Agriculture (CDFA) Hydrilla Eradication Program

Clear Lake, California

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Sponsored by California Department of Food & Agriculture (CDFA)

Integrated Pest Control Branch, Division of Pest Prevention

Hydrilla Eradication Program

I. Introduction

Assembled by CDFA Hydrilla Eradication Program Supervising Scientist, Dr. Patrick Akers, on October 22nd and 23rd, 2009, this Science Advisory Panel (SAP) investigated the historical and current eradication efforts against hydrilla (*Hydrilla verticillata (L.f.) Royle)* in Clear Lake, California. On October 22nd the SAP reviewed a CDFA broadcast herbicide application using one of the standard herbicides for the program (Sonar* SRP slow release pellet formulation; active ingredient: fluridone) and associated sampling and survey techniques for presence of hydrilla. The panel members met subsequently at the Lake County Agricultural Commissioner's Office in Lakeport, California, on October 23rd, 2009, for a full-day of discussion based on Patrick Aker's 1994 - 2009 synopsis of program operations. The SAP's discussion and recommendations for future program directions are addressed in this document.

A. Background and Problem Statement

Hydrilla is a major threat to California's water resources, including dangers to the viability of water delivery for irrigation, domestic and industrial uses, ecological threat to native species, as well as interference with flood control systems and recreational uses of waterways. Hydrilla in Clear Lake immediately threatens both localized in-lake uses and the greater Clear Lake ecosystem. Outside of the immediate impact to Clear Lake, hydrilla presents a risk of infesting Cache Creek and potentially, through hydraulic connectivity, some of California's most important water resources including networks of irrigation canals vital to California agriculture and the 1,000-plus miles of Sacramento - San Joaquin Delta (SSJD) waterways. In addition to this threat, the continued presence of hydrilla in Clear Lake provides the possibility of its transport to other waters of the state and region through water conveyance, boat traffic, and related recreational activities. Therefore, *eradication of hydrilla at Clear Lake is critical to protecting the State of California's water resources*.

However, eradication of hydrilla is a complicated and multi-year task due to its reproductive biology. Likely one of the most adaptable submersed aquatic plants and often referred to as the "Perfect Aquatic Weed“ (Langeland, 1996) hydrilla is able to regenerate itself four different ways: (1) fragmentation, (2) tubers, (3) turions, and (4) seeds.

B. Historical Survey and Treatment Protocols

From 1994 - 2009, the CDFA hydrilla eradication protocol has been based on the following premises: (1) intense detection surveys by boat crews visually scanning the water column and utilizing grappling hooks to physically collect, classify, and record locations of hydrilla; (2) herbicide applications to eliminate the potential for spread via fragments; (3) herbicide treatments to stop further production of tubers and turions; (4) continued herbicide applications for three years after the last detection to target remaining sprouting tubers; and (5) continued visual water column scanning and grappling hook surveys. If no hydrilla is detected within 3-years of consecutive treatments, treatments cease and surveys continue another 3-years. Eradication is declared when all these criteria are met. It must be noted that a hydrilla find at any time within a specified treatment area leads to starting the entire protocol over. The herbicides that are used control the existing hydrilla biomass. However, due to reproduction mechanisms of hydrilla, treatments are done in consecutive years to deplete the “propagule” bank (described below). Eradication requires either depleting or removing the propagule bank, which is not a trivial task. It has been reported that hydrilla can produce more than 4 million propagules per acre (primarily tubers and turions).

C. Program Efficacy and Resurgence of Growth

As a result of sustained program operations between 1994 and 2002, hydrilla was not detected in Clear Lake in 2003. Extensive seasonal surveys carried-out in 2004, 2005 and 2006 also found no hydrilla. However, in 2007, hydrilla was detected in Clear Lake after (4) years of apparent absence and continued to be found in several locations in 2009. It is highly probable that hydrilla tubers in the top layers of sediment, or "tuber bank", resulted in the re-emergence of hydrilla in Clear Lake waters during the 2007 and subsequent 2008 and 2009 observation periods. Hydrilla tubers have been known to lie dormant and viable for over 7-10 years in sediment and thus could become re-established even after many years of perceived absence. However, it is unclear what stimulated the tuber bank to sprout over a relatively large area after several years of dormancy, or whether monitoring/survey methods were inadequate to detect a “patchy” distribution of small plants that eventually reached “detectable” scale (size, number per acre).

D. Address Questions posed by CDFA and Identify Necessary CDFA Programmatic Changes

The SAP responded specifically to questions posed by CDFA Supervising Scientist, Dr. Patrick Akers, relating to programmatic treatment and survey operations at Clear Lake.

Treatments:

1. What improvements can be made to the current Sonar* SRP (active ingredient: fluridone) aquatic herbicide treatment regimen? This question most specifically related to the timing, frequency of applications, methods of application, and application total dose.

2. Is the current (3)-year consecutive treatment after last "known" hydrilla find a best practice? What is the best scenario for periods of follow-up treatment?

