Evaluating Impacts of LakeMaid Plant Control

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Abstract

The LakeMaid is a mechanical control technique for removing nuisance aquatic vegetation in small areas around docks. Direct impacts of the LakeMaid on water quality and the potential for spread of viable plant fragments were evaluated in this study. Analyses of water nutrient concentrations (total and dissolved phosphorus, nitrate and nitrite, and organic carbon) and measurements of conventional water quality parameters, as well as fragment density were conducted over a 10-day treatment period. A mesocosm experiment and plant biomass and nutrient estimations were also performed. The LakeMaid successfully removed all plant biomass without affecting nutrient concentrations or water quality in the treatment areas. The likelihood of spreading plant fragments is high, but in areas of extensive infestation, like the San Joaquin River Delta, this may not be a management concern. In general, the LakeMaid proved to be a successful, cost-effective, low maintenance plant control method for small areas where additional plant fragmentation is tolerable.

Key Words: mechanical control, fragments, re-growth, San Joaquin River, Egeria densa, Ceratophyllum demersum

Introduction

Introduced aquatic plants impair the use of water resources in many ways. Problems associated with exotic plants include degradation of water quality, interference with flood control measures, obstruction of boat traffic, and decreased recreational opportunities (Madsen 1997, 2004; Pimentel et al. 2000). The LakeMaid was invented as a non-chemical control method for small areas (up to 230 m^2 at a time), particularly around docks, in water bodies that are infested with invasive plant species. Rooted plants are removed from the sediment and captured by underwater rakes that are pulled by a water pump driven floating arm. The floating arm cycles back and forth in an arc from a fixed attachment point. Arm length and cycling frequency can be modified as can rake depth. This study evaluates whether the LakeMaid can effectively eliminate nuisance plants from the treatment area and the potential impacts of this method on the nearby ecosystem. The LakeMaid has been well publicized (Kretsch 2003) but not yet independently studied. Potential impacts of this mechanical control method include water quality changes and production of viable fragments.

The Sacramento-San Joaquin River Delta (California, USA) is impacted by introduced plant species, including *Egeria densa* (Brazilian Egeria) and *Eichhornia crassipes* (water hyacinth) (Bock 1969; Anderson 1990; California Department of Boating and Waterways 2001). Control of these plants using pesticide applications entails potential risks to both humans and wildlife. Due to the Talent decision (243 f. 3d 526 (9th Cir. 2001) Headwaters, Inc. vs. Talent Irrigation District, the U.S. Court of Appeals for the Ninth Circuit), National Pollution Discharge Elimination System (NPDES) permits and requisite monitoring are now required in California for application of aquatic herbicides. The permitting and monitoring costs have added considerable expense to chemical pesticide control options (Siemering 2004). Not only is the examination of alternative control methods required in NPDES permits, but the study of such methods may identify techniques that small businesses, including marinas, resorts, and other shoreline property owners may find useful, where the high regulatory costs of chemical pesticide applications make them prohibitive.

The Aquatic Pesticide Monitoring Program, funded by the California State Water Resources Control Board, evaluated many non-chemical alternative control methods (Greenfield et al. 2004). One major concern with mechanical plant control methods is the spread of plant infestations due to an increased production of plant fragments. For species like *Egeria*, *Ceratophyllum demersum* (coontail), and *Hydrilla verticillata*, which reproduce by stem fragments (DiTomaso and Healy 2003), the production of viable fragments can cause re-infestation of a treated area or spread infestations to new regions. Long-term water quality impacts from re-suspension of particle-bound nutrients and other contaminants that were immobilized in the sediment are another concern, particularly for treatments which disturb sediments (Getsinger et al. 2002).

We performed an experimental application of the LakeMaid at three marina docks to evaluate its cost effectiveness and environmental impacts. Paired treatment and reference stations were monitored for effects on water chemistry. The treated areas were sampled before and during treatment to assess the extent of fragment production, and a mesocosm study was set up to evaluate whether fragments in the treatment areas were viable. Finally, information was compiled to evaluate cost effectiveness of the LakeMaid.

Materials and Methods

Site Description

Three marinas in the San Joaquin River Delta were chosen as study sites (Paradise Point Marina, King Island Resort, and Ladd’s Stockton Marina) (Figure 1). They were all located on either the San Joaquin River or Disappointment Slough, within a six-mile radius of one another (within latitude N 37°58.616’ and N 38°03.394’ and longitude W 120°25.077’ and W 121°27.518’). At each marina, one treated site and one reference (untreated) site was established. The distance between treated and reference sites was 100 – 300 m. The sites were near frequently used boat slips and docks. The selected marinas had dense vegetation (more than 50% of the area covered by submerged plants). *Egeria* and coontail were the most abundant plant species at the study sites and therefore used in the mesocosm experiments. Both reproduce vegetatively by turions and stem fragments. *Egeria* produces neither fruits nor seeds in the western United States, whereas coontail also reproduces by seed (DiTomaso and Healy 2003). Additionally, *Lemna minuscule* (duckweed), *Cabomba caroliniana* (fanwort), *Chladophera spp*, *Myriophyllum hippuroides* (western water milfoil), *Hydrocotyle ranunculoides* (floating pennywort), and water hyacinth were present in minor amounts.

