Environmental Assessment

Mattamuskeet National Wildlife Refuge Cyanobacteria Treatment in Lake Mattamuskeet

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This Draft Environmental Assessment (EA) is being prepared to evaluate the effects associated with the proposed action and complies with the National Environmental Policy Act in accordance with Council on Environmental Quality regulations (40 CFR 1500-1509) and Department of the Interior (43 CFR 46; 516 DM 8) and U.S. Fish and Wildlife Service (550 FW 3) regulations and policies. The National Environmental Policy Act (NEPA) requires examination of the effects of proposed actions on the natural and human environment. Appendix A outlines all law and executive orders evaluated through this Environmental Assessment.

Proposed Action

The U.S. Fish and Wildlife Service (Service) is proposing to conduct a trial treatment of cyanobacteria, also known as blue-green algae, using a sodium percarbonate-based algaecide, Lake Guard® Oxy, in Lake Mattamuskeet at Mattamuskeet National Wildlife Refuge (MNWR). This treatment is intended to reduce the cyanobacteria populations to allow for the re-establishment of beneficial algae and phytoplankton communities and to increase water clarity in Lake Mattamuskeet. The treatment would take place in a controlled experimental study over approximately 600 acres in several coves around the lake's perimeter, with turbidity curtains effectively isolating the treatment's effects in these areas. The treatment would be extensively monitored prior to, during, and after treatment to determine its success in reducing cyanobacteria and to evaluate possible impacts to other resources. Results of the study would be used to evaluate the treatment for use as part of a restoration strategy in other areas of the lake to improve water quality and restore healthy aquatic communities of submerged aquatic vegetation (SAV). Subsequent treatments would be subject to additional permitting by the North Carolina Division of Water Resources (NCDWR) as well as requirements under NEPA.

The proposed action directly supports the following goals and objectives from the refuge's Comprehensive Conservation Plan (CCP, U.S. Fish and Wildlife Service [USFWS] 2008), Habitat Management Plan (HMP, USFWS 2017), and the Lake Mattamuskeet Watershed Restoration Plan (LMWRP, North Carolina Coastal Federation [NCCF] 2019).

CCP:
Objective 1-1: Migratory Waterfowl – Annually provide the foraging, sanctuary, and other biological needs for 200,000+ migratory waterfowl.
Objective 1-2: Fish – Continue to protect fish and their habitats and expand cooperation with universities and other agencies to monitor fish population status; increase applied research especially with regard to baseline surveys and carp management.
Objective 2-1: Open Water Habitat – Maintain 40,276 acre (16,299 hectare) as open water habitat in Lake Mattamuskeet and associated canals. In addition, cooperate with the North

Carolina Department of Environment and Natural Resources to develop and implement a SAV [submerged aquatic vegetation] monitoring program for the lake.

HMP:
Goal 4.1: Maintain good water quality and healthy SAV communities in the 40,276-acre (16,299-hectare) Lake Mattamuskeet.

LMWRP:
Goal: Restore water quality and clarity: Reduce nutrients, sediments, and phytoplankton blooms; promote the growth of SAV and remove the lake from the NC 303(d) list of impaired waters; establish and maintain SAV within the lake; enhance and maintain the health of the lake's natural resources (waterfowl and wildlife).
Objective: Determine how to effectively improve and meet water quality standards within the watershed. Actions: Evaluate water quality monitoring results within the lake watershed.

A proposed action is often iterative and evolves over time during the process as the agency refines its proposal and learns more from the public, Native American Tribes, and other agencies. Therefore, the final proposed action may be different from the original proposed action. The final decision on the proposed action will be made after the conclusion of the public comment period for the EA.

Background

National Wildlife Refuges are guided by the mission and goals of the National Wildlife Refuge System (Refuge System), the purposes of an individual refuge, Service policy, and laws and international treaties. Relevant guidance includes the Refuge System Administration Act of 1966, as amended by the Refuge System Improvement Act of 1997 (16 U.S.C. 668dd et seq.), Refuge Recreation Act of 1962, and selected portions of the Code of Federal Regulations (CFR) and Service Manual.

Mattamuskeet NWR was established in 1934 pursuant to:

- 16 U.S.C. 742f (a) (4) (Fish and Wildlife Act of 1956)
- 16 U.S.C. 715d (Migratory Bird Conservation Act of 1929)
- 48 Statute 195 (National Industrial Recovery Act 1934)
- Executive Order 6924 (December 18, 1934)

The primary purposes of the refuge are:

…as a refuge and breeding ground for birds and wild animals, and (2) that such portions as the Secretary of Agriculture [Interior] may deem proper be reserved for use as a shooting area, to be operated under a cooperative agreement or lease…With regard to the waters…the

Secretary of Agriculture [Interior]…may enter into a cooperative agreement or lease…said waters may be used for fishing purposes… (Executive Order 6924, dated December 18, 1934).

…for use as an inviolate sanctuary, or for any other management purpose, for migratory birds. 16 USC 715d (Migratory Bird Conservation Act of 1929).

…for the development, advancement, conservation, and protection of fish and wildlife resources… 16 U.S.C. 742f (a) (4) … for the benefit of the United States Fish and Wildlife Service, in performing its activities and services. Such acceptance may be subject to 742f (b) (1) (Fish and Wildlife Act of 1956).

The mission of the Refuge System, as outlined by the Refuge System Administration Act, and as amended by the Refuge System Improvement Act, is:

"... to administer a national network of lands and waters for the conservation, management and, where appropriate, restoration of the fish, wildlife, and plant resources and their habitats within the United States for the benefit of present and future generations of Americans."

The Refuge System Improvement Act mandates the Secretary of the Interior to administer the Refuge System to:

- provide for the conservation of fish, wildlife, and plants, and their habitats within the Refuge System;
- ensure that the biological integrity, diversity, and environmental health of the Refuge System are maintained for the benefit of present and future generations of Americans;
- ensure that the mission of the Refuge System described at 16 U.S.C. §668dd(a)(2) and the purposes of each refuge are carried out;
- ensure effective coordination, interaction, and cooperation with owners of land adjoining refuges and the fish and wildlife agency of the states in which the units of the Refuge System are located;
- assist in the maintenance of adequate water quantity and water quality to fulfill the mission of the Refuge System and the purposes of each refuge;
- recognize compatible wildlife-dependent recreational uses as the priority general public uses of the Refuge System through which the American public can develop an appreciation for fish and wildlife;
- ensure that opportunities are provided within the Refuge System for compatible wildlife-dependent recreational uses; and
- monitor the status and trends of fish, wildlife, and plants in each refuge.

In accordance with the purposes of the refuge and the mission of the Refuge System, it is a priority of the Service to provide a healthy aquatic ecosystem at Mattamuskeet NWR by restoring SAV and improving water quality and clarity in Lake Mattamuskeet for the benefit of

Service trust species and priority resources of concern. The 50,180-acre (20,307-hectare) refuge is dominated by the 40,276-acre (16,299-hectare) lake, which is a shallow basin ranging from 0.1 to 6 feet (0.03-to 2 meters) deep.

Historically, the lake's vegetation was dominated by SAV, including wild celery (*Vallisneria americana)*, sago pondweed (*Stuckenia pectinate)*, southern naiad (*Najas guadalupensis)*, redhead grass (*Potamogeton perfoliatus)*, and algae *(Chara* spp. and *Nitella* spp). In shallow lake systems such as Lake Mattamuskeet (averaging just 1.5 feet in depth), an abundance of SAV is a critical component of the aquatic ecosystem as it stabilizes substrate, prevents wind-driven re-suspension of fine sediments, and constitutes critical habitat and food sources for birds, fish, and invertebrates (Geist & Hawkins 2016). The SAV was the primary food source for wintering waterfowl in the area, providing over 34,000,000 energy use days of forage. Collectively, annual wintering waterfowl populations on the lake often exceeded 250,000 ducks, geese, and swans. In 2020, during a revision to update waterfowl objectives for the refuge, calculations determined that the absence of SAV and associated invertebrates and seeds in the lake, compared to values from the literature, resulted in a loss of over 20,000,000 energy use days for waterfowl (Hagy 2019, McCain et al. 2019, Bauer 2018, Gross et al. 2020).