3. What are possible alternative herbicides? What is the possibility of combination treatments (multiple herbicides utilized simultaneously or sequentially)?

4. Are there methods of treatment or control other than aquatic herbicides or other integrated treatment options that should be considered?

Surveys:

1. What improvements can be made to the current survey design and efficacy evaluations?

2. What improvements can be made in assessing the status of the tuber bank?

II. Project Setting

A. *Hydrilla* Biology

1. Reproduction and Dispersal. Hydrilla can reproduce and disperse through four mechanisms: (1) **stems** fragmented and dislodged by boat propellers, wave action, fishing lines and waterfowl activity are able to spread hydrilla both within Clear Lake and within the region if a viable hydrilla stem fragment, or other propagule, is trailered out of Clear Lake and into another system; (2) **tubers** (botanically referred to as "subterranean turions") are produced on the tips of downward-growing shoots in the top layers of sediment (2 to >20 cm deep) and these can remain viable for several years; (3) **axillary turions** are produced at the leaf axils (shoot nodes) and thus capable of efficiently spreading hydrilla within Clear Lake since shoot fragments with these turions can drift; and (4) **seed production** is also possible since the infestation at Clear Lake is a monoecious biotype (both male and female flowers are present on the same plant), but seeds have not been found in Clear lake to date. *It should be noted that the CDFA protocol stated above should also preclude seed production since herbicide treatments should prevent plants from reaching the flowering stage.*

2. Growth. Hydrilla is able to tolerate a wide variety of water quality conditions. It has the ability to grow in water depths from a few inches to depths of greater than 20 feet if water is clear enough to allow sufficient light to penetrate to those depths. There are a few relatively deep zones in Clear Lake but these are minority areas compared to the majority of the shallow lake bottom (see "B" below).

B. Environmental Geography of Clear Lake

Located at 1,329-feet in elevation, ~44,000-surface acre Clear Lake is the State of California's largest natural lake completely within the limits of state borders. Twenty-miles long and eight miles wide with ~100 miles of shoreline, this shallow, eutrophic water body has an average depth of 26 feet separated into two main basins: the main basin and lower arms connected by a high energy exchange narrow. The main, bowl-like basin is relatively shallow and mean depths are less than 26 feet whereas the lower arms are deeper (maximum depth 60 feet) and average depths are greater than 26 feet.

Clear Lake is a warm, nutrient rich water body. Average temperature between May 1st and December 1st is 60 degrees Fahrenheit. Waters are usually turbid and clarity is often less than 1.5 feet, especially after July each summer due to algal blooms. The main basin, with its shallow depths, provides habitat for large communities of dense aquatic weeds. These communities are not dominated by hydrilla due to ongoing eradication efforts, but both native and non-native pondweeds are dominant. It should be noted that hydrilla makes up only a very small percentage of the overall aquatic plant community due to aggressive management.

Predominant weather patterns in the Clear Lake basin provide wind-filled days producing rough, powerful, fetch-based swells on Clear Lake. Prevailing winds normally move from west to east across the lake body. The combination of shallow depths and persistent wind create an environment with the potential for a great deal of water movement and vertical mixing throughout the water column. Thus there is essentially no thermal stratification.

Sometimes referred to as the *Bass Capital of the West*, Clear Lake waters serve many recreational and tournament-based freshwater anglers. In a typical year, Clear Lake hosts more than 150 events with boats transported in-and-out of the basin. While this is an enormous boost to the Clear Lake economy, it is a pathway for the spread of hydrilla *and* associated non-native invasive aquatic plants (and animals).

Clear Lake waters empty into Cache Creek at the eastern reach of the lake (See Clear Lake Management Units Map in Figure 1 on following page 7). This potential dispersal pathway is considered a threat to receiving waters of Cache Creek; specifically, a direct pathway, via the Yolo Bypass, leading into the Sacramento - San Joaquin Delta and numerous irrigation districts.

