Planktonic:

In-water Intervention and Prevention Strategy
Limited Supporting Field Data

Benthic:

In-water Intervention and Prevention Strategy
No Available Supporting Field Data

Manipulating fish populations in ponds, lakes, and reservoirs to control cyanobacteria populations has been undertaken in multiple locations throughout the world over the past four to five decades. Some investigations report successful reduction of cyanobacteria biomass through stocking of herbivorous fish populations that ingest cyanobacteria, such as silver and bighead carp Xie and Liu (2001). Zhang, Xie, and Huang (2008) suggested that stocking with filter feeders (carp) in lakes with low macrozooplankton densities will reduce phytoplankton and cyanobacteria, as cyanobacteria have been shown to make up 84.4% of the phytoplankton silver carp consume (Chen et al. 2006). Other investigations have removed fishes that graze on zooplankton (Pot and Heerdt 2014), while still others have increased piscivorous fish stocks (Carpenter, Kitchell, and Hodgson 1985) to increase large fish predation on planktivorous fish that ingest herbivorous zooplankton, such as daphnids; by doing so, the herbivorous zooplankton can increase to consume developing cyanobacteria.

Recent reviews (Lürling and Mucci 2020, Triest, Stiers, and Van Onsem 2016) suggested substantial uncertainty with these approaches and proposed that combining these techniques with other strategies or simply using other options may offer better chances for success at reducing cyanobacteria. The former research group summarized data from 34 studies that employed stocking with herbivorous fishes, fish removal, or stocking with piscivores. Adding filter feeding fishes succeeded in four of six times in reducing lake cyanobacteria; fish removal was successful in six of eight projects, while the addition of piscivores was successful only two of five instances. When fish removal and piscivore stocking were combined, cyanobacteria declined in five of eight lakes. Manipulation of fish through removal or piscivore additions, when combined with one or multiple additional strategies, was successful five of six times. Triest, Stiers, and Van Onsem (2016) state, “Reasons for success or failure … could be explained through bottlenecks encountered with fish removal, stocking densities, cascading effects, associated zooplankton grazing, diet shifts away from cyanobacteria, macrophyte recovery, nutrient or pH status.”

Hence, results from manipulating higher trophic levels of a water body’s food web remain uncertain and unpredictable.

PLANKTONIC AND BENTHIC
EFFECTIVENESS • Highly variable results • Any water body type • Any surface area or depth • Any trophic state, but typically most effective in eutrophic systems • Mixing regime: Meromictic, monomictic, or dimictic • Any water body use
NATURE OF HCB • Many HCB species • Toxic and nontoxic HCBs • Intervention and prevention strategy
ADVANTAGES • Elimination of HCBs in some systems • Reported improved water quality, clarity, and ecological benefits in some cases
LIMITATIONS • Highly variable results • Substantial costs • Some cyanobacteria survive fish gut passage to “seed” blooms in future years • Requires water quality, plankton, and fish monitoring pretreatment and short- and long-term (yearly) thereafter • Fish stock estimates are often uncertain • May require yearly adjustments in fish stocks

Food web manipulations require substantial short- and long-term monitoring prior to and following treatment, not only for cyanobacteria but also for densities of fish species and crustacean zooplankton. Adjustments in fish stocks may be necessary over time, necessitating a substantial investment in time and money. In addition, nutrient concentrations and turbidity should also be monitored, as adding fishes can induce bottom disturbance, nutrient release, and sediment resuspension.

COST ANALYSIS

Manipulating densities of higher tropic levels is costly and requires stock assessments, fish capture and removal, or fish purchases and additions. Monitoring lake response for cyanobacteria is the direct measure for success, but determining zooplankton densities and abundances of herbivorous and piscivorous fish through time may be necessary to maintain conditions detrimental to cyanobacteria accumulation.

Relative cost per growing season: Food web manipulation

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

REGULATORY AND POLICY CONSIDERATIONS

State officials should be consulted on any plans to remove or add fish stocks to natural waters.

CASE STUDY EXAMPLES

Netherlands: ter Heerdt and Hootsmans (2007) report an 85-ha shallow peaty lake fish removal that resulted in <25 kg/ha benthivorous fish and <15 kg/ha planktivorous fish stocks. This removal resulted in clear water, reduced filamentous cyanobacteria, and increased *Bosmina* spp. populations. Following cyanobacteria disappearance, *Daphnia* spp. dominated the zooplankton that kept phytoplankton abundances low.

China: Lu et al. (2006) stocked Lake Yuehu with herbivorous tilapia (*Oreochromis niloticus*) at 3–5 g/m3. Compared to the previous year's 70% cyanobacteria, the cyanobacteria biomass was reduced to 22.1% in 2001 and 11.2% in 2002. In another system, tilapia fingerlings were added at 8–15 g/m3. The cyanobacteria bloom disappeared in 20 days.

Texas, U.S.: In contrast to the successes above, largemouth bass were stocked in a Texas reservoir. Although the impact passed down to the phytoplankton, cyanobacteria densities did not change, and large cyanobacteria replaced edible phytoplankton species (Drenner et al. 2002).

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