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A cost and environmental analysis of aquatic plant management in California

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Significance

The control of invasive aquatic plants in California is an important issue. The impairment of waters throughout the state has lead to research, as well as litigation, focused upon solving the issue. Removal of nuisance aquatic plants is necessary, but the total treatment costs for different methods vary. The two main methods are chemical and non-chemical control techniques. Some environmental advocacy groups feel that non-chemical methods are not utilized enough, whereas many aquatic herbicide users feel that non-chemical methods are either ineffective or too costly. The inaccuracies of these assumptions can be resolved using an approach that evaluates the total costs for different treatment methods.

This document promotes aquatic plant management decisions that use the consideration of treatment, regulatory, and environmental costs. By incorporating these costs, management solutions will be more cost effective. The methodology described in this report can be used as a guide for managers to choose appropriate management alternatives.

Problem Statement

As a result of (*Talent v. Headwaters*), a legal decision in the U.S. Ninth Circuit court in 2001, aquatic herbicide use is governed by the National Pollution Discharge Elimination System (NPDES). Water body managers must now acquire an NPDES permit for any chemical plant control strategy they employ. The cost of obtaining a NPDES permit ranges from $5,000 to $10,000, and monitoring costs for different herbicides range from $25,000 to $1 million depending on the herbicide and the size of the water body. The increased costs associated with the permit make chemical management strategies uneconomical for most small water bodies (the permit price is not based on acreage) and a much more attractive strategy for larger water bodies.

There has been little to no research conducted on the cost effectiveness of the chemical or non-chemical techniques used to control various plants in California. There is also a need to quantify environmental impacts and increased regulatory costs of different chemical and non-chemical aquatic plant management strategies. This information would be a valuable tool for California's water body managers.

Figure 1: Water hyacinth and Eurasian milfoil growth at Stone Lakes NWR, Elk Grove, CA. Summer 2003. *Photo courtesy of Ben Greenfield, SFEI.*

The *goal* of the workgroup was to integrate control, regulatory, and environmental costs of various aquatic plant management strategies to assist aquatic plant managers in their decisions.

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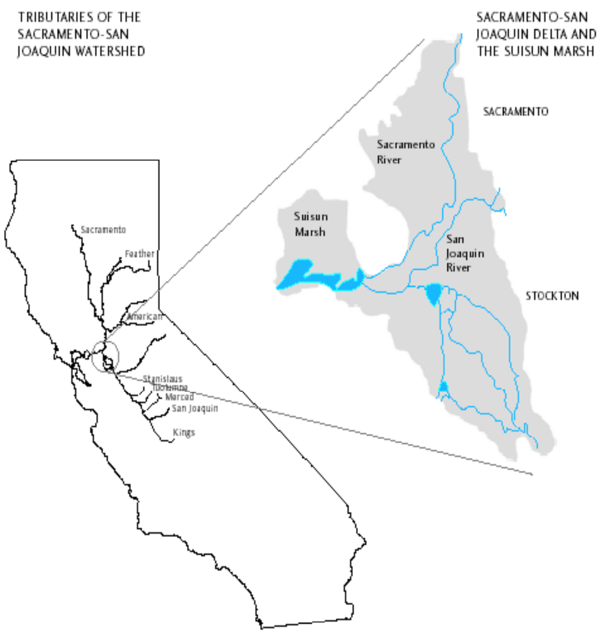
Method and Approach

Input for his document was generated from an extensive literature review, surveys conducted with water body managers from California and Washington states, and interaction with regulatory agencies and aquatic plant management experts. Two case studies were used as examples to exhibit and quantify some of the environmental impacts and increased regulatory costs associated with different plant management strategies. The case studies involved sites (**Figure 2**) within the Sacramento/San Joaquin Delta (Delta), California.

Figure 2: Sacramento/San Joaquin Delta and Suisun Marsh. *Copyright SFSU Romberg Tiburon Center for Environmental Studies.*



This document is comprised of *three* general sections. The *first* section addresses the control costs of a variety of chemical and non-chemical aquatic plant control techniques. It also includes analyses that reveal the most cost-effective approach to managing aquatic plants at four specific sites based solely on control cost. The *second* contains a case study that incorporates regulatory costs and replacement costs for fish killed from specific aquatic plant management techniques at Big Break. The *third* section contains a case study that evaluates the cost-effectiveness of several aquatic plant control strategies at Stone Lakes National Wildlife Refuge (NWR). This section also describes a model that predicts decreases in dissolved oxygen (DO) from different management scenarios to determine replacement costs for killed fish.