The study sites were subject to tidal cycles but salinity remained below two parts per thousand. A week with moderate tides was selected for evaluation of treatment effectiveness and ecosystem impacts. Prior to treatment, carbon, nitrogen, and phosphorus concentrations in the water column were determined at all marinas. No significant differences between the treatment and reference sites were observed for these nutrients (Analysis of Variance $p > 0.05$ in all cases). All treatment and sampling events took place in July and August of 2004.

LakeMaids

Two 36-foot and one 20-foot long LakeMaid units (Lake Restoration Inc., Rogers, MN) were deployed, one per marina. The LakeMaids operated 24 hours a day for ten consecutive days. Areas of 50 m^2 at Ladd's Stockton Marina, 130 m^2 at King Island Resort, and 200 m^2 at Paradise Point Marina were treated. The machines use a standard 110 V power outlet and draw 12.5 amperes. The life expectancy of the machines is estimated to be 10 years by the manufacturer, with a shorter life-time in salt and brackish water. A P 4400 Kill A Watt^{TM} Power Meter (P3 International Corporation, New York, NY) was used to determine the electricity consumed over the study period. The consumption per kilowatt-hour was determined to evaluate the cost of operating a LakeMaid. The hourly rate was calculated for Stockton, CA, where Pacific Gas & Electric charges $0.11 per kilowatt-hour.

Experiment Overview

Water Chemistry

Water chemistry samples were taken prior to the start of the treatment period, as well as 24, 72, and 240 hours into the treatment at the six different sites (three treated and three reference sites). Water quality parameters analyzed included total suspended solids (TSS), dissolved organic carbon (DOC), total organic carbon (TOC), as well as total phosphorus and dissolved ortho-phosphate. Ortho-phosphate is the most thermodynamically stable and biochemically available form of phosphorus in natural waters (Snoeyink and Jenkins 1980). Nitrate (NO_3), nitrite (NO_2), and total Kjeldahl nitrogen (TKN) were also analyzed. Total nitrogen was calculated as the sum of NO_2, NO_3 and TKN. These parameters were analyzed by the California Department of Fish and

Game (Water Pollution Control Laboratory, Rancho Cordova, CA) and California Laboratory Services (Rancho Cordova, CA). Water samples were taken inside the treatment area at the midpoint boom rake radius, between sweeping cycles of the LakeMaid at 1 m water depth. Dissolved oxygen (DO), temperature, pH, electrical conductivity (EC), and turbidity were measured immediately below the water surface and at 1m depth at all stations using a WTW Multi 340i multimeter.

Statistical analyses of the LakeMaid treatment and reference plots were performed using repeated measures Analysis of Variance (ANOVA). Repeated measures ANOVA is an appropriate method for modeling changes in environmental variables measured repeatedly over time in the same experimental sites (Von Ende 2001). Repeated measures ANOVA was performed on each chemical parameter, with evaluation of overall changes over four measurement dates, in addition to the impact of the LakeMaid treatment on nutrient levels over time (i.e., a date by treatment interaction). All measurements were assessed for statistical significance by comparing the Huynh-Feldt Epsilon corrected p-value to an α value of 0.05 (Von Ende 2001). All statistical analyses were performed in SAS (SAS Institute 1990).

Mesocosm

Mesocosm experiments were conducted to investigate the potential for plant fragment re-growth. The fragment re-growth was evaluated on *Egeria* and coontail at the Paradise Point Marina. For each plant species, five gallon buckets were filled with 10 cm of relatively undisturbed sediment from the Paradise Point Marina reference site. Ten fragments of various lengths, generated by the LakeMaid, were planted into each of the first five buckets. Fragment size and number of nodes were recorded to document physical characteristics and determine the potential for re-growth (Sabol 1987). Five buckets were planted with ten intact plants from the reference site to function as a positive control in regards to overall growth conditions in the mesocosms. The remaining five buckets contained sediment only and no fragments, providing a negative control to show whether small fragments or coontail seeds were introduced into the mesocosm with the sediment. All buckets were closed with insect screen and rubber cords to avoid loss or mixing of fragments. The buckets were then secured with rebar at the bottom of a shallower part of the marina (about one meter depth at low tide) where the mesocosms were covered by water at all times. Four to five times during the test period, the insect screens were cleaned with a soft brush to maintain sufficient light exposure and water exchange for the plants. Repeated measures ANOVA was used to document significant changes in growth characteristics for the positive control and experimental plant samples over time (Von Ende 2001).