Unfortunately, due to excessive nutrients, reduced flow to Pamlico Sound, and an overabundance of invasive common carp (*Cyprinus carpio*), the lake conditions began to decline in the early 1990s in both water quality and clarity. During this period of decline, water quality monitoring documented increases in nutrients, harmful algae blooms, and turbidity in the lake. A summary of monitoring data collected since 1981 indicates that SAV declines in the lake were attributed to poor water quality and clarity, mainly regarding observed increases in nitrogen and phosphorous content, followed by lake-wide eutrophication – contributing to cyanobacterial harmful algal blooms (cyanoHABs) – and an overabundance of invasive carp. The increased turbidity and decreased water clarity from these phytoplankton and suspended sediments prevent sunlight penetration, which is required for SAV to germinate and photosynthesize. The excessive nutrients shifted the lake from a clear lake dominated by SAV to a turbid lake dominated by phytoplankton, like cyanobacteria (Moorman et al. 2017). By 2017, refuge staff were unable to locate a single plant during the annual SAV survey. Having suffered a total loss of SAV, the Lake Mattamuskeet substrate is barren today (Moorman et al. 2017). In 2016, NCDWR listed the lake on the 303(d) list of impaired waters due to high pH and chlorophyll-*a*, both of which are indicators for cyanoHABs which produce cyanotoxins (U.S. Environmental Protection Agency [USEPA] 2016).

In a multi-stakeholder effort to improve water quality in Lake Mattamuskeet, the Service, North Carolina Wildlife Resources Commission (NCWRC), Hyde County, North Carolina Coastal Federation (NCCF), and local stakeholders collectively drafted the LMWRP, which was released in 2018 with an Addendum approved in 2019 (NCCF 2019). The plan includes Best Management Practices (BMPs) and strategies to improve Lake Mattamuskeet's water quality and restore SAV

to the lakebed. The stakeholder team continues to pursue implementation of the plan's goals and objectives.

In 2022 the Service was approached by the University of North Carolina Institute of Marine Sciences (IMS) and BlueGreen Water Technologies (BlueGreen), who were evaluating water bodies in North Carolina for a pilot study of a cyanobacteria treatment. After further discussions, the project team determined that Lake Mattamuskeet was their preferred site for the study. The Service recognizes the potential of the proposed study to inform restoration efforts and help achieve goals identified in the LMWRP (NCCF 2019).

Purpose and Need for the Action

The purpose of this proposed action is to treat cyanobacteria (i.e., trigger a population collapse of cyanobacteria) within Lake Mattamuskeet, in compliance with the refuge purposes and establishing legislation. The need for this action is to evaluate the effectiveness of a cyanobacteria treatment and the role it may play in restoring the ecosystem integrity of the lake (i.e. improving water quality and clarity, re-establishing SAV, and re-establishing populations of green algae). The results of this study would be used to determine the effectiveness of cyanobacteria treatments and their possible environmental impacts in Lake Mattamuskeet. Cyanobacteria treatments may be a valuable component of a larger effort to improve the lake's biological integrity, diversity, and environmental health. Treating these algal blooms may be an important step in SAV restoration, which is imperative for the refuge to meet its goals and objectives in its CCP (USFWS 2008) HMP (USFWS 2017), and the LMWRP (NCCF 2019).

Alternatives

Alternative A – Continuance of Current Management Practices (No Action)

Under Alternative A, a trial cyanobacteria treatment would not occur, and refuge management would continue without changes. Control of cyanobacteria would be solely dependent on indirect approaches to reduce the excessive nutrients that cause the cyanobacteria blooms. The refuge does not control or regulate off-refuge nutrient inputs. Drainage from the watershed is allowed to flow through existing canals and enter the lake, so efforts to redirect drainage or reduce these inputs are dependent on voluntary actions by landowners and other partners. Projects to reduce nutrient inputs often involve multiple partners, require lengthy planning and design, and are dependent on available funding.

Under Alternative A, cyanobacteria would continue to dominate the lake and SAV would not be restored while excess nutrients remain in the system. Lake Mattamuskeet would remain in a hypereutrophic, algae-dominated system with poor water quality and clarity unless other measures implemented are sufficient to restore or improve the health of the lake. The proposed management action would not be implemented and would not contribute to meeting the goals and objectives in the refuge's CCP, HMP and LMWRP.

Alternative B – Cyanobacteria Treatment within Lake Mattamuskeet Using Lake Guard® Oxy (Proposed Action)

Under the Proposed Action Alternative B, the refuge would implement a trial cyanobacteria treatment within Mattamuskeet NWR. The treatment would be subject to permits from the NCDWR and applied in accordance with a Special Use Permit (SUP) issued by the Service. Lake Guard® Oxy would be subject to approval through the Service's Pesticide Use Proposal system.

This treatment would entail extensive monitoring efforts via 38 autonomous probes to capture the turbidity, temperature, chlorophyll-b (Chl-b, used as indication of the total biomass of green algae), phycocyanin (PC, used as indication of the total biomass of cyanobacteria), and conductivity. These data, in addition to satellite imagery and historical data, would be used to create a BlueGreen Intelligence Map, a proprietary mapping tool from BlueGreen, used to track and target cyanobacterial bloom locations, duration, and intensity. With these monitoring efforts, the treatment would be customized to fit Lake Mattamuskeet's unique characteristics, minimizing the amount of pesticide required to meet the goal of collapsing the cyanobacteria population, and to track subsequent blooms for preventive treatments.

The experimental treatment would occur in four bays – two in the West Basin and two in the East Basin. Each bay would be separated from the remainder of the lake by turbidity curtains extending from the water surface to the lake bottom. Each of the bays would have another similar bay to act as a control, having a turbidity curtain but not receiving treatment (Figure 2, Appendix B). IMS would provide independent monitoring before, during, and after the treatment (see Appendix C). The results of this monitoring would allow IMS to provide an independent evaluation of the treatment's success and an assessment of any positive or negative impacts to water quality and ecosystem health.

The method of application (by boat or aerially) of the granular Lake Guard® Oxy product may vary based on weather conditions (e.g., wind speed and direction, temperature, and relative humidity) to follow spray drift management guidelines. The treatment would take place, if possible, in the winter or early spring when conditions are less conducive to cyanobacterial growth to limit the amount of product needed to control the cyanobacteria populations; however, the product may still be used in other seasons for similar effect. As indicated by the label for the product and Table 1 (see Appendix B), the dosage is dependent on the cyanobacteria cell density. This adaptive approach, made possible by extensive monitoring of cyanobacteria, would ensure that the minimum amount of required product would be used, resulting in less chance of exposure to wildlife and aquatic species.

The results of this experimental approach would establish the efficacy of the product, the specific needs for Lake Mattamuskeet, and the effects of the product on the ecosystem. A technical advisory group consisting of staff from IMS, BlueGreen, NCDWR, and the Service, would evaluate the results and provide recommendations on whether to pursue additional

cyanobacteria treatments in other parts of the lake. Subsequent treatments in other areas of the lake would be subject to additional permitting by the NCDWR as well as requirements under NEPA.