III. Review of Current Project Challenges and Methods

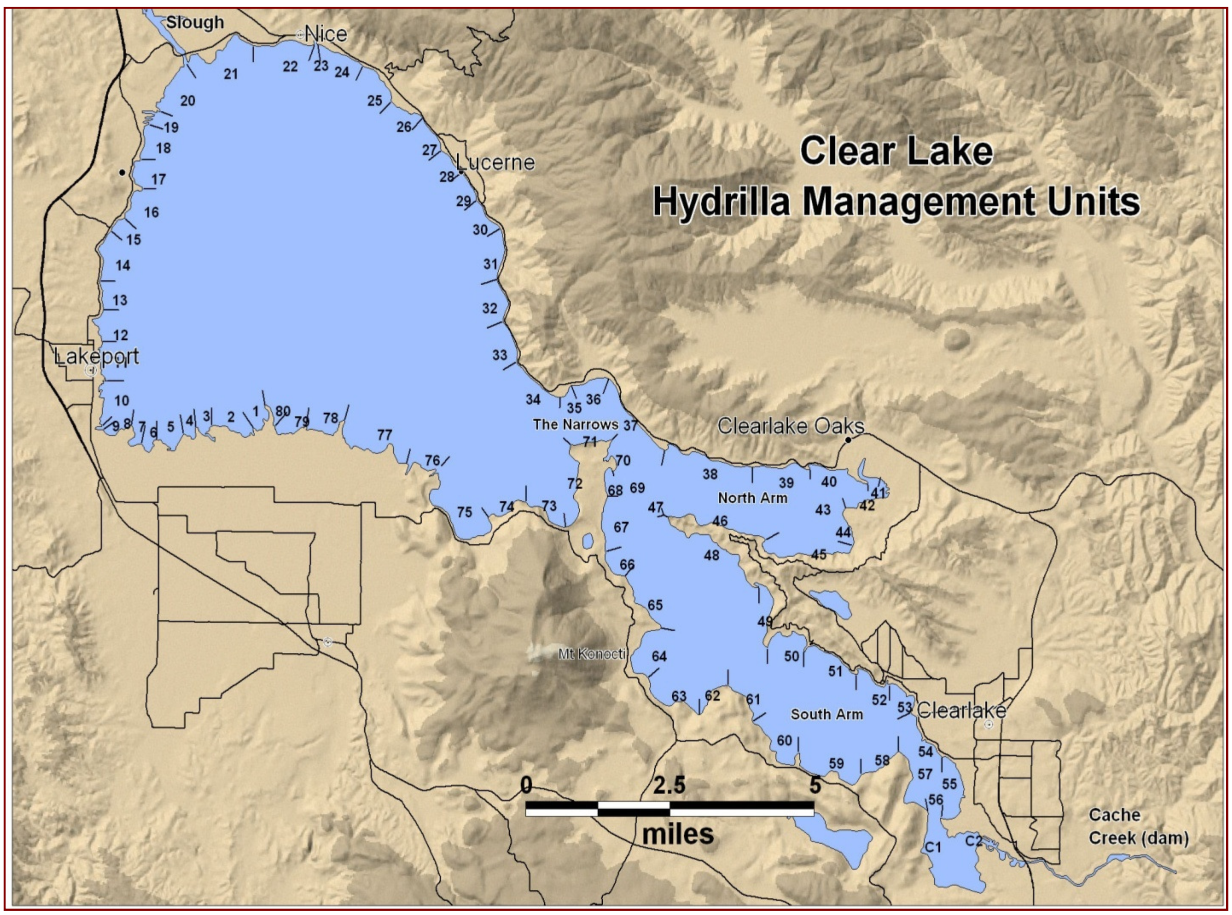


Figure 1. Clear Lake *Hydrilla verticillata* Management Units.

A. Environmental Challenges

The combination of moderate-to-high wind velocities, water movement, generally high turbidity (low visibility) shallow water, and dense submerged aquatic weed beds complicate field operations for surveys (monitoring) and herbicide applications.

B. Logistic Challenges

Clear Lake's very large surface acreage (~44,000-acres) provides multiple logistical difficulties for CDFA's Hydrilla Eradication Management. The number and sizes of the areas slated for survey and treatments appear to exceed the current projected resources (personnel, equipment, and supplies).

C. Basic Work Unit = Management Unit

Figure 1 shows the +/- 85 management units around the lakeshore. Primarily organized to assign seasonal surveys, these management areas are based on shoreline landmarks and are not equal in length or total area. Typically, management units extend 500 - 800 feet from shore or out to the 15 - 20 foot bathymetric depth contour zone that is the assumed limitation of hydrilla colonization in Clear Lake. On a typical survey day, each boat crew of (3) surveys (2) management units. Combined with 100 miles of shoreline, the CDFA Hydrilla Eradication Program requires *surveying and possibly treating more than (11) square miles of Clear Lake waters*. This is a very large undertaking for multiple years and needs to have resources commensurate with the task.

D. Strengths and Weaknesses of Current Survey Method

Currently, search patterns within each management unit are undirected, unrecorded, and generally unsystematic. Typically an airboat travels in a zigzag pattern from shoreline to deeper waters and back during each survey period while surveyors visually scan near-surface waters for floating hydrilla fragments or subsurface plants. The search intensity (area searched or time spent per acre) within each management unit is not standardized. A custom made, small grappling hook is simultaneously dragged behind the boat to snag plant stems in the non-visible layers of the water column to bottom substrate. The procedure for deploying the grappling hook is not standardized (distance and direction from the boat that the hook is thrown, duration of the drag). It is therefore impossible to pinpoint the location that a snagged plant was originally growing at once it is pulled into the boat. When a floating fragment ("floater") is found, the near-region search intensifies and all *floaters* are captured. When an *intact plant* is located, the survey hooking ceases, an approximate latitude/longitude is recorded and called into management, and a preliminary treatment is initiated.