Measurement of Fragment Density

Plant fragment samples were collected before the LakeMaid operation, three through six days into the operation, and ten days after the start. Within the treated area, a three-gallon bucket sieve (0.5 mm diameter) with a floatation device was dragged for 10 m through the water with the mouth of the bucket perpendicular to the water surface. This method was repeated five times at random locations throughout the treatment area. Fragments were keyed, counted, and measured for wet weight, number and length of stems, and number of nodes. To determine differences in fragment characteristics, changes were assessed over three measurement dates at the three different marinas using repeated measures ANOVA (Von Ende 2001).

Plant Biomass and Nutrient Content

To evaluate the effectiveness of the LakeMaid, three grabs of plant samples were taken at each marina with a metal rake from the bottom of random areas inside the treatment zone. The rake samples were conducted at the beginning, the middle and the end of the study period. The plant material, collected by the rake with one swoop, was brought to the surface, spun in a salad spinner, and weighed to evaluate the efficacy and progress of the sweeping operation (Treibitz et al. 1993). Since the size of the area sampled with each grab may have varied, the results were only used to estimate relative changes in plant abundance over the course of the experiment.

Furthermore, 0.5 cubic meter of an untreated, shallower area was marked for plant density samples. A volume rather than an area was chosen for this experiment to capture floating as well as rooted plants. The plants in this volume were removed, keyed, counted, measured, and weighed. Characteristics determined included weight (wet weight per 500 liter), number of stem fragments per 500 liter, number of stem fragments per unit wet weight (stem density), and nodal distribution (number of nodes per stem).

To determine plant nutrient concentration estimates, eight plant samples were taken at the Paradise Point Marina and King Island Resort. Four samples were taken from the reference sites and four from within the treatment area at the beginning of the sweeping operation. Four of the plant samples (two each from the reference and treated areas) were collected in shallower areas (< 1 m depth) and four from deeper areas (about 2 m depth). After being dried for 48 hours at 80°C and ground to fine powder, the plants were analyzed for total nitrogen and total carbon using a Perkin-Elmer Model 2400 CHN analyzer with acetanilide as a standard (Eadie 1997). Tissue phosphorus was determined on dried ground samples using the method described by Anderson and Ingram (1993).

Control Costs

Information on purchase prices (http://www.lakerestoration.com), labor for installation and maintenance (personal communication with Kevin Kretsch, Lake Restoration, Inc.), and fees for electricity (personal communication with PG & E Stockton, CA) were compiled to evaluate the control costs of the LakeMaid. Chemical application cost included NPDES permit fees (U.S EPA, 1999), costs for herbicides and labor (personal communication with Jay Kasheta, licensed applicator for Cygnet Enterprises West, Inc.), and costs for monitoring and reporting (based on an average of analytical costs for northern California laboratories) were calculated for comparison purposes.

Results and Discussion

Water Chemistry

Repeated measures ANOVA provided no evidence that the LakeMaid operation influenced site water chemistry during the treatment period. Chemical parameters evaluated for statistical significance included dissolved oxygen, electrical conductivity, total organic carbon, total suspended solids, turbidity, total nitrogen, total phosphorus, and ortho-phosphate (Table 1).

No significant difference between the three LakeMaid treated and the reference stations was found for any of these chemical parameters during the treatment period ($p > 0.05$ in all cases). Dissolved organic carbon concentrations were predominantly non-detects. Graphical analysis indicated close correspondence between treatment and reference samples from each location, with no apparent difference resulting from the LakeMaid treatment (e.g., Figure 2).

The study results suggest that sweeping of selected areas is unlikely to have significant impacts on water quality. Few changes in water chemistry were observed at the experimental and reference sites, with slight fluctuations probably due to tidal cycles, since the variations at the treated and reference sites were consistent. The majority of samples were taken during slack tide after high tide but the exact sampling time relative to tidal cycles varied slightly among samples. The absence of strong patterns may be related to the small scale of this operation in comparison to larger scale mechanical harvesting projects (e.g., Carpenter and Adams 1976, 1978; Carpenter and Gasith 1978; Alam et al. 1996).

Mesocosm

A decline in the total number of plant fragments was recorded for the positive control and the experimental mesocosms for *Egeria* and for the experimental buckets for coontail using repeated measures ANOVA. Two to seven fragments per bucket disintegrated for coontail and two to ten fragments per bucket for *Egeria* (Table 2). The remaining experimental coontail fragments showed a slight increase in maximum length (7.6 cm) and maximum number of nodes (6 nodes) over the three-week test period (Table 2). However, no significant difference was displayed in comparison to the control regarding maximum length ($p = 0.77$; $N = 10$) and nodal distribution ($p = 0.17$; $N = 10$). For *Egeria*, repeated measures ANOVA suggested that the maximum number of nodes among remaining fragments of the experimental buckets increased significantly ($p = 0.002$; $N = 10$) compared to the positive control (Table 2). All negative controls showed no growth.