Affected Environment and Environmental Consequences

Lake Mattamuskeet's size and strategic location along the Atlantic Flyway make it the area's premiere overwintering site for migratory waterfowl. The priority species and identified resources of concern (ROCs, in Fiscal Year 2020 Memo from Refuge System Chiefs for biological planning and identifying ROCs on refuges) for the lake include tundra swans (*Cygnus columbianus)*, dabbling ducks (e.g., American wigeon [*Mareca americana]* and gadwall [*M. strepera*]), and diving ducks (e.g., ring-necked duck [*Aythya collaris]* and redhead [*A. americana]*). Species of concern include wintering and migratory waterfowl, long-legged wading birds (breeding and wintering), nesting ospreys (*Pandion haliaetus*), and anadromous and catadromous fish that depend on a healthy lake ecosystem to complete their life cycles. Lake Mattamuskeet also provides habitat and food resources for a plethora of wetland-dependent wildlife throughout the year, namely nesting habitat for osprey, great blue heron (*Ardea herodias)* rookeries, and resting and feeding areas for long-legged wading birds and shorebirds. Beneath the surface, Lake Mattamuskeet supports several economically and ecologically valuable freshwater fish, such as largemouth bass (*Micropterus salmoides*), black crappie (*Pomoxis nigromaculatus*), and bluegill (*Lepomis macrochirus*). Lake Mattamuskeet is connected to the Pamlico Sound through four main drainage canals. This unique connection creates a corridor for use of lake habitats by diadromous fish and crustacean species, including the identified ROC alewife (*Alosa pseudoharengus*), the American eel (*Anguilla rostrata*), and the blue crab (*Callinectes sapidus),* which are highly regarded for their relatively large size. This level of biodiversity has long promoted a healthy stream of public interest, attracting over 58,000 visitors annually who use the refuge for educational and recreational activities such as hunting, fishing, crabbing, and wildlife observation (Frew et al. 2018).

Collectively, Lake Mattamuskeet's rich history, cultural significance, and biodiversity make it a unique and invaluable public destination for Hyde County and North Carolina. However, since the 1990s, due to excessive nutrients and high turbidity, the clear water and abundance of SAV has shifted to an algal-dominated, hyper-eutrophic system with high turbidity, poor water quality, and an overabundance of invasive carp. This has resulted in a public outcry to restore the health of the lake and prompted the development of the LMWRP (NCCF 2019).

For more information regarding the affected environment, please see Section 2.2.1 *Lake Mattamuskeet* of the refuge's HMP, which is incorporated herein by reference (USFWS 2017).

This section analyzes the environmental consequences of each alternative on the affected resources, including direct and indirect effects as well as cumulative impacts. This EA only includes the written analyses of the environmental consequences on a resource when the impacts on that resource could be more than negligible and therefore considered an "affected

resource." The following resources either (1) do not exist within the project area or (2) would either not be affected or only negligibly affected by the proposed action: geology and soils, air quality, floodplains, wilderness, and cultural resources. If a future action should cause ground disturbance, the Service would follow all regulations and policies related to managing cultural and historic resources.

Terrestrial Wildlife and Aquatic Species

Affected Environment

Description of Affected Environment for the Affected Resource

The refuge and its surrounding waters support many species of resident and migratory fish and wildlife. Of these, 48 species are fish, 145 are birds, 48 are reptiles and amphibians, and 40 are mammals. The refuge supports wildlife species that are important from both a regional and a national standpoint. Its large size and vegetative diversity make the refuge a haven for species that require aquatic and wetland habitats.

The refuge is situated roughly at the midpoint of the Atlantic Flyway and is a valuable feeding and resting area for numerous species of wintering waterfowl. Tundra swans, coots, and more than 25 duck species winter either on the refuge or in the sounds and rivers adjacent to the refuge. Populations of migratory waterfowl peak from November through February.

Lake Mattamuskeet provides over 40,000 acres of open water for resting, feeding, and escape cover. The most prevalent wintering species are found in Lake Mattamuskeet, moist-soil units, and refuge marshes and include northern pintail *(Anas acuta*), green-winged teal (*Anas carolinensis)*, gadwall, American wigeon, mallard (*Anas platyrhynchos*), and American black duck (*Anas rubripes*). Other species wintering or migrating on the refuge and surrounding waters may include blue-winged teal (*Anas discors*), ring-necked duck, northern shoveler (*Spatula clypeata*), greater scaup (*Aythya marila*), lesser scaup (*Aythya affinis*), canvasback (*Aythya valisineria*), ruddy duck (*Oxyura jamaicensis*), redhead, bufflehead (*Bucephala albeola*), hooded merganser (*Lophodytes cucullatus*) and red-breasted merganser (*Mergus serrator*). Tundra swan numbers increased steadily to a peak of over 30,000 birds counted during the mid-winter survey in 2008. Since this time, mid-winter counts have decreased to under 10,000 swans recorded in 2016, with a notable decline in the number of swans observed on the lake. This could potentially be attributed to the loss of SAV that has occurred during this period.

Although celebrated primarily for its waterfowl, Mattamuskeet NWR also provides habitat for formerly listed species, such as the bald eagle (*Haliaeetus leucocephalus*) and peregrine falcon (*Falco peregrinus anatum*). During the summer months, the refuge provides important habitat for breeding ospreys, herons, wood ducks, and other migratory bird species.

Submerged aquatic and emergent vegetation in the lake provide an important nursery habitat and refuge for migratory fish, blue crabs, and other aquatic invertebrates. Anadromous fish and

blue crabs can enter the lake through the water control structures when the gates are open. In addition, resident finfish require aquatic habitat of adequate depth and structure, good water quality, appropriate salinity levels, and access to the habitats in which they spawn.

Description of Cumulative Impacts, Environmental Trends, and Planned Actions

Water quality degradation caused by excessive nutrients and sediment entering the lake, an overabundance of carp, and harmful algal blooms continues unabated. Rising water levels in the Pamlico Sound and sediment-filled drainage canals continue to reduce drainage of the lake, causing it to function much like a sediment basin. Unconsolidated sediment continues to accumulate in the lake and is readily resuspended by the bottom-feeding behavior of common carp as well as wind and wave action. Algal blooms also cover the lake surface and block light from reaching the SAV, meaning that the vegetation cannot photosynthesize (Moorman et al. 2017). Consequently, each of these factors contribute to high light attenuation resulting in an environment unconducive to SAV establishment and growth. The loss of this SAV-dominated ecosystem has had notable negative effects on fish and wildlife resources.

Restoration of the SAV community is one of the goals identified in the LMWRP, which includes several strategies and BMPs. The likely reduction of cyanobacteria under the proposed action would help address some of the priority concerns identified in the LMWRP (NCCF 2019). The project would be conducted concurrently with BMPs and other ongoing stakeholder efforts to reduce nonpoint source nutrient loading to the lake, thus providing the maximum chance of success. Additionally, the refuge is currently working towards establishing a contract for removal of invasive carp, which would remove a source of turbidity and help to improve water clarity and quality, thereby further enhancing the expected results of this project.

Impacts on Affected Resource

Alternative A – No Action

Treatments of the harmful algal blooms using Lake Guard® Oxy would not occur or be evaluated and cyanobacteria would continue to dominate the lake unless other measures are successfully implemented. The refuge would not take this step towards the fulfillment of the goals and objectives in the CCP (USFWS 2008), the HMP (USFWS 2017), and the LMWRP (NCCF 2019) to restore SAV and a healthy aquatic ecosystem. As a result, short and long-term impacts from this no action alternative would be a perpetuation of degraded habitat for wildlife, especially aquatic species, unless other measures are successfully implemented.

Alternative B – Cyanobacteria Treatment

While treatment of the cyanobacteria with this product is expected to improve water quality, there are potential adverse impacts to wildlife to be considered. The Environmental Protection Agency (EPA) label for Lake Guard® Oxy indicates that it is toxic to birds. This statement was originally used in the EPA's Biopesticides Registration Document for the active ingredient used in Lake Guard® Oxy (USEPA 2002). This original product was intended to be applied to

terrestrial environments, presumably making it more accessible to ingestion by birds. The EPA's Biopesticides Registration Document states:

> The end-use product is to control algae, moss and slime molds and is sold for use on lawns and ornamental plants around residences, and for horticultural and commercial use, as shown on the label of the product. When applied in accordance with directions on the label, the unstable nature of the chemical accounts for the use of the product without harm to birds and other terrestrial animal species. In the presence of water, the active ingredient rapidly breaks down to hydrogen peroxide and sodium carbonate, and hydrogen peroxide rapidly breaks down, on contact, to water and oxygen, neither of which presents toxicological concern (USEPA 2002).