Each management unit is surveyed between (7) and (9) times per season and *comprises 80 - 85 percent of the total eradication project effort*. A single boat crew spends 3 to 4 hours searching a typical management unit, though units vary in size. While survey crew members can identify all common submerged aquatic vegetation in Clear Lake, crews do not record the relative (percent) composition of species since they are focused on hydrilla. Additionally, the size (e.g. length) of hydrilla found is not recorded.

A *find* is anything from a single plant fragment to a large topped-out plant. There is currently no attempt to measure the efficacy of the survey methodology. In other words, there is no measure of the crews' ability to find a plant that is "known" to be present. Although significant resources are spent surveying the lake, there is no gauge of efficiency of the survey methods and how much confidence can be estimated of finding a single hydrilla plant in 11 square miles, under water, visually looking down from a boat or dragging a grappling hook. Current survey techniques might be more capable at finding beds of plants or documenting relatively large areas, but more unlikely to find single plants, small plants sprouting from tubers, or small infestations. For eradication, it is critical to find hydrilla at the single plant stage or in small quantities before the plant can become established and fragment or produce tubers. Research has shown hydrilla can go from a tuber to producing a new tuber in as little as 30 days.

The impact of personnel changes year-to-year on survey efficiency is also unknown, but expected to have some impact as new employees are trained. Training of new personnel is critical on both survey methods and plant identification, and formal protocols should be established and written moving forward.

IV. Project History Summary

A. Survey Results 1994 - 2003 versus 2007 - 2009

Figure 2 is a synoptic, GIS-based portrayal of hydrilla finds between 1998 and 2009.

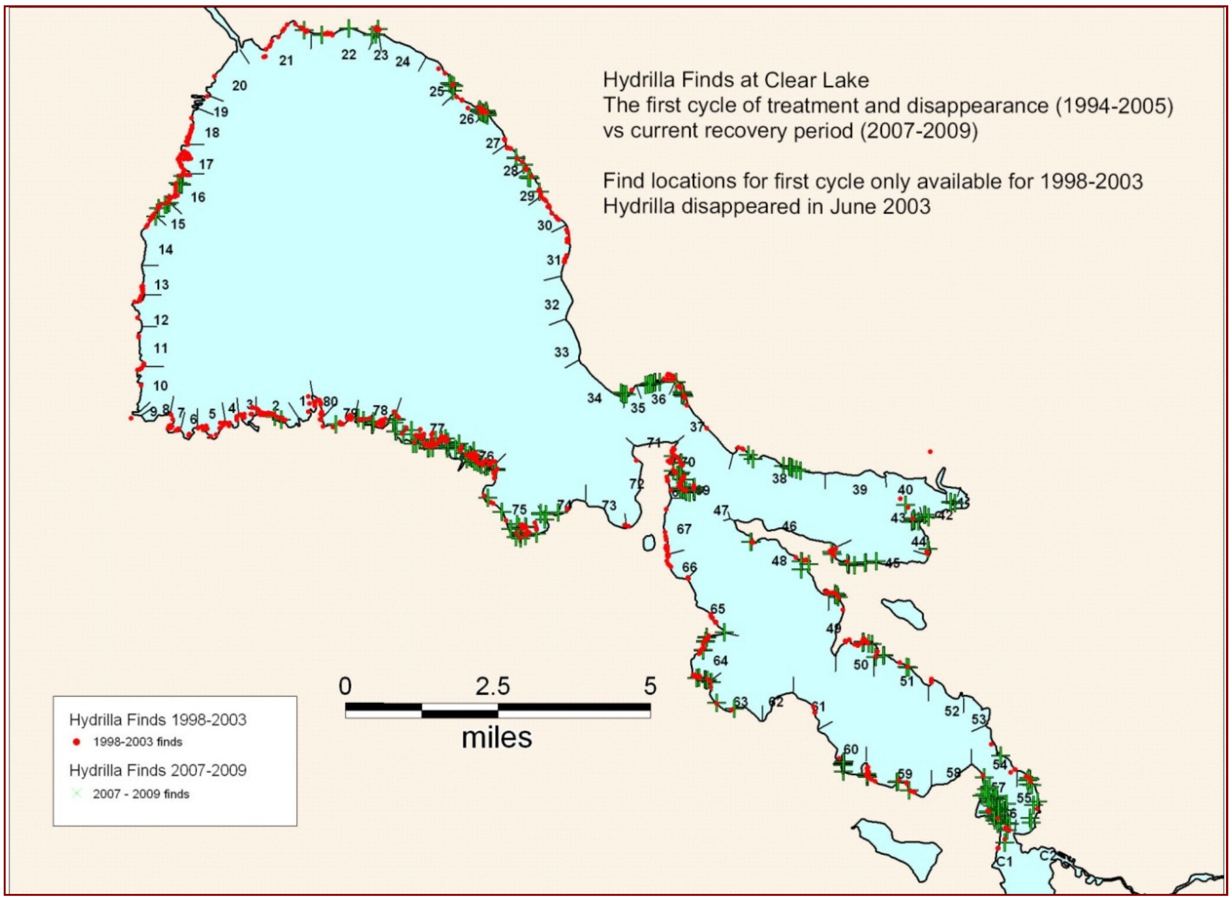
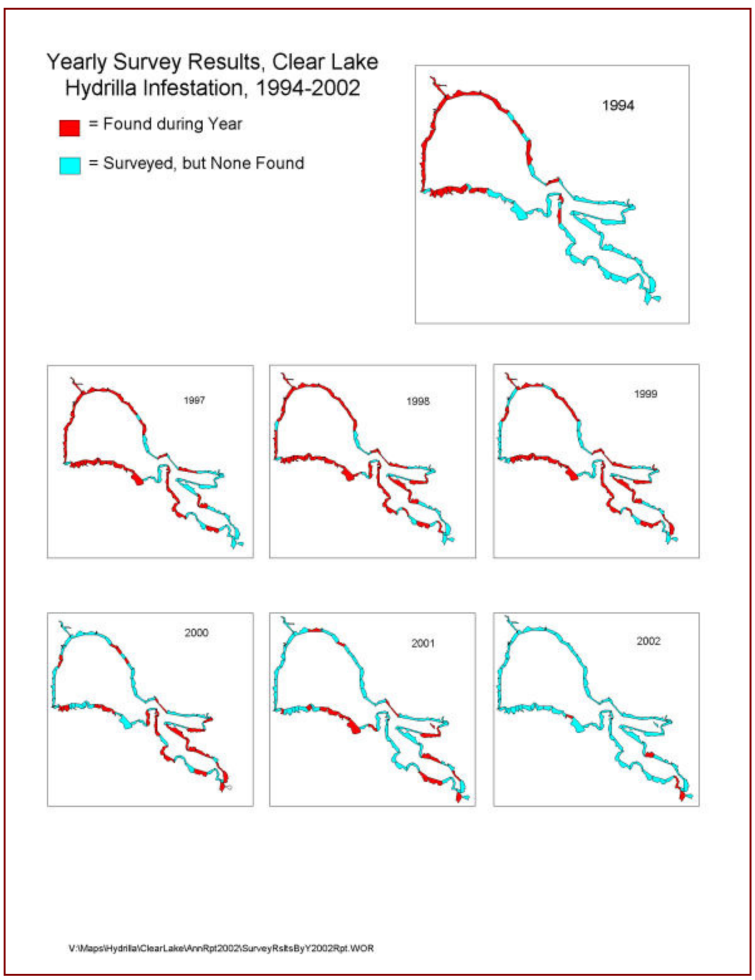