The observed increase in growth for coontail and *Egeria* fragments was expected because these plant species spread through fragmentation (DiTomaso and Healy 2003). Since these fragments were collected in close vicinity of the LakeMaid during treatment, the results suggest that the LakeMaid operation does result in viable fragment production. Decreasing fragment numbers for the positive control of *Egeria* were probably caused by high amounts of particulate matter being moved around during each tidal cycle. The insect screens covering the buckets closest to the dock rapidly overgrew with algae and filled up with silt. Even brushing the screens several times during the test period probably did not allow for sufficient light to the buckets at all times. Although DiTomaso and Healy (2003) stated that *Egeria* grows best under low light (± 100 lux) and that coontail tolerates low light levels, disintegration of plant fragments and occasional loss of leaves suggested that light may have been a limiting factor for the growth experiment.

Measurement of Fragment Density

Repeated measures Analysis of Variance did provide evidence that LakeMaid treatment influenced *Egeria* and coontail fragment production over time. A significant change was found in both the abundance (Huynh-Feldt Epsilon corrected $p = 0.048$; $N = 3$) and total mass (Huynh-Feldt Epsilon corrected $p = 0.030$; $N = 3$) of fragments collected over three sampling dates at the three treatment sites. Figure 3 indicates a substantial increase in fragment abundance and mass three to six days after LakeMaid installation, with a decline to original abundance and mass eight to ten days after installation. Repeated measures ANOVA did not provide evidence of changes in *Egeria* fragment average stem length or number of nodes, or in any coontail fragment attributes ($p > 0.05$; $N = 3$ in all cases) over the three sampling events.

Fragments of *Egeria* and coontail in all size classes were present in the samples taken within the treatment area. Fragments accumulated in bundles mostly around the dock where the LakeMaid swept them. Often fragments stuck to the rakes and were pulled along with the movement of the arm. The experiment indicated a similar increase in *Egeria* and coontail fragment mass and stem number after three days at all three marinas. Fragment mass was about 50 times higher at days three to six of the treatment period than it was before the start. The number of stems was approximately 35 times higher during the same time period. At day ten, fragment mass and stem numbers per sample were almost back to the initial occurrence at all three experimental sites.

The results of the fragment tests suggest that over a short time period (two to nine days) fragmentation of plants in the treated area will increase drastically, although plant fragments will be present at all times. In addition to the LakeMaid generated fragments, fragments can be generated naturally, by boat traffic, or by other mechanical control operations, and these fragments, regardless of source, can potentially cause reintroduction of new plants (Olem and Flock 1990). The manufacturer of the LakeMaid recommends an operation time of initially seven days to clear submerged aquatic weeds from an area. According to our results, after that time period, the generated fragments floating in the water seemed to have dispersed and only a slightly higher number of fragments remain in the treatment area after ten days (Figure 3).

Plant Biomass and Nutrient Content

In general, nuisance plant control was achieved in the treatment areas within ten days. For Paradise Point Marina and King Island Resort, rake plant biomass went almost down to zero at the end of the 10-day study period (Figure 4). In between day one and day six an average of 397 g of plant material was brought up with a single rake sample (range of 78 g to 1546 g). At day 10, treatment areas at both marinas showed almost no plants at the bottom. At Ladd's Stockton Marina, the weight of scooped up samples was evenly distributed over the sampling period with an average of 356 g for the nine samples taken (average on day 1 = 359 g, on day 5 = 313 g, and on day 10 = 397 g). At this marina, the plant material was initially very thick, and the rakes of the machine had to be positioned closer to the surface in order for the machine to function. Progress was made by lowering the rakes over time, but the clean-up of this area was not accomplished within the period of this study.

Plant tissue nitrogen (N) concentrations showed high variation in the King Island Resort samples. The overall mean tissue N differed among sites and depths (1 to 2 m), with an overall coefficient of variation of 42%. The shallow part of the reference site had the lowest mean value of 2.9%. The overall N:P ratios varied from 9.7 to 34.0 and were generally higher at King Island Resort compared to Paradise Point Marina, though there was no significant difference between the two sites (two-tail t-test: $p = 0.08$). The average N:P ratio for aquatic plants and algae is similar to that of terrestrial plants and lies at about 12 to 13 (Guesewell and Koerselman 2002; Knecht and Goeransson 2004). The high N:P ratio and lower P concentration seen at the deeper part of the King Island Resort, suggest a stronger phosphorus limitation (Cornett 2001).

Mean tissue C varied from 22.0 to 31.3% with a C:N ratio between 4.0 and 8.6. Relatively lower carbon concentrations (22 to 23% at Paradise Point Marina and 26 to 27% at King Island Resort) were observed for the reference sites of this study. Carbon concentrations in *Egeria* and coontail plant tissue were relatively low for summer sampling as compared to the 35 to 40% mean tissue concentrations determined by Spencer and Ksander (1999a). This resulted in lower C:N ratios than usual; seasonal and spatial variability are common in tissue nutrient concentrations (e.g., Spencer and Ksander 1999b).