Lake Guard® Oxy is a granular product that would be applied directly to the water surface and expected to fully dissolve within a matter of hours, limiting the likelihood of consumption by wildlife. There are no research studies available addressing whether birds would consume hydrogen peroxide (H_2O_2), the active ingredient in Lake Guard® Oxy (correspondence between BlueGreen and NCDWR 2023). Multiple studies show that the cells of birds and bats are remarkably resistant to the oxidative stress brought on by H_2O_2 (Ogburn et al. 1998; Brunet-Rossinni 2004). Additionally, veterinary medicine has found H_2O_2 to be an effective emetic in dogs, with mild adverse effects (e.g., lethargy and nausea, Khan et al. 2012). For fish, treatment using H_2O_2 has been instrumental in sanitization efforts against such diseases as columnaris and has been used as a safe emetic for largemouth bass (Bowker et al. 2013; Speare & Arsenault 1997; Miranda 1986). BlueGreen has used this product in several other projects without a single report or observation of wildlife consumption, illness, or mortality related to this product. Furthermore, they have observed that fish have actively avoided the product, which has been attributed to the nociceptors in their mouths detecting the small amounts of H_2O_2 being slowly released into the water (correspondence between BlueGreen and NCDWR 2023). Thus, the toxicity of the product to wildlife and aquatic species would be expected to be minimal.

An acute toxicity test (modified LC50) was conducted on *Ceriodapnia,* a small aquatic invertebrate commonly used in toxicity tests, to determine the product's effect. The results of the toxicity test indicated a half maximal inhibitory concentration (IC50) of 37.5 mg/L, which means that 50% of the *Ceriodaphnia* organisms had biochemical or biological functions inhibited at the concentration of 37.5 mg/L of Lake Guard® Oxy. However, in consulting the aquatic toxicologist at the Division of Water Resources of North Carolina Department of Environmental Quality, the recommendation was to use the test's resulting Chronic Value of 36.7 mg/L of product as the maximum use limit (MUL) when applying Lake Guard® Oxy. As indicated by the product label and Table 1 (see Appendix B), all dosage rates fall under this MUL except for the highest doses, in which case the treatment area would be reduced by half. It is worth mentioning that on Lake Guard Oxy's product label, which is certified to NSF/ANSI/CAN/60, there is a MUL of 33 mg/L when using the product to meet drinking water standards. Therefore, the Chronic Value of 36.7 mg/L resulting from the *Ceriodaphnia* toxicity

test is above the MUL 33 mg/L that is listed on the Lake Guard Oxy product label, further emphasizing the relative safety of the product regarding sensitive aquatic organisms like *Ceriodaphnia*. Per the results of the acute toxicity tests, 36.7 mg/L would be the maximum dose concentration allowed for the proposed treatment.

Another potential adverse effect from this project would be the temporary disturbance to waterfowl, nesting ospreys, and heron rookeries from boat traffic associated with treatments and monitoring. Due to the loss of SAV in the lake, bird use along the shoreline and in the bays proposed for initial treatment is lower than in years when SAV was present. Most waterfowl using the lake in winter are in large open water areas. Therefore, the impacts would be expected to be minimal and temporary.

The 38 autonomous probes for the monitoring efforts prior to a potential treatment were installed in January 2023 under SUP R23-001, with special conditions to ensure the right of the refuge to revoke or revise BlueGreen's methodology to accommodate the needs of the wildlife and aquatic species. There is routine maintenance associated with the probes that requires boating to the locations of the probes approximately monthly. Additionally, SUP R23-003 with special conditions was issued to IMS to conduct routine independent monitoring and water sampling (Figure 3, Appendix B). Both permits require notice to the refuge prior to the visit, and the disturbance to the wildlife and aquatic species would be monitored closely. If at any point the monitoring efforts cause undue disturbance to the habitat and/or wildlife, the refuge would re-evaluate the methodology and make necessary changes to ameliorate the issues.

A second SUP to BlueGreen would be required for the proposed treatment. The SUP would include stipulations that if at any point application of the product itself caused unreasonable harm to the habitat and/or wildlife, the refuge would re-evaluate the methodology and make necessary changes. Furthermore, if observations by refuge staff indicated birds or other wildlife were attracted to the product, SUP stipulations would require efforts be taken to deter birds or other wildlife from harmful use or consumption of the product. Continuous observations would be required during treatments to monitor wildlife response.

The potential beneficial effects of this project would be: 1) increased water clarity from reducing the cyanoHABs, 2) decreased cyanotoxins, 3) increased green algae, and, perhaps, 4) increased biodiversity of fish. The increased water clarity would be influential in the efforts to restore SAV to the lakebed, which would provide essential habitat for fish and other aquatic life and an important food source for waterfowl. The reduction of cyanobacteria populations and the associated cyanotoxins would reduce this threat to wildlife and public health. Additionally, one study found that a diversity of green algae species proved to be a strong competitor against dominant cyanobacteria (Nolan & Cardinale 2019). Thus, this treatment would have the potential to reduce the cyanobacteria to the point that beneficial green algae species could effectively compete and control the cyanoHABs. Finally, BlueGreen has observed in some of their previous projects that there was an increased biodiversity in fish species found after the

cyanobacteria populations collapsed (correspondence between BlueGreen and NCDWR 2023). For instance, following treatment using Lake Guard® Oxy in Lake Minneola in Florida, the Florida Fish and Wildlife Conservation Commission noticed that the largemouth bass populations showed increasing trends in weight, length, and biomass post-treatment, indicating that the treatment did not negatively affect the fish populations and may instead have had a positive impact (Rozman et al. 2022). Therefore, the proposed cyanobacteria treatment in Lake Mattamuskeet is expected to benefit to a wide array of wildlife and aquatic species. Successful implementation of the proposed action, coupled with other restoration techniques, is expected to improve water quality, water clarity, and habitat quality and quantity by promoting the reemergence and successful restoration of SAV and ultimately the renewal of one of the premiere Atlantic Flyway overwintering waterfowl sites and important nursery for numerous aquatic species.

Threatened and Endangered Species, and Other Special Status Species

Affected Environment

Description of Affected Environment for the Affected Resource

The refuge supports several species of special status. The state endangered American peregrine falcon primarily uses the grassland and wetland habitats on the refuge. The federally endangered red wolf (*Canis rufus*) occurs on the refuge but has not been documented along the perimeter of the lake where the treatment would take place as there is more suitable habitat for the red wolf in other areas of the refuge. The secretive, federally threatened eastern black rail (*Laterallus jamaicensis jamaicensis*) has not been recorded on the refuge, but there is marsh habitat that may be suitable for them. The following federally threatened species may occur but have not been documented on the refuge: rufa red knot (*Calidris canutus rufa*), and piping plover (*Charadrius melodus*). In 2021, the federally threatened sensitive joint-vetch (*Aeschynomene virginica*) was planted in Farm Area 2 (FA-2) in a restoration effort on the refuge and was documented again in 2022 in FA-2 and Impoundment 10N. Since the treatment would take place solely in the lake, these plants should be far enough away to be undisturbed by the project. There is suitable habitat for the federally endangered northern long-eared bat (*Myotis septentrionalis*), but this species has not been documented on the refuge and should not be affected by the proposed cyanobacteria treatment. The American alligator (*Alligator mississippiensis*) is listed as threatened due to similarity in appearance to other listed crocodilian species that do not occur on the refuge. Bald eagles are frequently observed on the refuge, especially in winter, and might experience minor temporary disturbance from noise and boat traffic. Their use of the lake has diminished with a decrease in water quality and a decrease in prey species using the lake. Nesting has occurred on the refuge in the past but there are currently no known nest sites.

Description of Cumulative Impacts, Environmental Trends, and Planned Actions

Water quality degradation and the subsequent loss of the SAV community has had notable negative effects on numerous fish and wildlife resources including Threatened, Endangered,

and Special Status species. Restoration of the SAV community is one of the goals identified in the LMWRP, which includes several strategies and BMPs. Additionally, the refuge is currently working towards establishing a contract for removal of invasive carp which would remove a source of turbidity and help to improve water clarity and quality.