Figure 2. Clear Lake *Hydrilla verticillata* Finds Per Management Units – 1998 to 2009.

B. 1994 - 2003

In 1994, hydrilla was originally discovered predominately on the west and southwest shores of Clear Lake and in more sparsely scattered amounts in the northern reach of the main basin. During the time period stretching from 1994 - 1998, the densities of colonization decreased in the original region but like the prevailing westerly winds blowing across the lake, hydrilla continued to spread eastward. As the program chronology continued, project year 1999 marked the first time hydrilla completely disappeared from a number of the management units that were found infested in 1994. The 1999 - 2001 project years continued the trend of the mid- to late 90's: hydrilla infestations continued to spread eastward but the infestations in previous units continued to disappear. Year 2002 surveys proved the lowest number of hydrilla finds since 1994 and *by June 23rd, 2003, there was no vegetative hydrilla found in Clear Lake*.

Figure 3. Clear Lake *Hydrilla verticillata* Finds Per Management Units – 1997-2002.



C. 2004 - 2006

As a result of 1994 - 2003 program operations, *hydrilla was not detected in Clear Lake waters from June 2003 - 2006*. Due to this result and following standard protocol, treatments took place in 2005 but no treatments were initiated in 2006. Survey protocol remained on schedule in 2006.

D. 2007 - 2009

Hydrilla reappeared in project year 2007 and as a result, treatments resumed. During 2007, 72 hydrilla finds were scattered throughout the lake. The number of scattered finds increased in 2008 to 196, but regional areas of greater hydrilla frequency were also detected. In 2009, likely as a result of treatments, the number of hydrilla finds reduced to 76 lake-wide. Some regional hydrilla acreage and biomass "hot spots" were recorded each year during 2007 and 2009 while other hot spots were detected in only a single year. Spatial distribution of hydrilla during 2007 re-emergence through 2009 was similar to distribution between 1994 - and 2003. As a result of the hydrilla resurgence between 2007 and 2009, total treated acres increased from 248 acres in 2007 to 719 acres in 2009.

E. Summary Table 1994 - 2009

Please see following page 13 for **Table 1: Acres under treatment and numbers of finds, by year, in the Clear Lake Hydrilla Eradication Project.**

Table 1: Asterisk references.

*: The meaning of "acres infested/treated" appeared to change during the course of the project as treatments shifted from herbicide active ingredient copper to fluridone, approximately 1996-1998. Until about 1998-1999, treatments appeared to be more tightly limited to the areas that were actually thought to contain plants. Later treatments with active ingredient fluridone allowed for buffers around plant finds. The expansion of treated area after 1998 reflects increased buffer size more than any expansion in the number or area of plants. Currently, a single plant, even a single stem, leads to treating a five-acre square centered on that find.