Control Costs

In comparison to chemical treatment, the LakeMaid appeared to be a low cost method for small areas. It controlled plant growth in the treatment plots for about half the estimated cost of an application of Komeen (chelated copper) or Reward (diquat dibromide) in a similar size area. The initial purchase cost for each LakeMaid was approximately \$2,000, installation and maintenance (two visits) were \$600, and the electricity costs for the machine was estimated at \$0.07 per hour, (\$24 for the two-week treatment period). The cost for each LakeMaid operation thus totaled approximately \$2,624. The LakeMaid could also be repositioned within a marina to broaden the treatment area. For comparison, the current California aquatic pesticide NPDES permit fee is \$1,000, event-based monitoring, laboratory analysis, and reporting by a scientific consulting firm was estimated at \$4,000, and the cost for chemicals and labor was \$174, for a total cost of approximately \$5,174 (for an area of approximately 200 m^2). Both treatment types most likely would have to be repeated during the growing season, with additional chemical and monitoring costs for the pesticide treatment. In addition, amortization of the LakeMaid purchase costs over its ten year life span would result in considerably lower per anum costs when compared to chemical weed control.

Conclusion

The LakeMaid achieved the removal of nuisance aquatic plants from the marina near dock areas in a short time frame and appears to be a viable option for similar small areas needing control. Although the clean up was effective in the treated area, the fact that reproduction and dispersal of these plants via fragments of shoots and rhizomes (rooted or free floating) occurs indicates the need to consider additional factors when evaluating the effectiveness of the LakeMaid method (Parsons 1997; Anderson 2000; Greenfield et al. 2004). In the Stockton area, an increased fragment production of *Egeria* and coontail may not impose a higher risk for spreading the plant infestation, since these species are already widely distributed and cover about 3,900 acres in the Sacramento-San Joaquin Delta (Pennington 2004). In areas where there is little additional infestation, the increased fragment production by the LakeMaid could have significant consequences. Impacts on water quality due to the operation were not significant. An earlier treatment start date (e.g., in April or May) could have minimized maintenance effort and shortened treatment time due to less plant growth and less density in plant mats in spring and the beginning of the summer. In comparison to chemical treatments, the LakeMaid costs significantly less for treating very small areas of plant infestations.

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List of Tables

Table 1. Mean results and standard error for water chemistry parameters for all three treatment and reference (Ref) sites. Samples were averaged for 1 m and surface readings for conventional water quality parameters.

Table 2. Averaged mesocosm results and standard deviations for coontail and *Egeria densa*.

Table 1

Event	**DO** mg/L	**EC** µS	**pH**	**TOC** mg/L	**Total Phosphorus** mg/L	**Dissolved ortho-Phosphate** mg/L	**Dissolved Nitrate + Nitrite** mg/L	**TKN** mg/L	**TSS** mg/L
Pre	4.96±0.40	327±91	7.5±0.06	1.8±0.14	0.08±0.01	0.08±0.01	0.58±0.23	0.47±0.05	3.7±0.54
24 hrs	5.38±0.61	326±86	7.6±0.02	2.53±0.58	0.1±0.02	0.08±0.02	0.67±0.29	0.5±0.09	4.03±0.25
72 hrs	5.14±0.55	320±87	7.6±0.04	2.83±0.25	0.09±0.02	0.07±0.01	0.52±0.22	0.59±0.12	3.87±0.07
10 days	6.84±0.11	327±84	7.9±0.09	2.53±0.45	0.09±0.02	0.08±0.01	0.41±0.17	0.51±0.11	4.57±0.44
Pre-Ref	4.72±0.86	322±159	7.6±0.1	1.65±0.45	0.09±0.02	0.07±0.02	0.57±0.39	0.44±0.07	4.07±0.73
24 hrs-Ref	5.41±1.3	319±152	7.7±0.2	3.35±1.19	0.1±0.04	0.08±0.03	0.69±0.52	0.45±0.17	5.5±1.59
72 hrs-Ref	5.71±0.92	319±154	7.6±0.04	2.67±0.9	0.09±0.03	0.07±0.02	0.58±0.43	0.51±0.15	4.5±0.9
10 days-Ref	5.58±1.88	315±147	7.7±0.1	3.13±1.54	0.09±0.03	0.08±0.03	0.52±0.39	0.66±0.27	4.0±0.47

Table 2

		Coontail		Egeria	
Treatment	**Measurement Type**	**Start**	**End**	**Start**	**End**
Experiment	Max Length	35.2 ± 10.2	42.8 ± 19.6	34.2 ± 12.4	29.4 ± 13.1
Positive Control	Max Length	49.8 ± 21.5	46 ± 16.3	32.6 ± 11.6	10 ± 16.5
Experiment	Max Nodes	16.4 ± 4.7	22.4 ± 8.3	31.8 ± 13.6	48.6 ± 23.4
Positive Control	Max Nodes	20.6 ± 4.5	22 ± 5.3	39.2 ± 9.7	7.8 ± 12.3
Experiment	Number of Fragments	10 ± 0	6.6 ± 2.6	10 ± 0	8.4 ± 2.1
Positive Control	Number of Fragments	10 ± 0	10.6 ± 1.3	10 ± 0	0.8 ± 1.3

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Figure 1: Study area in the Sacramento-San Joaquin River Delta.

