natural bodies. These methods are unstable in natural environments and some microorganisms may even affect non-target organisms. Moreover, due to regulatory requirements and limitations on public acceptance, it is fundamentally difficult to directly introduce foreign microorganisms into natural water bodies (Abate et al., 2024).

Large aquatic plants, as well as filter-feeding organisms (such as mussels, shellfish, zooplankton and certain fish), and some allelochemicals secreted by plants, can also play a role in assisting in the control of algal blooms by altering the food chain, competing for nutrients and sunlight, and releasing inhibitory substances. Through management, by strengthening the population of filter-feeding organisms, the number of cyanobacteria can be reduced, and the algal community can shift towards a less harmful direction; in freshwater environments, restoring seagrass beds, algal fields and emergent plants can provide habitats for natural algal-killing bacteria, making the ecosystem more stable and preventing harmful algae from dominating. Based on plant management strategies, such as adding straw and reed to the water or using purified allelochemicals, they have shown inhibitory effects on algal growth in experimental conditions and small ponds. However, as these methods are used more frequently in practice, their effectiveness becomes less reliable, and they usually cannot be relied upon alone to control algae (Anabtawi et al., 2024). In summary, relying solely on these biological means often does not significantly improve water quality. In other words, biological control should be regarded as part of a long-term comprehensive management approach. At the same time, it is necessary to reduce nutrient input, restore the ecosystem, and carefully consider its benefits and potential problems (Abate et al., 2024).

5 Integrated Management and Practical Applications

5.1 Water pollution control and nutrient management

When dealing with harmful algal blooms, people are increasingly focusing on controlling the nutrient flow throughout the entire river basin. These nutrients come from various sources, such as farmlands, livestock farms, and centralized discharge sources like urban domestic sewage and rainwater (Feng et al., 2024). Global studies have found that nitrogen and phosphorus in rivers flowing into the ocean must be controlled simultaneously; controlling only one of them will still lead to excessive algal growth. The research suggests that nitrogen and phosphorus reduction targets should be set based on the actual conditions of each river basin, while also considering the impact of climate change on water volume, temperature, and extreme weather. This is the fundamental approach for long-term control of algal blooms.

The combination of catchment analysis models and ecological risk assessment tools has now been able to assist in designing and optimizing the best management methods (referred to as BMP). In the Taihu Lake Basin of China, a SWAT–Bayesian Network model shows that reducing fertilizer usage by 40% can maximize the reduction in the probability of harmful algal blooms in the model; at the same time, extensive planting of vegetation filter strips can also bring additional governance effects. Combining these two measures can significantly reduce the risk of harmful algal blooms, even maintaining stability under extreme climates (Liu et al., 2024; Lin et al., 2025). In the Malmaino sea area of Spain, a similar SWAT+-Lagoon modeling study found that the comprehensive application of BMP measures (reducing fertilizer use, planting vegetation filter strips, crop rotation, etc.), can reduce the number of days with harmful algal blooms by 81%, and the chlorophyll a content during the algal bloom period by 50%, with much better effects than single measures (Pacheco et al., 2025). Interviews with water management personnel in the United States also indicate that measures for nutrient management, especially BMP measures in the agricultural sector and urban fertilizer control measures, are the main methods for preventing harmful algal blooms. However, relevant personnel also admit that "under the influence of climate change, harmful algal blooms will not disappear in the short term" (Goodrich et al., 2024).

5.2 Ecological restoration: artificial wetlands and ecological floating islands

Combining ecological restoration projects with the best management methods for river basins can intercept nutrients and rebuild the local food web. Around eutrophic lakes (such as the wetlands along Lake Erie), restoring wetlands can enhance the natural ability to intercept nutrients, buffering the entry of phosphorus and nitrogen before they reach the open waters prone to cyanobacteria blooms. Research summaries on eutrophication and