EXECUTIVE SUMMARY

The Aquatic Pesticide Monitoring Program Alternatives Program was established to develop practical recommendations for alternative aquatic pest control methods that may be used in California waters. The end-users of this information include the California State Water Quality Control Board, special interest groups, and the state, local, and private agencies that control aquatic plants. The APMP Alternatives Project aims to help understand the feasibility of non-chemical aquatic plant control methods as alternatives to chemical control in California waters. It includes three components, each of which are summarized here and presented in separate reports:

1. A thorough review of alternative aquatic pest control methods for potential use in California waters (Greenfield et al. 2003).
2. Research projects that evaluate effectiveness and potential environmental impacts of different control methods (SFEI et al. 2003).

Alternatives Project Methods Review

The APMP Alternatives Program methods review (Greenfield et al. 2003) is an exhaustive compendium of alternative methods for control of aquatic vascular plants, algae, and mosquitoes. It summarizes the findings from 177 journal articles, reports, and web documents and from interviews with 77 aquatic resource managers from California and other U.S. states. The methods review is intended for practitioners wishing to identify alternative methods for aquatic pest control that may not require NPDES permitting. The review critically evaluates aquatic pest control methods, discussing environmental impacts, feasibility, and areas for future research. This review also includes general information on regulatory and permitting requirements. Finally, it includes an Appendix presenting recommendations for specific species and water body types.

In addition to registered pesticides, aquatic pest managers can use biological control methods, physical and mechanical control methods, and non-conventional
chemical control methods. Additionally, preventive measures may be implemented to reduce the probability of infestations occurring in a water body. Table 1 presents a complete list of potential control methods discussed in the APMP Alternatives Project methods review. Many methods are currently being explored or developed for use by California practitioners in specific management circumstances. These include manual removal, acetic acid amendment, predatory fishes for mosquito control, and bottom barriers. Many methods are commercially available from California private contractors. The review includes a list of contractors who regularly perform control using methods including mechanical harvesting, cutting, rotovation, and sediment removal. California has a Triploid Grass Carp permitting program, which is appropriate for some management conditions.

Table 1. Methods available for control of aquatic pests in California waters.

<table>
<thead>
<tr>
<th>Physical and Mechanical Control Methods</th>
<th>Biological Control Methods</th>
<th>Preventive Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical Harvesting</td>
<td>Triploid Grass Carp</td>
<td>Early Detection</td>
</tr>
<tr>
<td>Mechanical Cutting</td>
<td>Other Herbivorous Fishes</td>
<td>Quarantine</td>
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<tr>
<td>Rotovation and Rototilling</td>
<td>Fish Biomanipulation</td>
<td>Regulation</td>
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<tr>
<td>Hydroraking</td>
<td>Terrestrial Herbivorous Mammals</td>
<td>Education and Outreach</td>
</tr>
<tr>
<td>Weed Rollers</td>
<td>Gastropod Mollusks</td>
<td>Riparian Buffer Strips</td>
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<tr>
<td>Lake Sweepers</td>
<td>Insects</td>
<td>Retention Pond or Wetland Construction</td>
</tr>
<tr>
<td>Diver-operated Suction Dredging</td>
<td>Non-Insect Crustaceans (for mosquito control)</td>
<td>Watershed Best Management Practices</td>
</tr>
<tr>
<td>Sediment Removal</td>
<td>Predatory fishes (for mosquito control)</td>
<td></td>
</tr>
<tr>
<td>Shading</td>
<td>Commercially Available Biocontrol Agents</td>
<td></td>
</tr>
<tr>
<td>Piping</td>
<td>Microbial Pathogens (e.g., cyanophages)</td>
<td></td>
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<tr>
<td>Bottom Barriers</td>
<td>Fungal Pathogens</td>
<td></td>
</tr>
<tr>
<td>Manual Removal</td>
<td>Organic Material Amendment</td>
<td></td>
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<tr>
<td>Water Level Manipulation</td>
<td>Acetic Acid</td>
<td></td>
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<tr>
<td>Channel Clearing</td>
<td>Plant Competition</td>
<td></td>
</tr>
<tr>
<td>Mechanical Excavation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exposure to Extreme Environmental Conditions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aeration, Oxygenation, and Water Circulation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nutrient Removal</td>
<td></td>
<td></td>
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</tbody>
</table>

**Non-conventional Chemical Controls**
- Calcium based Products
- Aluminum based products
- Nitrate
- Aquashade
- Salt (Sodium Chloride)

Like permitted chemical pesticides, alternative aquatic pest control methods, when used improperly, can present environmental risks to aquatic ecosystems. Environmental impacts can include adverse effects on local animal communities, and
effects on water chemistry. As with chemical control, alternative control methods can sometimes be difficult to obtain permits for use in specific California waters. Often times, many agencies must be contacted with permitting requests, requiring considerable initial effort for trying new methods.