Figure 2. Total organic carbon concentrations at all study sites. Note that broken lines indicate treated site concentrations, solid lines indicate reference sites.

Figure 3. Measurement of fragment weight and stem density during the study period. Note log scale on y-axis.

Figure 4. Mean rake samples and standard error taken over the 10-day study period. PP = Paradise Point Marina, KI = King Island Resort, LS = Ladd’s Stockton Marina.

Figure 1

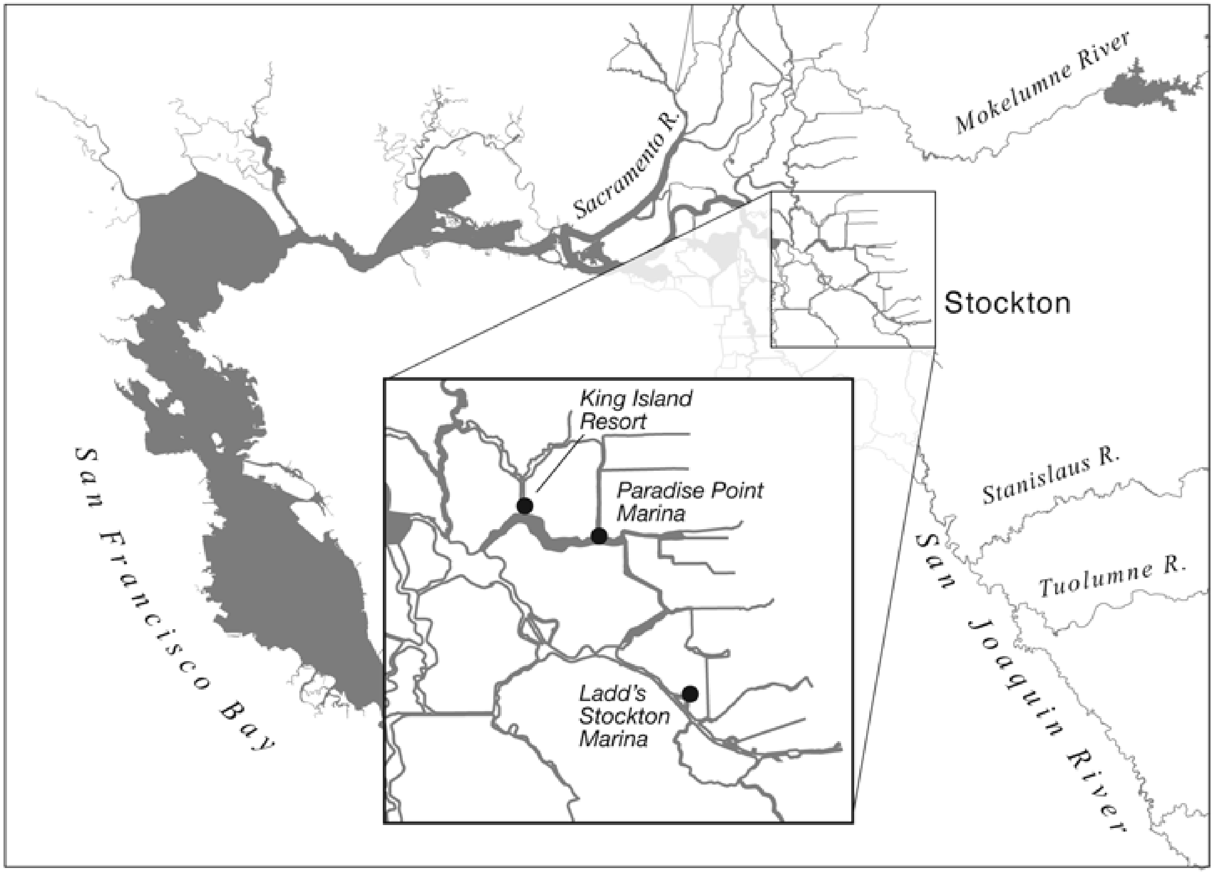

Sacramento R.
Mokelumne River
Stockton
King Island Resort
Paradise Point Marina
Ladd's Stockton Marina
Stanislaus R.
Tuolumne R.
San Joaquin River
San Francisco Bay