Impacts on Affected Resource

Alternative A – No Action

Treatments of the harmful algal blooms using Lake Guard® Oxy would not occur or be evaluated and cyanobacteria would continue to dominate the lake unless other measures are successfully implemented. The refuge would not take this step towards the fulfillment of the goals and objectives in the CCP (USFWS 2008), the HMP (USFWS 2017), and the LMWRP (NCCF 2019) to restore SAV and a healthy aquatic ecosystem. As a result, short- and long-term impacts from this no action alternative would be a perpetuation of degraded habitat and poor water quality unless other measures are successfully implemented.

Alternative B – Cyanobacteria Treatment

Under Alternative B, there would be minimal expected adverse impacts to threatened, endangered, and special status species. Limited habitat disturbance in emergent zones around the perimeter of the lake during cyanobacteria treatments would occur, which could have minimal effects on peregrine falcons and American alligators. Other federally threatened or endangered species (i.e., red wolf, northern long-eared bats, and sensitive joint vetch) do not use the habitat where treatment would occur or have not been documented on the refuge (i.e., eastern black rail, rufa red knot, and piping plover), so the proposed treatment would have minimal to no impact on those species. Bald eagles may experience increased energy expenditure due to being flushed during treatment and monitoring activities (Boyles 1995). Similar habitat in undisturbed areas would be available in adjacent areas.

Successful implementation of the proposed action is expected to improve water quality, water clarity, and habitat quality and quantity by promoting the reemergence and successful restoration of SAV. Restoring this natural community would result in indirect benefits to Threatened, Endangered, and Special Status species. The refuge consulted with the Service's Raleigh Ecological Services Field Office pursuant to Section 7 of the Endangered Species Act and received concurrence. The Proposed Action was determined to be "Not likely to adversely affect species or critical habitat" for all federally listed species in the area.

Habitat and Vegetation (including vegetation of special management concern)

Affected Environment

Description of Affected Environment for the Affected Resource

Today, the Lake Mattamuskeet substrate is barren, having suffered a total loss of all SAV due to poor water quality (i.e., eutrophication, high pH, high Chl-a, and phytoplankton dominance,

Moorman et al. 2017). As a result, Lake Mattamuskeet is listed on the 303(d) list of impaired waters and is subject to cyanoHABs that produce cyanotoxins (USEPA 2016). Further monitoring efforts confirmed that three cyanotoxins (cylindrospermopsin, microcystin, and saxitoxin) were present in the lake, with cylindrospermopsin concentrations bordering federal limits for no recreational contact (Moorman et al. 2017).

Description of Cumulative Impacts, Environmental Trends, and Planned Actions

Declines in SAV were first observed in the late 1990s with a total absence of SAV observed by 2017. A summary of monitoring data collected since 1981 indicates that SAV declines in the lake were attributed to poor water quality and clarity, mainly regarding observed increases in nitrogen and phosphorous content, followed by lake-wide eutrophication.

Ongoing stakeholder efforts to implement BMPs and develop projects that reduce nonpoint source nutrient loading to the lake will continue. Additionally, the refuge is currently working towards establishing a contract for removal of invasive carp which would remove a source of turbidity and help to improve water clarity and quality, thereby further enhancing the expected results of this project. Successful implementation of the proposed action is expected to improve water quality, water clarity, and habitat quality and quantity by promoting the reemergence and successful restoration of SAV.

Impacts on Affected Resource

Alternative A – No Action

Treatments of the harmful algal blooms using Lake Guard® Oxy would not occur or be evaluated and cyanobacteria would continue to dominate the lake unless other measures are successfully implemented. The refuge would not take this step towards the fulfillment of the goals and objectives in the CCP (USFWS 2008), the HMP (USFWS 2017), and the LMWRP (NCCF 2019) to restore SAV and a healthy aquatic ecosystem. As a result, short and long-term impacts from this no action alternative would be a perpetuation of degraded habitat for wildlife due to the absence of SAV unless other measures are successfully implemented to restore it.

Alternative B – Cyanobacteria Treatment

The proposed action alternative would treat cyanobacteria, which is expected to improve water quality and clarity, promote conditions for SAV restoration, and provide a healthier aquatic ecosystem. SAV restoration is the indicator for a healthy lake ecosystem. The return of SAV (e.g., wild celery, sago pondweed, southern naiad, redhead grass, and beneficial algae) would restore an important habitat for waterfowl, native fish, and other aquatic species. In addition, the cyanobacteria treatment would help in meeting the goals and objectives in the CCP (USFWS 2008), the HMP (USFWS 2017) and the LMWRP (NCCF 2019) to restore SAV and a healthy aquatic ecosystem.

Water Quality and Resources

Affected Environment

Description of Affected Environment for the Affected Resource

Lake Mattamuskeet drains to the Pamlico Sound through four outfall canals. Each of the four outfall canals has a tide gate that opens when the head pressure is greater on the lake side. This prevents the saltier sound water from entering the lake but allows drainage of lake water into the Pamlico Sound, an estuary of national significance along with the Albemarle Sound. Due to higher water levels in the Pamlico Sound, the tide gates are remaining closed for longer periods of time, thus reducing water flow out of the lake. Three cyanotoxins (cylindrospermopsin, microcystin, and saxitoxin) are present in the lake, with cylindrospermopsin concentrations bordering federal limits for no recreational contact (Moorman et al. 2017). During high lake head pressure on the tide gates, this toxic water drains through the four outfall canals into the Albermarle-Pamlico Sound.

Description of Cumulative Impacts, Environmental Trends, and Planned Actions

Ongoing stakeholder efforts to implement BMPs and develop projects that reduce nonpoint source nutrient loading to the lake will continue. Additionally, the refuge is currently working towards establishing a contract for removal of invasive carp which would remove a source of turbidity and help to improve water clarity and quality, thereby further enhancing the expected results of this project. Successful implementation of the proposed action is expected to improve water quality, water clarity, and habitat quality and quantity by promoting the reemergence and successful restoration of SAV. Restoring the SAV and water quality in Lake Mattamuskeet would also benefit the downstream estuary of national significance and the two federally listed sturgeon species that depend on this estuary.

Impacts on Affected Resource

Alternative A – No Action

Treatments of the harmful algal blooms using Lake Guard® Oxy would not occur or be evaluated and cyanobacteria would continue to dominate the lake unless other measures are successfully implemented. The refuge would not take this step towards the fulfillment of the goals and objectives in the CCP (USFWS 2008), the HMP (USFWS 2017), and the LMWRP (NCCF 2019) to restore SAV and a healthy aquatic ecosystem. As a result, short and long-term impacts from this no action alternative would be a perpetuation of degraded habitat and water quality unless other measures are successfully implemented.

Alternative B – Cyanobacteria Treatment

The proposed alternative would lead to the reduction of cyanoHABs in Lake Mattamuskeet which would address one of the priority actions identified in the LMWRP (NCCF 2019). This action would treat cyanobacteria and is expected to result in improvements in water quality and clarity by reducing algal blooms that increase light attenuation. Reducing the cyanoHABs

would also cause a decrease in the cyanotoxins they produce (i.e., cylindrospermopsin, microcystin, and saxitoxin), promote conditions for SAV restoration, and provide a healthier aquatic ecosystem. The cyanobacteria treatment would also help in meeting the goals and objectives in the CCP (USFWS 2008), the HMP (USFWS 2017) and the LMWRP (NCCF 2019) to restore SAV and a healthy aquatic ecosystem.

Visitor Use and Experience

Affected Environment

Description of Affected Environment for the Affected Resource

The refuge provides opportunities for compatible wildlife-dependent recreational uses, including hunting, fishing, wildlife observation and photography, environmental education, and interpretation. Most of these uses occur in the general vicinity of the refuge visitor center and along Hwy. 94 that crosses the lake. The polluted conditions in the lake, due in part to active cyanoHABs, have reduced the quality of visitation on the refuge. The loss of SAV has resulted in less use of the lake by wildlife, particularly waterfowl, fish and crabs. There has been a subsequent decrease in the quality of wildlife observation, photography, and fishing opportunities on the lake itself.