**: A find can be anything from a single stem caught on a sampling hook to a topped-out patch several meters in diameter.

***: Too abundant to quantify. In the first year, many of the "Acres Infested" represented solid stands.

Table 1: Acres under treatment and numbers of finds, by year, in the Clear Lake Hydrilla Eradication Project 1994 - 2009.

Year	Acres Infested/Treated*	Number of Finds***
1994	425	***
1995	532	***
1996	646	218
1997	648	207
1998	870	197
1999	957	144
2000	1149	78
2001	1135	47
2002	1440	13
2003	1256	1
2004	520	0
2005	219	0
2006	0	0
2007	248	72
2008	599	196
2009	719	76
Total	**11,363 acres**	**1,249 finds**

F. Treatment Methods and Regimens

1994 - 2003

Based on 1994 protocols, sites having new hydrilla finds were treated first with a chelated copper-based contact herbicide (e.g. Komeen*) at 1 ppm to immediately burn-down and decrease plant biomass to prevent potential for fragmentation and thereafter treated with fluridone-based Sonar* SRP. In the event of large hydrilla biomass, a second application of chelated copper may have been utilized. The Sonar SRP treatment was generally 140 ppb per year. This was applied over (7) treatments at 20 ppb ~every two weeks between May 15th and September 15th. This concentration was based on 6 feet of water – not calculating the actual average depth for the individual site.

When hydrilla was not identified in surveys from a treatment area during 1994 - 2003, the 140 ppb Sonar* SRP regime was continued for one more year with reductions in concentration in subsequent years: 120 ppb the second year and 100 ppb for year three. If no hydrilla was detected in year four, treatments ended and surveys continued.

During this project era (1994-2003) specific treatment areas were not mapped; rather, mapping was based on pre-defined numbered management units and treatment areas were marked on the water by floating buoys.

2007 - 2009

During 2007 through 2009 a new hydrilla find was treated using the same protocols as in the prior years, with the following exception. The current CDFA Sonar SRP applications vary from the earlier protocol by utilizing 125 ppb per year, carried-out over (5) applications at 25 ppb each at five week intervals between mid-May and late-September. New hydrilla finds after August received 50 - 80 ppb prorated throughout the balance of the treatment season.

G. Project Resources and Costs

With a current annual project budget for Clear Lake of approximately $1 million per year, project resources are stretched and equipment appears to be dated. The program currently has a vehicle/vessel pool of (5) airboats (three 15 + years old), (2) general power boats, and (5) tow vehicles. This equipment is staffed by (4) boat crews with three staff members per boat.

In 2008 project cost was approximately $1.02 million. This was allocated as follows: $104,000.00 for contact herbicides (chelated coppers), $587,000.00 for systemic herbicide (Sonar SRP), $250,000.00 for seasonal boat crews, and $80,000.00 for miscellaneous logistics including water sampling, vehicle operation and maintenance, supplies and small equipment, and administrative support from Sacramento.

V. Scientific Advisory Panel Recommendations

A. Survey Method Efficacy Assessments

1. Panel recommends CDFA should devise a system to measure the efficiency of hydrilla detection, and establish criteria for acceptable detection. For example, develop protocol for utilizing fake (ersatz) "hydrilla" targets to quantify efficiency and efficacy. For example, rope loops on submerged pipe frames may be utilized in pre-determined management units. Alternatively, plastic plants are available that resemble hydrilla; these could be weighted, combined to various "colony sizes" (e.g. 0.1 m^2, 0.5 m^2, 1 m^2), tagged with a code (by location) and their locations mapped using GPS. The survey crew would not know the locations. A similar program used in the *Caulerpa taxifolia* eradication program in southern California may serve as a model for designing the efficacy assessment. Other options include using plastic plant combined with living native plants such as sago pondweed to provide a more natural physical structure.

Crews should have at least one high quality underwater camera w/ lights and telemetry (cable) to a surface monitor so that when somewhat clear conditions occur, visual searches can be made in "hot spots" or other treatment areas. Alternatively, snorkeling and/or diving could be an option when conditions are favorable.

2. Employ GPS/GIS-based systems for recording all survey tracks and positive detection events to verify complete coverage per management unit area. The position of every hydrilla detection should be recorded with differentially-corrected GPS (DGPS). DGPS units should be easy to operate for all staff members in order to maintain ability and focus for visually scanning waters. Eradication surveys warrant high resolution DGPS, however, the cost of accurate and precise units should be in-line with overall project budget permitting units on each survey boat.

3. Create GIS-based survey grids to guide survey navigation and enable repeatability and continuous, complete coverage through time in individual management zone. All vessel operators should use DGPS to navigate.