Figure 2

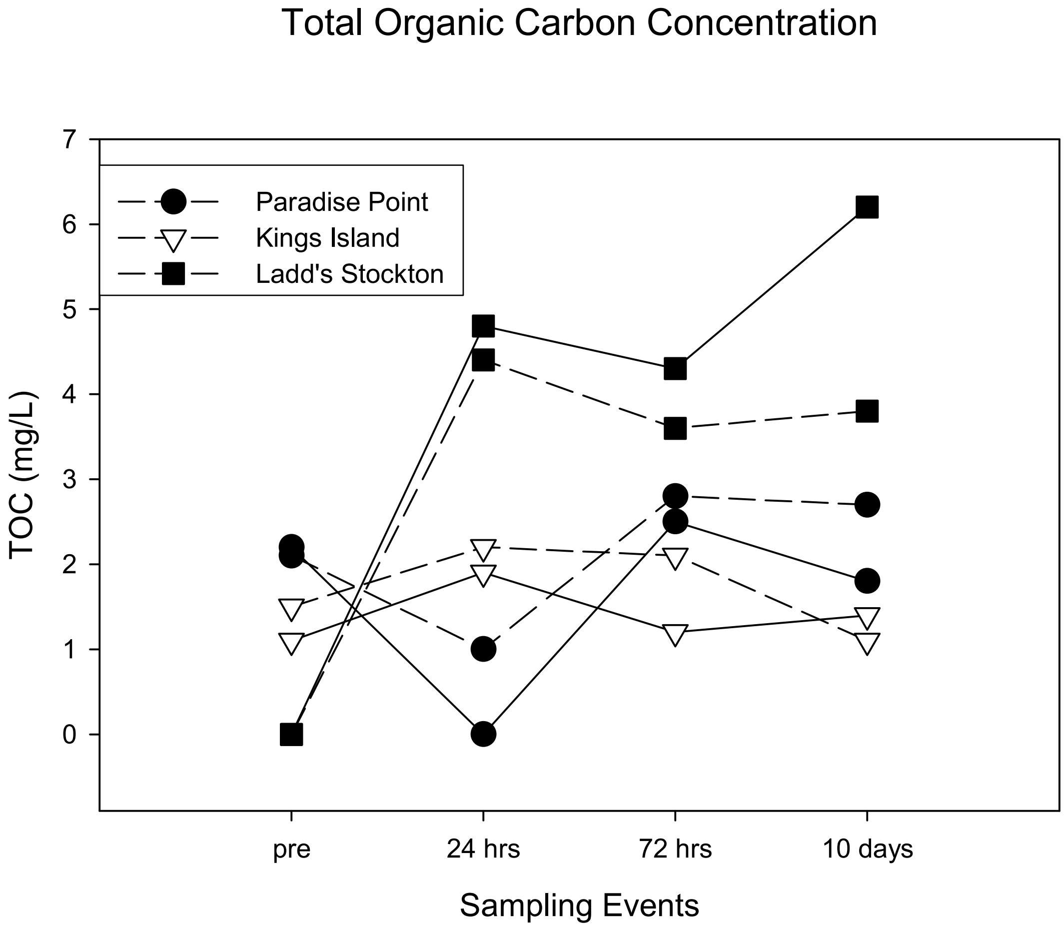

Total Organic Carbon Concentration
TOC (mg/L)
7
6
5
4
3
2
1
0
pre
24 hrs
72 hrs
10 days
Sampling Events
Paradise Point
Kings Island
Ladd's Stockton