The Hyde County Chamber of Commerce lists the refuge as one of the area's main attractions. Historically, the refuge averages about 37,000 visitors per year (Caudill & Carver 2019). Visitors come to hunt, fish, observe wildlife, and be present in nature.

Description of Cumulative Impacts, Environmental Trends, and Planned Actions

Visitation to the refuge has been increasing in recent years. Visitation for consumptive uses, include hunting and fishing, and non-consumptive uses, such as wildlife observation and photography and environmental education. Between 2016 to 2019, the refuge recorded an increase in visits, going from 76,500 to 87,516 visits. In 2020, the number of visits dropped to 78,247 due to the closure of Hyde County in April 2020 because of the Coronavirus Pandemic (USFWS 2020). Tourism in the general area, related primarily to the county's abundant wildlife, has remained strong. There has been a recent increase in interest by local and state partners in restoring the Mattamuskeet Lodge and promoting it as a tourist attraction.

Impacts on Affected Resource

Alternative A – No Action

Treatments of the harmful algal blooms using Lake Guard® Oxy would not occur or be evaluated and cyanobacteria would continue to dominate the lake unless other measures are successfully implemented. The refuge would not take this step towards the fulfillment of the goals and objectives in the CCP (USFWS 2008), the HMP (USFWS 2017), and the LMWRP (NCCF 2019) to restore SAV and a healthy aquatic ecosystem. As a result, short and long-term impacts from this no action alternative would be a perpetuation of degraded habitat and water quality which result in a decrease in the quality of visitation.

Alternative B – Cyanobacteria Treatment

The deteriorated and polluted state of the lake reduces the quality of visitor experiences. The refuge was required to post water warning signs at popular visitor locations to inform refuge visitors about the cyanoHABs present in the lake. The reduction of cyanoHABs in addition to implementing BMPs in the LMWRP (NCCF 2019) would improve water quality and help restore SAV. This would provide a healthier environment for the public and wildlife.

Disturbance (noise and rapid movement) from boating for monitoring treatment efforts would be a short-term, direct impact. Boating activity would result in a small amount of disturbance to the visiting public, including those on shore and in boats. In addition, some of the bays along the perimeter of the lake may be temporarily closed to fishing for the dispersal of the product. Probes placed in the water for the continuous monitoring efforts may impact navigation as they would have to be avoided by boaters. Boating restrictions and the presence of probes may have a short-term, indirect effect on other recreational users such as visitors engaged in wildlife observation near these activities.

Long-term impacts of a cyanobacteria treatment are expected to promote SAV restoration and lead to improved habitat that would provide higher quality opportunities for hunting, fishing, and wildlife observation and photography for refuge visitors. Improved habitat and water quality would provide a more aesthetically pleasing experience as well as healthier and more diverse populations of fish and wildlife, benefiting all refuge visitors.

Administration, Refuge Management, and Operations

Affected Environment

Description of Affected Environment for the Affected Resource

BlueGreen would conduct routine maintenance on the 38 probes deployed in January 2023 under SUP R23-001 to monitor water quality and the University of North Carolina IMS would independently conduct routine water quality monitoring at several locations on the lake (Figure 3, Appendix B), so the refuge would incur no cost and very little time commitment for monitoring. In addition, the dispersal of the product Lake Guard® Oxy would be done by BlueGreen or other licensed professionals under refuge supervision. Refuge staff may provide support and guidance but are not responsible for carrying out any of these activities. There are two permanent refuge staff members and three additional Service employees that would interact with project partners and potentially provide support and guidance.

Description of Cumulative Impacts, Environmental Trends, and Planned Actions

The administration and maintenance related to implementation of the proposed alternative would not materially interfere with or detract from fulfillment of the refuge purpose(s) and the Refuge System mission.

Impacts on Affected Resource

Alternative A – No Action

With this no action alternative, the refuge would continue daily operations with no short-term impacts. However, the long-term impacts may include reduced chances of success in fulfilling the goals and objectives in the CCP (USFWS 2008), the HMP (USFWS 2017), and the LMWRP (NCCF 2019) to restore SAV and a healthy aquatic ecosystem. Refuge staff would continue to invest time and effort looking for alternatives to achieve management plans' goals and objectives.

Alternative B – Cyanobacteria Treatment

Under Alternative B (the proposed alternative), the cyanobacteria treatment using Lake Guard® Oxy would take place via licensed professionals contracted by BlueGreen under refuge supervision. Maintenance done to the autonomous probes or other water quality instruments would also be completed by BlueGreen as well as IMS. The effects of the treatment would be evaluated and monitored jointly by BlueGreen, IMS, and Service staff. While Bluegreen would be primarily responsible for monitoring wildlife response during and immediately following treatment, refuge staff would also be present to confirm observations and ensure no unreasonable harm to wildlife. Close coordination with refuge staff would be required for all activity taking place on the refuge. However, the time commitment and effort would have negligible long-term negative effects. Potential positive impacts of SAV restoration and a healthier aquatic ecosystem – the refuge's main objective – would outweigh any inconvenience. No additional increase in costs for administration, law enforcement, biological monitoring and research, or annual maintenance is anticipated for either alternative.

Socioeconomics: Local and Regional Economies

Affected Environment

Description of Affected Environment for the Affected Resource

The refuge draws visitors, which provides local businesses and the county with many opportunities for ecotourism, hunting, fishing, photography, and wildlife observation. In 2006, a study found that the total, annual direct expenditures directly related to refuge visits were over $7 million while the total, annual, direct expenditures not directly related to refuge visits were over $4.5 million (Vogelsong 2006). Plus, the contribution of recreational spending in local communities was associated with about 23 jobs, $554,000 in employment income, $115,000 in total tax revenue, and $1.8 million in economic output (Caudill & Carver 2019). This increased spending in the local area generates and supports economic activity within Hyde County.

Description of Cumulative Impacts, Environmental Trends, and Planned Actions

Wildlife-dependent recreation is an important socioeconomic driver in this local area. People come from around the world to see the wintering migratory waterfowl, hunt, fish, and experience the wonders of Lake Mattamuskeet and Hyde County. The refuge provides an important sanctuary to the area's wintering waterfowl that helps maintain quality hunting experiences on surrounding private lands. Hunting guides, outfitters, restaurants, and lodging businesses rely on ecotourism. Because of the lake's importance to the county's economy, the quality of the habitat for wildlife is a prominent concern. Improved habitat for wildlife and aquatic species would mean better opportunities for hunting, fishing, wildlife observation and photography, and any other wildlife-dependent recreational activity.

Impacts on Affected Resource

Alternative A – No Action

The refuge would continue current management without treating the cyanobacteria in the lake. This alternative would have no short-term impacts; however, the local economy would suffer in the long term due to the loss of an opportunity to improve visitor experience and draw in more business to the various tour guides, restaurants, and lodging found in the county.

Alternative B – Cyanobacteria Treatment

With this alternative, the cyanobacteria treatment would take place and is expected to improve the water quality and habitat. In as much as these improvements lead to a healthier lake, they would increase the quality of hunting, fishing, and other wildlife-dependent recreational activities that are a major draw for tourists to the area. Consequently, the local economy would be positively impacted in the short term and the long term.

Environmental Justice

Affected Environment

Description of Affected Environment for the Affected Resource

Executive Order 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations, requires all federal agencies to incorporate environmental justice into their missions by identifying and addressing disproportionately high or adverse human health or environmental effects of their programs and policies on minorities and low-income populations and communities.

In Hyde County – the county in which MNWR is located – the median household income is approximately $48,577 compared to the national average of $69,021; about 25% of the families in the county live below the poverty level; and approximately 45% of the county's population belong to a minority group (USDOC 2022).

Description of Cumulative Impacts, Environmental Trends, and Planned Actions

The Service has not identified any potential adverse environmental or human health impacts from these alternatives. Minority or low-income communities will not be disproportionately affected by any impacts from either of the alternatives.