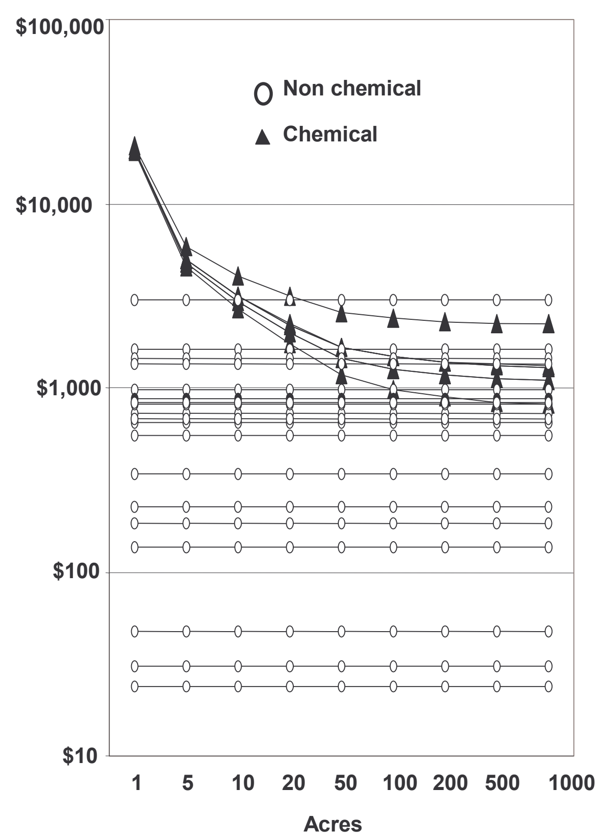
Results and Discussion

Control Cost Analysis

The control cost study compared the cost-effectiveness of various aquatic plant control methods. It used a structured set of questions to conduct an economic analysis of chemical and non-chemical treatments. The cost-effectiveness analysis only considered the private control costs paid to meet a management objective. The cost did not include estimates of damage or environmental costs. Costs were estimated through contact with managers and practitioners, surveys, and phone interviews.

Using the cost-effectiveness study, it can be concluded that for chemical management techniques, control costs per unit area were high for a low acreage site and

Figure 3: Cost ($) per acre by management technique.



decreased with increasing acreage (**Figure 3**). This trend resulted from the set-up and NPDES permitting costs incurred for any herbicide application to a water body in California.

Control costs for non-chemical techniques tend to be lower than costs for chemical control. There are less monitoring and no permitting costs required when employing non-chemical techniques. In the collection of general control cost data, four management scenarios in California were evaluated in detail: (1) the control of emergent vegetation at the Kern National Wildlife Refuge, (2) the control of Eurasian water milfoil, curly leaf pondweed, and free-floating green algae (pond scum) at the Big Bear Lake Municipal Water District, (3) the control of water hyacinth (**Figure 1**) at the Stone Lakes National Wildlife Refuge, Elk Grove, CA, and (4) the control of *Egeria densa* and water hyacinth at Big Break. The most cost effective management technique(s) for each scenario was as follows:

- Kern NWR--mowing, given that no more than four mowing events occur per season.
- Big Bear Lake--application of Sonar (fluridone) in combination with some harvesting.
- Stone Lakes NWR and Big Break--application of herbicides.

Case Study: Big Break

Big Break is the first case study presented in the report that was used to examine aquatic plant removal on a more specific basis. The Big Break study provided an analysis of management practices related to the eradication of *Egeria densa* and water hyacinth. Environmental costs and regulatory costs that mitigate environmental impacts were calculated (**Table 1**).

Table 1: Costs for management strategies at Big Break

	Chemical			Non-Chemical
Type	Diquat di-bromide	Fluridone	Chelated copper	Harvesting
Control Cost	$12,750	$153,000	$76,500	$357,000
Fish Kill	$0	$0	$0	$321
Mitigation	$150,332	$150,332	$1,399,832	$47,401
Total	$163,082	$303,332	$1,476,332	$406,882
Cost (acre^{-1})	$959	$1,784	$8,684	$2,393

The environmental impact at Big Break was quantified using damage cost avoidance. Fish species known to inhabit the *Egeria* beds are: threadfin shad, killifishes, largemouth bass, bluegill, inland silverside, and western mosquitofish. Chinook salmon was also included (although they have not been known to inhabit the weed beds) to provide a worst case scenario where federally threatened fish were killed. When mechanical harvesting occurs, there is a risk of killing fish that reside in plant beds. The estimated replacement value for fish killed by harvesting was $321. The cost associated with killing fish is an externality[2] that most mangers do not consider when choosing a management strategy.