4. Establish specific protocols to insure consistency in survey effort (specifically time) spent per unit area. Thus, regardless of the management zone size, a similar amount of effort is spent on a per acre basis. Systemize hooking methods: length of rope, maximum amount of time dragged, direction cast from boat (behind, to the side), etc. For seasonal employees, produce a simple training video for survey methods that should be reviewed at least twice annually that includes hydrilla identification.

5. Program should experiment with different under-water raking equipment and methods including, but not limited to, a thatch rake, hooking device, etc. and establish a standard written protocol. The efficiency of plant retrieval should be determined by using fixed "time and distance raked" in areas that have dense and sparse submersed weed populations either at Clear Lake or in other suitable waters.

6. Create survey protocols for varying intensities of searching in herbicide-treated versus untreated areas. More intense surveys should be conducted in areas not under treatment.

7. Quantify areal coverage (size) or surface area of hydrilla finds by category (e.g. floating fragments, intact plant, etc.) to estimate the size of the hydrilla find. Record presence of turions and condition of plant tissue if within a herbicide treatment area. These data can be obtained as part of the survey protocols and GIS documentations recommended in items 2 and 3 above.

8. Survey interval should be 3 – 6 weeks and targeted to assess each management unit at least six times per season, assuming that more systematic surveys are adopted.

9. After contact herbicide treatment, panel recommends returning to hydrilla find locations to look for possibility of more plants. (See recommendation No. 1)

10. Consult with experts to develop a cost-effective, rapid assessment, quantitative mapping technology-based detection program for both *above ground hydrilla biomass* as well as *tuber bank detection* in the top sediment layers. With more than 11 square miles of low-visibility (less than 1.5 feet) waters to survey, it is especially critical to quantify regions with high tuber productivity. An effective survey is the first step in efficiently planning for dredging sediments and removing tubers from Clear Lake.

B. Tuber / propagule Longevity and Follow - Up Treatment Period

1. Panel recommends collection of tuber core samples to assess the tuber bank in areas where hydrilla is found, and research should be supported to estimate tuber bank longevity in Clear

Lake. A standard protocol should be developed for monitoring tubers in a minimum percentage of treated areas on an annual basis.

2. Three years of follow-up treatment after the last hydrilla find is not long enough based on program history, and findings from eradication efforts in other states (see Pickerel Pond, Maine and Lake Manitou, Indiana). This was an arbitrary time that was established based on available information. Although this protocol has worked relatively well for the CDFA eradication program on Clear Lake and other sites, revised, biologically-based criteria should be developed and utilized to determine appropriate follow-up period for treatment. For example, tuber depletion rates and viability should be a main determining factor. This period should be verified by research, survey, and field observations.

3. Potential for seed production should be re-examined. This could be done in conjunction with No. 1 above (cores).

C. Treatments

1. Decrease the active ingredient load in the Sonar SRP pellets (currently 5%) and/or decrease the pellet size to increase pounds-per-acre applied at same overall concentration to improve uniformity of coverage over the sediment. For example a “loading” of 2.5% would double the current areal coverage of pellets (i.e. pellets /acre).

2. Use tuber bioassays in sediments from untreated versus treated management areas.

3. Panel recommends collection of plants from treated areas for biochemical assessment of herbicide exposure to document plant response under site-specific conditions (e.g. pigment based or enzyme assays such as EffecTEST* for fluridone). Documenting hydrilla response to treatments would allow for potential modifications to standard treatment protocol to improve performance under certain conditions. Further, hydrilla that is found should be monitored for herbicide susceptibility as appropriate using an additional biochemical assay technique (e.g. PlanTEST* for fluridone).

4. Establish a cutoff date of September 1st for systemic herbicide treatments with Sonar SRP after a new hydrilla find is located. After September 1st, utilize contact copper treatments every 30 days until the active treatment season ends. Treatment end date each year should be seasonal, but generally by the end of October.

5. Although the current herbicide selections were assumed to perform as intended, the feasibility of using additional contact and systemic herbicides should be further evaluated for future incorporation into the program as necessary. Some alternatives may include endothall (e.g. Aquathol K) alone or in combinations with newly registered ALS-inhibiting herbicides (e.g. Clearcast (a.i. imazamox) and Galleon SC (a.i. penoxsulam)), as well as diquat (e.g. Reward) and others that may be registered in the future.

6. Alternative methods for eradication should be further explored. Specifically, one such relevant method appears to be dredging and/or sediment removal at the site of hydrilla documentation to remove tubers. This could lessen the time required to deplete the tuber bank and achieve eradication. In order for successful, cost-effective dredging, sediment characteristics should be quantified and qualified in addition to the accuracy of survey measurements. More accurate documentation of the exact hydrilla find is necessary to pinpoint the location through enhanced and more accurate survey techniques to pinpoint the location. At a minimum, dredging should be evaluated at a pilot scale, with initial emphasis on relatively small infestations or isolated finds.