Monitoring

The refuge and NCWRC have conducted long-term monitoring to document the aquatic health of the lake and effectiveness of present management actions to inform future management. Since 2012, intensive water quality monitoring has been conducted in the lake and in each of the four outfall canals. In addition, two U.S. Geological Survey Continuous Water Quality Stations were installed in the east and west basins of the lake. Parameters collected include nutrients, pH, chlorophyll a, dissolved oxygen, specific conductance, and Secchi disk readings for water clarity. Since the early 1980s and during the summer months, the refuge conducts annual surveys for SAV and, in some years, osprey productivity in the lake. From November through early March, the refuge conducts aerial and ground wintering migratory waterfowl surveys. Every fall, the NCWRC conducts annual fish surveys in the lake and canals to monitor sportfish.

Extensive monitoring, specific to the proposed action, would be conducted before, during, and after the proposed treatment. Some monitoring has already been initiated to learn more about cyanobacteria in the lake and to establish baseline values. IMS would be responsible for monitoring the lake's water quality and effects of the proposed treatment. Their proposed monitoring plan states that they would, "monitor the phytoplankton community, optical water quality constituents, zooplankton community, and toxin levels" (Hall 2023). IMS would collect discrete samples to test several parameters of water quality (e.g., ammonia, nitrate and nitrite, total phosphorus) before and after the treatment. A total of 20 sampling sites were established under SUP R23-003, with two sites located at the two U.S. Geological Survey's continuous water quality monitoring stations in each basin; two additional sites in the middle of the east and west basins; and two sites within each of the proposed treatment and control bays (Figure 3, Appendix B). Monitoring by IMS is intended to capture any positive and negative impacts of the proposed action to water quality and ecosystem health. Their independent monitoring results would be used by the technical advisory group as the primary measure of the project's effectiveness. Details of the IMS monitoring are described in their Proposed Monitoring Plan for Assessing the Efficacy of Peroxide Treatment of Cyanobacteria in Lake Mattamuskeet (see Appendix C).

Additional monitoring would be conducted by BlueGreen to track cyanobacteria blooms and help direct algaecide treatments. The proposed action entails monitoring efforts via 38 autonomous probes to capture the turbidity, temperature, chlorophyll-b (Chl-b, used as indication of the total biomass of green algae), phycocyanin (PC, used as indication of the total biomass of cyanobacteria), and conductivity. These data, in addition to satellite imagery and

historical data, would be used to create a BlueGreen Intelligence Map to track and target cyanoHAB locations, duration, and intensity. With these monitoring efforts, the treatment would be customized to fit Lake Mattamuskeet's unique characteristics, minimizing the amount of product that would be required to meet the goal of collapsing the cyanobacteria population and would determine if any follow-up spot treatments would be required.

Visual assessments by refuge staff, the professional applicators, site visits from the project manager, and periodic flyovers by BlueGreen (correspondence between BlueGreen and NCDWR 2023) would also be relied upon. BlueGreen would provide an email address for the public to use to send in observations and other comments during treatment. If at any point the monitoring efforts were to cause undue disturbance to the habitat or wildlife, or the product itself was deemed harmful to the habitat, wildlife, or water quality, the refuge manager would re-evaluate the methodology and work with the project team to make necessary changes to minimize adverse impacts.

Summary of Analysis

Alternative A – No Action

As described above, there would be no trial treatment of the harmful algal blooms, and cyanobacteria would continue to dominate Lake Mattamuskeet. Minimal beneficial effects of this action are expected. Refuge and Lake Mattamuskeet goals, outlined in the CCP (USFWS 2008), the HMP (USFWS 2017), and the LMWRP (NCCF 2019), to restore SAV and a healthy aquatic ecosystem for the protection of habitat and wildlife would be less likely to be achieved in the foreseeable future. Wintering waterfowl numbers would likely continue to decline as well as the quality of the visitor experience on the refuge, which may lead to a reduction in benefits to the local economy.

Alternative B – Cyanobacteria Treatment

This proposed alternative helps meet the purpose and needs of the Service by evaluating the effectiveness of a cyanobacteria treatment to improve water quality and contribute to re-establishing SAV and green algae in Lake Mattamuskeet. This action would meet the refuge's goals of maintaining open water habitat in Lake Mattamuskeet and associated canals, maintaining good water quality and healthy SAV communities, protecting fish and their habitats, and providing foraging for 200,000 migratory waterfowl. Additionally, wildlife-dependent recreational opportunities may be improved for the public.

The Service has determined that the proposed action is compatible with the purposes of Mattamuskeet NWR and the mission of the Refuge System under the refuge's Research Compatibility Determination. The proposed action includes the study that would be conducted by IMS and extensive monitoring and treatment of four bays shown in Figure 2 (Appendix B).

The benefit to SAV restoration from reducing the cyanobacteria populations would result in cleaner water in the lake and in water discharging into the Albemarle-Pamlico estuary from the lake. This would benefit Service trust species and priority resources of concern including wintering and migratory waterfowl (e.g., American black duck, northern pintail, tundra swan), long-legged wading birds (breeding and wintering), nesting ospreys, and anadromous and catadromous fish that depend on a healthy lake ecosystem to complete their life cycles. Furthermore, Hyde County is largely reliant on a healthy and thriving Lake Mattamuskeet ecosystem, which remains one of the primary economic drivers for the area. Improvements in the habitat would provide higher quality wildlife-dependent recreational opportunities to the public. In addition, the cyanobacteria treatment would contribute to meeting the goals and objectives in the CCP (USFWS 2008), the HMP (USFWS 2017) and the LMWRP (2019) to restore SAV and a healthy aquatic ecosystem. Subsequently, this action could contribute to other efforts and BMPs to remove the lake from the 303(d) list for impaired waters and benefit the nationally significant downstream Albemarle-Pamlico estuary.

In summary, minimal negative direct, indirect, or cumulative impacts would be anticipated from the implementation of the Proposed Action Alternative of conducting a trial cyanobacteria treatment in Lake Mattamuskeet. This alternative would help meet the purpose and needs of the Service as described above by improving the habitat conditions for Service trust species, providing higher quality experiences for wildlife-dependent recreation, and meeting the Service's priorities and mandates. The Service believes that the Proposed Action meets compatibility requirements including the purposes of the refuge and the mission of the Refuge System.

List of Sources, Agencies, and Persons Consulted

BlueGreen Water Technologies
Lake Mattamuskeet Watershed Restoration Technical Working Group
Lake Mattamuskeet Watershed Restoration Collaboration including local stakeholders and Hyde County
North Carolina Department of Water Resources
North Carolina Wildlife Resources Commission
University of North Carolina Institute of Marine Sciences
U.S. Fish and Wildlife Service Ecological Services, Raleigh Office
U.S. Fish and Wildlife Service Division of Migratory Birds

List of Preparers and Reviewers

Abby Bourne, ACE-EPIC Biological Intern, Mattamuskeet National Wildlife Refuge
Kendall Smith, Refuge Manager, Mattamuskeet National Wildlife Refuge
Kelley Van Druten, Wildlife Refuge Specialist, Alligator River National Wildlife Refuge
Laura Housh, Planning Branch, Southeast Regional Office
Cindi Hall, Regional Planning Assistant, Southeast Regional Office

...

State Coordination

The refuge has collaborated with the NCWRC and Hyde County to develop the approved LMWRP. In addition, the refuge and NCWRC collaborate on the Mattamuskeet Watershed Restoration Technical Working Group that has thoroughly discussed the proposed cyanobacteria treatment, BMPs, and other actions to improve the health and quality of Lake Mattamuskeet's ecosystem.

Tribal Consultation and Cultural Resources

Pursuant to the National Environmental Protection Act, the National Historic Preservation Act, the Service's Native American Policy, Secretarial Order 3206 (American Indian Tribal Rights, Federal-Trust Responsibilities, and the Endangered Species Act), and Executive Order 13175 (Consultation and Coordination with Indian Tribal Governments), this action would have "no effect" upon any of the refuge's historic properties, including the architectural ruins and canal system associated with the early 20th century town of New Holland. Due to the nature of the action, the undertaking is deemed to be routine maintenance. Section 106 is not triggered and consultation with the Tribes and the North Carolina State Historic Preservation Office is not necessary. Should the scope of the project change, further review by the Service would be required.