Chemical management strategies are regulated by the NPDES permit to prevent fish kills and environmental damage. Permit users are obligated to mitigate adverse water quality conditions. The *three* areas of mitigation examined were sampling, monitoring, and surveying. The analysis yielded mitigation costs that ranged from $163,000 to $1,476,500. The range included costs from chelated copper, diquat dibromide, and fluridone application, in addition to a non-chemical option of mechanical harvesting. All management strategies were rated based on the cost to obtain the management goal, the replacement cost for killed fish, and the mitigation cost. The management strategy that resulted in the lowest overall cost was the use of diquat dibromide at Big Break (**Table 1**).

Case Study: Stone Lakes National Wildlife Refuge

The Stone Lakes NWR case study incorporated site characteristics from South Stone Lake to analyze how water hyacinth management impacts aquatic habitat. The ability to predict the effect that plant management has on dissolved oxygen, and ultimately fish habitat, can provide valuable information about the magnitude and duration of potential environmental impacts.

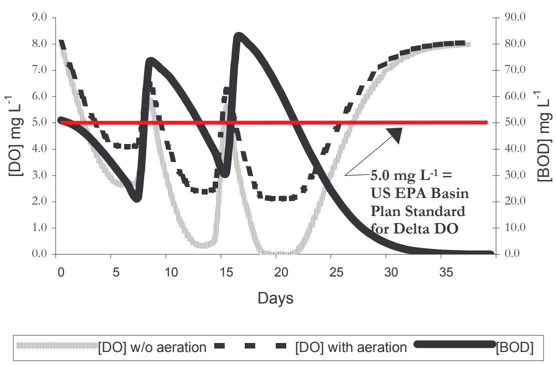
The biodegradation of plant material depletes ambient dissolved oxygen levels in a water body. Dissolved oxygen levels that fall below minimum concentrations essential for fish survival, will result in a fish kill.

The model predicted the effects that three 33-acre treatment events would have on lake dissolved oxygen

[2] Externality—a negative consequence for which the cost is not incorporated into the purchase price of a good.

levels given a treatment interval of 7 and 15 days. Results from the 7-day treatment interval predicted hypoxia at day 6, days 10 to 14, and days 17 to 24 (**Figure 4**). Anoxia occurred from days 19 to 21 when re-aeration was not considered. Results from the 15-day treatment interval predicted hypoxic conditions on day 6, days 20 to 21, and days 35 to 36.

Figure 4: Results from the 7-day treatment interval. Concentrations in mg L^{-1}.



Fish not adapted for surface respiration would die during anoxia, while all fish would experience increased respiration and reduced growth during hypoxia. Fish species that would die from the 7-day scenario are: the black crappie, largemouth bass, bluegill, warmouth, brown and black bullhead, and the white catfish. The model considered the replacement cost of killed fish as the environmental impact. Prices per pound per fish were multiplied by the total weight for each fish species found in the lake. The cost to restock fish species that would die from a 7-day treatment interval is $41,200 (**Table 2**).

Table 2: Costs for management strategies at SLNWR

Type	Chemical	Non-Chemical		
	Herbicide Treatment	Shredding	Harvesting	Hand pulling
Cost (acre^{-1})	$315	$817-$954	$683-$693	$333-$1600
Fish Kill	$0	$0-$41,189	$0	$0

Plant management that requires treatment interval durations of 15-days, rather than 7-days, may incur higher equipment mobilization costs, but would result in a smaller environmental cost associated with low dissolved oxygen concentrations causing widespread fish kills.

Conclusions

This analysis employed a comprehensive approach to determine the cost-effectiveness of chemical and non-chemical aquatic plant management strategies. It is unique because it considered environmental, regulatory, and control costs. Few environmental cost analyses have been performed for aquatic plant management practices.

Primary research has begun to value the environmental cost to incidental take an endangered species and its habitat[3], but there are knowledge gaps about how incremental degradation of environmental amenities should be valued. Future research could include: a more comprehensive economic valuation of environmental impact costs, a study on cost savings from the formation of herbicide management groups, addressing accuracy issues with the BOD model parameters, and a cost determination of various management strategies in different aquatic settings.

This document has compared the overall costs of several management techniques, and has made recommendations based on the most cost-effective alternative. This report will hopefully improve aquatic plant management decisions by accounting for not only control costs, but also costs from potential environmental damages.

http://www.bren.ucsb.edu/~pest

[3] Loomis, J.B., White, S.D., 1996. Economic Benefits of Rare and Endangered Species: Summary and meta-analysis, Ecological Economics, 18:197-206.