7. Quantify logistics for appropriate dredge sites including size of site and distance to sediment disposal sites.

8. Consult with herbicide manufacturers or other experts to customize treatment protocols to specific characteristics of individual treatment areas instead of using a standard protocol for every site. Depending on the size and location of treatment areas, and overall infestation of hydrilla, treatments may be adjusted that still ensure successful control of existing biomass.

9. Due to the proximity to the mouth of Cache Creek, current abundance of hydrilla, and based on previous growth and presence trends, treat the entire management units (56 - 57) in the lower arms Indian Island Region estimated at ~1,000-acres.

10. It is recommended that the whole lake littoral zone area be considered an eradication site, not simply specified management units or areas.

11. Alternative eradication strategies including grass carp, herbivorous insects, fumigants, and draining-the-lake were discussed, but based on CDFA input and other considerations they most likely are neither realistic nor feasible. However, small, site-specific exposure/-draining may be feasible.

12. An anti-migration structure (trash rack) should be constructed at the Cache Creek Dam to stop the movement of hydrilla fragments downstream. This would require regular cleaning and maintenance, but many such structures are used at a smaller scale in many irrigation canals in the Western United States and California.

VI. Scientific Advisory Panel General and Administrative Recommendations

A. Research to Stimulate Sprouting

1. More research should be conducted on methods or mechanisms to overcome dormancy in hydrilla tubers to determine if there are possibilities that haven't been explored.

2. Alternative systemic herbicides to fluridone that have been shown to inhibit propagule production should be evaluated (e.g. ALS inhibitors: penoxsulam, bensulfuron methyl, etc.).

B. Regulatory Initiatives

1. Utilizing methodology similar to other regional programs in place, vis-a-vis Lake Tahoe, set-up boat inspection stations at boat ramps and/or heavily-traveled highways entering or exiting the Clear Lake Basin. This would require training of inspectors.

C. Scale of Required Resources

1. With over 11 square miles of suitable hydrilla *habitat* to survey and possibly treat, the scale of CDFA resources should be ramped-up to be equivalent to the money per unit area granted to the successful *Caulerpa taxifolia* eradication effort in Agua Hedionda Lagoon and Huntington Harbor in Southern California. Based on analysis, the program realistically requires a minimum of $2 million of additional funding per year. Thus, a *total* of $3 million per year is needed.

D. Scientific Advisory Panel to reconvene in October 2011

1. October 2009 meeting in Clear Lake was to brainstorm and spearhead program adaptation and evolution. In order to measure success and adapt to success/failures of suggested protocol changes, group should meet in ~October 2011.

E. Confirm hydrilla eradication is possible

1. All four panel members firmly stated that in their respective professional opinion, eradication of hydrilla in Clear Lake is possible with an increase in resources and methods available (e.g. dredging) for realistic programmatic operations.

F. Documentation of SOPs on Treatment and Survey Methodology

1. Develop written, adaptive and flexible, SOPs and/or guidelines on treatment and survey and treatment methodologies. These should be reviewed at least annually by CDFA and all new crew/staff should be familiar with them and properly trained on each operational activity.

G. Additional Permanent Staff

1. The size of Clear Lake and the importance of this eradication effort quantify and qualify the necessity for securing funds for additional permanent staff to cover not only current workload, but enable program innovation and necessary improvements.

H. Collaboration with partner agencies and research groups

1. Panel strongly recommends continued collaboration with partner agencies and research groups including, but not limited to, the California Department of Boating & Waterways Aquatic Weed Unit, the USDA Agricultural Research Service, and the California Department of Water Resources.

I. Percent of Budget for Focused Research

1. Where and when questions arise in program operations, a percentage of the budget should be applied to focused and applied research specific to the Clear Lake hydrilla eradication program. This money could be used to evaluate survey techniques, hydrilla tuber dynamics, dredging, and alternative eradication methods.

J. Agenda with California Invasive Species Council

1. Communication and same-page status should be achieved with the California Invasive Species Council in order to promote program understanding and gain a regional, if not state-wide, understanding of the Clear Lake Program.

K. Contingency plan to eradicate hydrilla from Cache Creek and SSJD

1. With the viability of hydrilla making its way towards Cache Creek and into the waters of the SSJD, a CDFA-sponsored contingency plan should be developed with other agencies and water districts for rapid response to such a downstream infestation.

L. Umbrella plan for SSJD

1. The survival of the peoples and cultures of the State of California is commensurate with the viability of Sacramento - San Joaquin Delta. The unique and complicated estuarine system, dictated by the tidal exchanges of ocean and rivers, presents an enormous challenge for managing exotic invasive submerged aquatic vegetation. It is therefore essential that stake holding agencies develop a specific, rapid assessment and response plan for eradicating hydrilla from SSJD waters in the event hydrilla is found in this system.

VII. Works Cited

Langeland, K.A. 1996. *Hydrilla verticillata* (L.F.) Royle (Hydrocharitaceae), "The Perfect Aquatic Weed". Castanea 61:293-304

http://www.in.gov/dnr/fishwild/files/fw-Lake_Manitou_AVMP_2009_Update_Fulton_County_Feb_2010.pdf