Figure 3

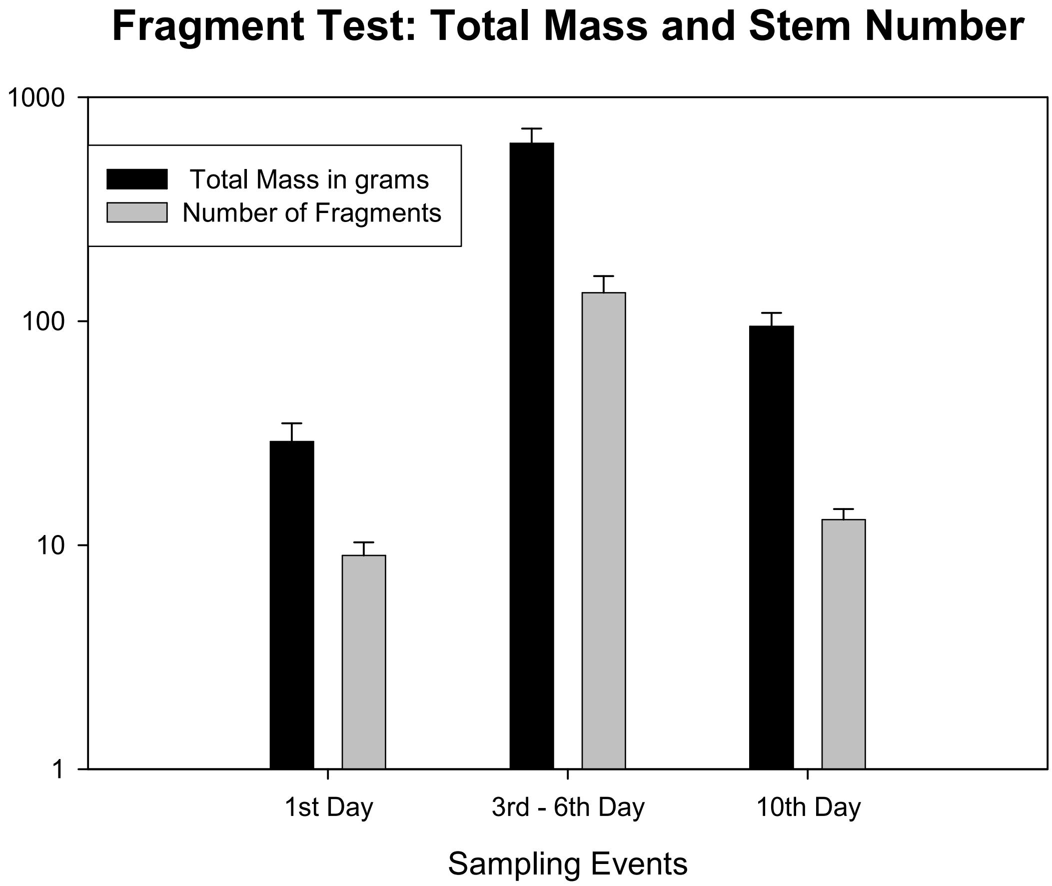
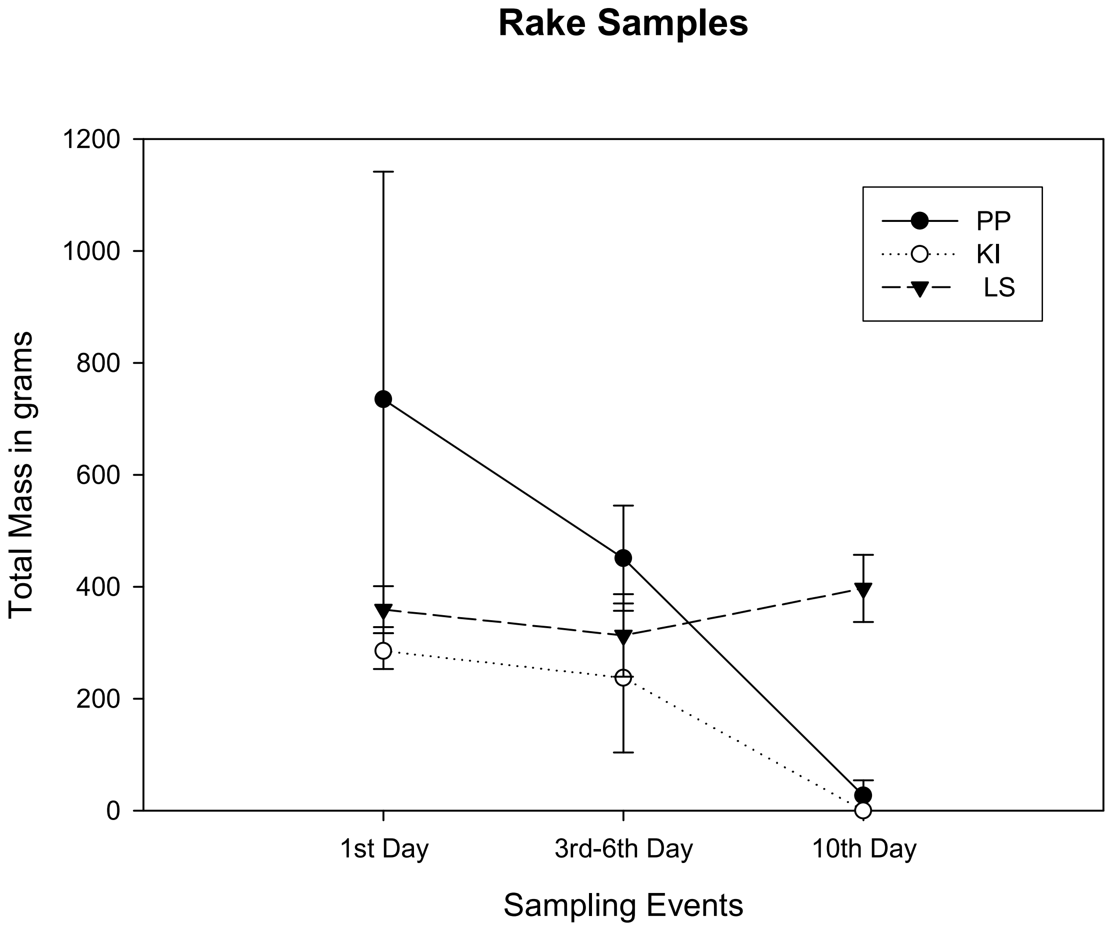

Fragment Test: Total Mass and Stem Number
1000
100
10
1
Total Mass in grams
Number of Fragments
1st Day
3rd - 6th Day
10th Day
Sampling Events

Figure 4


Rake Samples
Total Mass in grams
0
200
400
600
800
1000
1200
1st Day
3rd-6th Day
10th Day
Sampling Events
PP
KI
LS