***Planktonic:***

*In-water Prevention Strategy*
*Limited Supporting Field Data*

***Benthic:***

*Strategy Not Applicable*

Artificial circulation and mechanical mixers have been successfully used in lakes and reservoirs as physical controls to increase oxygen concentrations in bottom waters and to destratify the water column to remove the optimal habitat for buoyant cyanobacteria (Beutel and Horne 1999, Bormans, Marsálek, and Jancula 2015, Visser et al. 2016). Artificial circulation and mechanical mixers completely mix a stratified lake or reservoir, redistributing oxygen and nutrients throughout the water column (Hudson and Kirschner 1997).

Generally, these techniques also cause a temperature increase in the deep layers and a temperature decrease in the upper layers, while increasing spatial phytoplankton distribution and concentration due to an increase in the limiting nutrient entrained from the hypolimnion or resuspended from the sediments (Visser et al. 2016).

The two most common types of destratification are air injection and mechanical mixing (Hudson and Kirschner 1997). Air injection is a “bottom-up” approach that quickly pumps air to the bottom of the lake so that it will rise and carry the water from the hypolimnetic layers to the top layer (Hudson and Kirschner 1997). Mechanical mixing uses a “top-down” approach wherein a rotating propeller in the surface layers pushes the water downward, displacing bottom waters to the surface, where they are reoxygenated by the atmosphere (Hudson and Kirschner 1997). Popular commercially available models are powered by solar panels. Although artificial circulation is beneficial for oxygen and nutrient redistribution, the ecological effects on plant and animal life of destratifying a lake are not always predictable and could potentially be harmful (Hudson and Kirschner 1997).

| **PLANKTONIC** |
|---|
| **EFFECTIVENESS**<br>• Water body type: Pond, lake/reservoir<br>• Any surface area<br>• Depth: Deep; requires large hypolimnion; avoid in shallow, unstratified systems<br>• Any trophic state, but typically most effective in eutrophic systems<br>• Mixing regime: Meromictic, monomictic, or dimictic<br>• Any water body use<br>• Watershed loading levels will impact effectiveness |
| **NATURE OF HCB**<br>• Repeating HCBs<br>• Toxic and nontoxic HCBs<br>• Targets all algal species<br>• Prevention strategy |
| **ADVANTAGES**<br>• No waste or by-products produced<br>• Readily available equipment<br>• Successful full-scale implementation<br>• Reported water quality and ecological benefits<br>• Indiscriminate of algae species<br>• In areas around the devices, habitats supporting cyanobacteria are lost |

**LIMITATIONS**
- High installation costs
- High operational costs associated with use
- Needs infrastructure (electricity, boat ramp, etc.)
- Limited scalability
- Potential unintended water quality impacts
- Potential unintended biological impacts
- Potential aesthetic concerns

These physical controls are most effective in systems that have or are expected to experience extensive, sustained nutrient and sediment loading and require remediation beyond periodic intervention strategies to protect the water quality and ecosystem (Bormans, Marsálek, and Jancula 2015). Often artificial circulation and mechanical mixers are used in conjunction with watershed controls and algaecide treatments (Bormans, Marsálek, and Jancula 2015, Moore and Christensen 2009, Visser et al. 2016). Artificial circulation and mechanical mixing methods can cause a change in composition from cyanobacterial dominance to green algae and diatoms if the water body is deep enough to limit light availability (Bormans, Marsálek, and Jancula 2015, Visser et al. 2016).

Successful deployment of artificial circulation and mechanical mixers can establish a diatom population, allow this diatom population to persist longer, and remove limiting nutrients from the water column so that fewer nutrients are available in the epilimnion for cyanobacterial growth (Bormans, Marsálek, and Jancula 2015). Unanticipated biological effects associated with destratification may result from mechanical mixing due to sudden water quality and chemistry changes; however, some biological and ecological benefits may also result from this process (Pastorok, Ginn, and Lorenzen 1981). Artificial circulation may allow for deeper zooplankton distribution and refuge from predators in the dark bottom waters during the day (McComas 2003). In addition, the expanded aerobic environment may enhance growth and expansion of cold-water fish habitat and populations due to increased oxygen concentrations, increased visibility, and greater zooplankton density (Rieberger 1992).

**COST ANALYSIS PER GROWING SEASON: ARTIFICIAL CIRCULATION AND MECHANICAL MIXERS**

| ITEM | RELATIVE COST PER GROWING SEASON |
|---|---|
| Material | $$ |
| Personal Protective Equipment | $ |
| Equipment | $$$ |
| Machinery | $$ |
| Labor | $$ |
| O & M Costs | $$$ |
| **OVERALL** | **$$$** |

The costs of installing and maintaining an artificial circulation or mechanical mixing system are relatively high (mostly due to operating costs for successful applications) and dependent on the type of equipment and local power rates (Bormans, Marsálek, and Jancula 2015). The use of photovoltaic technologies and availability of brand-name, solar-powered mechanical mixers may help mediate power costs. Some cost estimates can be found in Appendix C.2 of HCB-1 (ITRC 2021).

**REGULATORY AND POLICY CONSIDERATIONS**

Before implementing a management action, you should establish a cause–effect linkage between the problem and the proposed management approach (Hickey and Gibbs 2009, USEPA 2000). Because multiple stressors and environmental factors combine to cause the effects observed in aquatic ecosystems, an integrated approach with multiple management measures is often required to holistically address ecological issues in lakes. The decision to introduce an artificial circulation or mechanical mixing system should be based on a thorough understanding of the factors contributing to recurrent blooms and preliminary research to establish that a destratification approach is a feasible option for reducing the frequency and severity of HCBs.

This assessment must also include social and cultural values that need to be considered on a case-by-case basis with public and multiagency consultation, which could uncover concerns with a specific product or approach. The selection and decision-making process may need to be modified accordingly. Any supplementary watershed controls or algaecide treatments must comply with policies and regulations as enacted by the appropriate oversight agency or authority. For some lakes, additional approval may be required from the U.S. Fish and Wildlife Service and the National Oceanic and Atmospheric Administration's National Marine Fisheries Service under the Endangered Species Act (ESA) if endangered, threatened, or otherwise special status species are present, or if the lakes are in conservation land (USFWS 2020). Special consideration for protection of native or indigenous species may be made. If structures are deployed in a water body the U.S. Army Corps of Engineers (USACE) may also need to be contacted.

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