In some situations, mechanical methods such as harvesting and rotovation could actually increase an aquatic plant infestation over the long-term, or cause the infestation to spread more rapidly to new areas. Caution is particularly warranted with introduction of non-native biocontrol species, given the fact that introduced plants or animals could reproduce and spread to new water bodies, causing permanent ecological changes in widespread areas.

**Research Projects in 2003**

In 2003, the APMP Alternatives Program conducted four separate research projects to evaluate alternative aquatic plant control methods in a variety of management scenarios. These projects are presented in SFEI et al. (2003) and summarized in Table 2.

<table>
<thead>
<tr>
<th>Method Evaluated</th>
<th>Target Plants</th>
<th>Environmental Studies</th>
<th>C/E Study?</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand Held Power Cutters</td>
<td>Emergent</td>
<td>Water Quality</td>
<td>Yes</td>
<td>1</td>
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<tr>
<td>Gypsum Application</td>
<td>Benthic Algae</td>
<td>Water and Sediment Quality</td>
<td>Yes</td>
<td>2</td>
</tr>
<tr>
<td>Alum Application</td>
<td>Benthic Algae</td>
<td>Water and Sediment Quality</td>
<td>Yes</td>
<td>2</td>
</tr>
<tr>
<td>Goat Grazing</td>
<td>Riparian and Emergent</td>
<td>Water Quality</td>
<td>Yes</td>
<td>1</td>
</tr>
<tr>
<td>Mechanical Harvesting</td>
<td>Submerged and Algae</td>
<td>Water Quality and Fish Mortality</td>
<td>No</td>
<td>3</td>
</tr>
<tr>
<td>Mechanical Shredding</td>
<td>Floating (Water Hyacinth)</td>
<td>Water Quality</td>
<td>Yes</td>
<td>In Prep.</td>
</tr>
<tr>
<td>Mechanical Excavation</td>
<td>Floating</td>
<td>Water Quality</td>
<td>Yes</td>
<td>1</td>
</tr>
<tr>
<td>Chemical and Mechanical</td>
<td>Floating</td>
<td>Water Quality</td>
<td>Yes</td>
<td>1</td>
</tr>
</tbody>
</table>


**Note:** C/E Study indicates whether cost-effectiveness data were evaluated.

All APMP Alternatives research projects evaluated the water quality impacts of aquatic plant control methods. In general, water quality impacts were temporary or were not apparent. Mechanical harvesting operations caused temporary increases in turbidity and nutrients in northern California lake systems (e.g., Figure 1). In water bodies where harvesting was conducted routinely, the effects on water quality appeared to be short-
lived, and unlikely to adversely affect beneficial uses (David and Greenfield 2003). Similarly, mechanical excavation and operation of hand-held power cutters for vegetation removal had only short-lived effects on water quality of small streams and irrigation drainages. Temporary increases were observed in turbidity, and were sometimes observed in total phosphorus and total Kjeldahl nitrogen (Blankinship et al. 2003). Goat grazing operations in or adjacent to small streams, caused temporary increases to turbidity, as well as total and fecal coliform (Figure 2; Blankinship et al. 2003).

Figure 1. In 4 of 5 California water bodies, turbidity increased immediately after mechanical harvesting but returned to pre-harvesting conditions within 3-6 days of sampling (David and Greenfield 2003).

Figure 2. Temporary increases were observed in turbidity and bacteria density (total coliform, fecal coliform, and E. Coli) after goat grazing in a California stream (Blankinship et al. 2003).
The APMP Alternatives Program included an evaluation of alum and gypsum for potential use in controlling nuisance benthic algae in a culinary reservoir (Grabow et al. 2003). The alum and gypsum study was inconclusive with respect to the expected environmental impact of application of these alternative chemicals. Results indicated both beneficial and adverse effects of chemical application for control of taste and odor producing nuisance algae. In laboratory aquaria, application of alum and gypsum reduced water and sediment total phosphorus concentrations. Gypsum also reduced benthic algae coverage. Nevertheless, a taste and odor producing compound of concern to culinary water management districts (geosmin) was increased in the alum and gypsum treated aquaria, relative to control aquaria (Grabow et al. 2003).

Mechanical shredding to control water hyacinth generates a substantial amount of organic material, which is released back into the water body (Figure 3). Consequently, shredding appeared to have significant water quality impacts in backwater sloughs. Water quality was reduced after shredding in an irrigation ditch containing dense water hyacinth stands. Field sampling indicated significant decreases in dissolved oxygen, with corresponding increases in nutrients, dissolved organic carbon, and biological oxygen demand. Water quality was not significantly affected after shredding in a tidally influenced wetland (Ben Greenfield, in preparation).
Effects to fishes, wildlife, and other non-target species can be a concern for all aquatic pest management methods. David and Greenfield (2003) documented that mechanical harvesting operations removed numerous small fishes, crayfish, and tadpoles from several California water bodies. However, sensitive or endangered species were not harvested, and only one adult sport fish was harvested. These findings suggested a relatively small overall impact of routine harvesting on aquatic animal populations in California waters (David and Greenfield 2003).

**Economic Evaluations**

Corresponding with the field research projects, APMP Alternatives Program researchers also collected and evaluated preliminary data on cost-effectiveness of alternative control methods (Table 2). It was not possible to make broad generalizations regarding the relative cost-effectiveness of conventional chemicals, versus alternative methods.
Depending on the management circumstance and methods used, alternative methods varied significantly in terms of relative cost effectiveness, when compared to conventional pesticide application. For control of emergent and riparian vegetation, goat operations were similar or better in cost-effectiveness, when compared to conventional chemical application. In contrast, use of hand-held power cutters was significantly more costly than either chemicals or goat grazing (Blankinship et al. 2003). For control of benthic algae, application costs for alum or gypsum were generally comparable to the costs of copper application (Grabow et al. 2003). If alum or gypsum prove to be effective in controlling taste and odor producing compounds associated with benthic algae, they may be a cost-effective alternative to copper. Mechanical shredding cost-effectiveness varied substantially depending on the size of the water hyacinth plants to be controlled. For moderate sized plants (two foot stem length), shredding may be reasonably cost-effective. For large plants typical of areas having several years of growth (four through five foot stem length), shredding efficiency is extremely low, and shredding will not be cost-effective (Ben Greenfield, in preparation). For low flow irrigation canals, mechanical excavation, either alone or in combination with chemical application, was substantially more costly than chemical treatment alone (Blankinship et al. 2003).

An Environmental Economics workgroup met several times in 2003 to develop a methodology for evaluating the cost-effectiveness of alternative aquatic plant control methods. The methodology was conceived and written by Roger Mann (2003) and peer reviewed by workgroup participants. The methodology presents detailed guidance for how to conduct cost-effectiveness analyses and cost-benefit analyses to compare potential aquatic plant control methods. Practitioners wishing to formally compare the potential costs of potential management options can use Mann (2003) as a guiding framework.

Mann (2003) discusses environmental costs not routinely included in evaluations of the cost-effectiveness of potential pest control options. Guidance is included regarding how to estimate the dollar value of environmental costs (Mann 2003). Environmental cost determination can be extremely difficult and costly to undertake, and limited quantitative information is currently available on the dollar values of environmental costs associated with aquatic plant control methods.
As with the research studies, statewide data compilations indicated that the relative cost-effectiveness of conventional pesticides versus alternative methods varied among different management scenarios (Wittmann 2003). Wittmann (2003) calculated the relative cost-effectiveness of chemical versus various non-chemical control methods for four local aquatic plant management problems in California waters. For two management scenarios (control of floating or submerged aquatic plants in different Delta water bodies), conventional pesticides proved most cost-effective or feasible. For one management scenario (control of Eurasian water milfoil in Big Bear Lake), a combination of chemical application and mechanical harvesting was determined to be most cost-effective. For one management scenario (control of emergent wetland vegetation in the Kern National Wildlife Refuge), mowing was determined to be most cost-effective.

**Project Directions in 2004**

For the APMP Alternatives Program, additional funds remain to conduct more work in 2004. Planned allocations of remaining funds are as follows:

Further evaluation of mechanical shredding. Mechanical shredding is likely to be substantially more cost effective in spring or summer than the 2003 shredding date (late September, 2003). Applications have been submitted for permits to conduct shredding on a pilot basis in spring or summer of 2004.

Additional research projects. The following research projects are under consideration for the APMP Alternatives Program in 2004

1. Determining the viability of fragments produced when non-native Spartina are controlled by mechanical rotovation.
2. Evaluation of the LakeSweeper, a hydraulically driven series of rakes for control of submerged aquatic vegetation around docks.
3. Field evaluation of a mechanical chopper that pulls submerged plants at the root ("the Crusher").
4. Determination of potential water quality impacts from the use of grass carp to control aquatic vegetation
5. Field evaluation of the effectiveness of acetic acid for the control of aquatic vegetation

6. Water level manipulation for mosquito control

References

(Reports and Chapters Produced For the APMP Alternatives Project)