Public Outreach

The LMWRP (2019) was a collaboration process with stakeholders representing private landowners, Hyde County, Service, NCWRC and local businesses that met regularly and included numerous public meetings and updates. In addition, following the approval of the LMWRP, a new Memorandum of Understanding between Service, NCWRC and Hyde County was approved to continue the collaboration to implement the LMWRP.

This Draft EA will be available for public review for 30 days. The public will be notified about the comment period by posting notifications at the refuge's Visitor Center, on the refuge website (https://www.fws.gov/refuge/mattamuskeet), on the North Carolina Refuges Facebook page (https://www.facebook.com/USFWS.NC/), and through an informational bulletin in local newspapers.

Determination

This section will be filled out upon completion of any public comment period and at the time of finalization of the Environmental Assessment.

The Service's action will not result in a significant impact on the quality of the human environment. See the attached "Finding of No Significant Impact."

The Service's action may significantly affect the quality of the human environment and the Service will prepare an Environmental Impact Statement.

Signatures

Submitted by:
Project Leader Signature:
Date:

Concurrence:
Regional Historic Preservation Officer Signature:
Date:

Concurrence:
Refuge Supervisor Signature:
Date:

Approved:
Regional Chief, National Wildlife Refuge System Signature:
Date:

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Appendix A – Other Applicable Statutes, Executive Orders, and Regulations

Cultural Resources

- American Indian Religious Freedom Act, as amended, 42 U.S.C. 1996 – 1996a; 43 CFR Part 7
- Antiquities Act of 1906, 16 U.S.C. 431-433; 43 CFR Part 3
- Archaeological Resources Protection Act of 1979, 16 U.S.C. 470aa – 470mm; 18 CFR Part 1312; 32 CFR Part 229; 36 CFR Part 296; 43 CFR Part 7
- National Historic Preservation Act of 1966, as amended, 16 U.S.C. 470-470x-6; 36 CFR Parts 60, 63, 78, 79, 800, 801, and 810
- Paleontological Resources Protection Act, 16 U.S.C. 470aaa – 470aaa-11
- Native American Graves Protection and Repatriation Act, 25 U.S.C. 3001-3013; 43 CFR Part 10
- Executive Order 11593 – Protection and Enhancement of the Cultural Environment, 36 Fed. Reg. 8921 (1971)
- Executive Order 13007 – Indian Sacred Sites, 61 Fed. Reg. 26771 (1996)

Fish & Wildlife

- Bald and Golden Eagle Protection Act, as amended, 16 U.S.C. 668-668c, 50 CFR 22
- Endangered Species Act of 1973, as amended, 16 U.S.C. 1531-1544; 36 CFR Part 13; 50 CFR Parts 10, 17, 23, 81, 217, 222, 225, 402, and 450
- Fish and Wildlife Act of 1956, 16 U.S.C. 742 a-m
- Lacey Act, as amended, 16 U.S.C. 3371 et seq.; 15 CFR Parts 10, 11, 12, 14, 300, and 904
- Migratory Bird Treaty Act, as amended, 16 U.S.C. 703-712; 50 CFR Parts 10, 12, 20, and 21
- Executive Order 13186 – Responsibilities of Federal Agencies to Protect Migratory Birds, 66 Fed. Reg. 3853 (2001)
- Natural Resources
- Environmental Assessment for Maximum Common Carp Removal at Lake Mattamuskeet 35
- Clean Air Act, as amended, 42 U.S.C. 7401-7671q; 40 CFR Parts 23, 50, 51, 52, 58, 60, 61, 82, and 93; 48 CFR Part 23
- Wilderness Act, 16 U.S.C. 1131 et seq.
- Wild and Scenic Rivers Act, 16 U.S.C. 1271 et seq.
- Executive Order 13112 – Invasive Species, 64 Fed. Reg. 6183 (1999)

Water Resources

- Coastal Zone Management Act of 1972, 16 U.S.C.
- 1451 et seq.; 15 CFR Parts 923, 930, 933
- Federal Water Pollution Control Act of 1972 (commonly referred to as Clean Water Act), 33 U.S.C. 1251 et seq.; 33 CFR Parts 320-330; 40 CFR Parts 110, 112, 116, 117, 230-232, 323, and 328

- Rivers and Harbors Act of 1899, as amended, 33 U.S.C. 401 et seq.; 33 CFR Parts 114, 115, 116, 321, 322, and 333
- Safe Drinking Water Act of 1974, 42 U.S.C. 300f et seq.; 40 CFR Parts 141-148
- Executive Order 11988 – Floodplain Management, 42 Fed. Reg. 26951 (1977)
- Executive Order 11990 – Protection of Wetlands, 42 Fed. Reg. 26961 (1977)

Appendix B – Figures and Tables

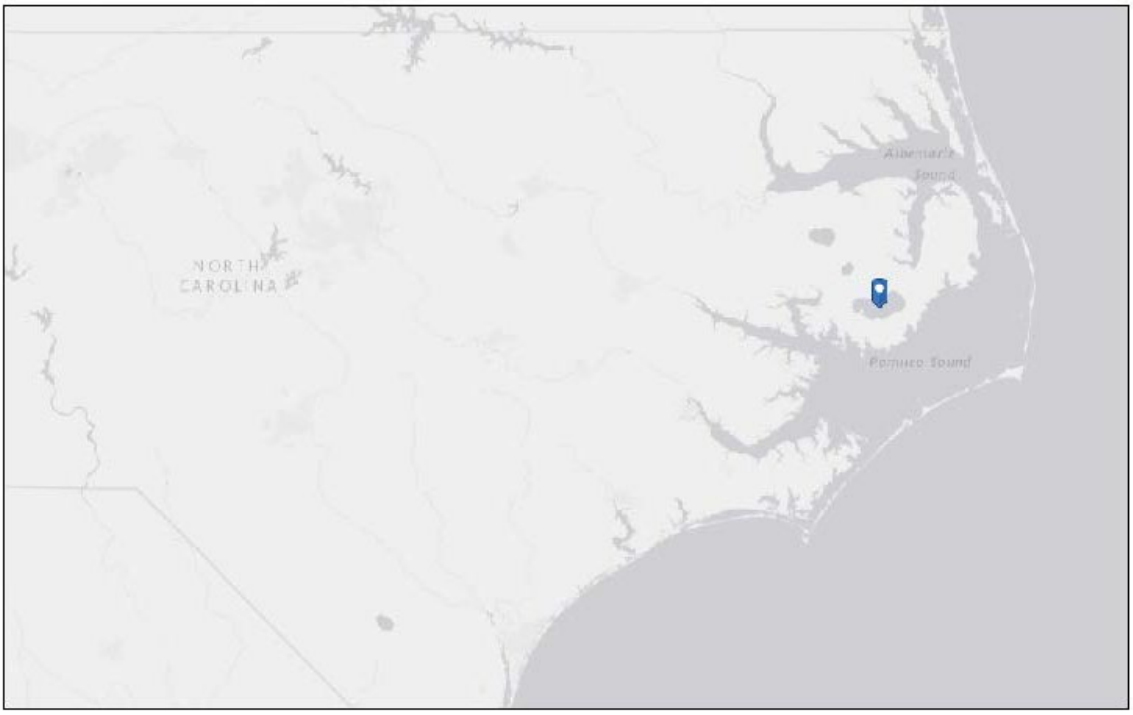

Figure 1: Location of Mattamuskeet National Wildlife Refuge in the U. S. Department of Interior, Fish and Wildlife Service Southeast Region, in relation to the Albemarle and Pamlico Sounds (estuaries).

Figure 2: An aerial image of Lake Mattamuskeet and the proposed sites for treatment with Lake Guard® Oxy and control sites. The red lines depict potential Treatment and Control Sites with white lines denoting turbidity curtain locations. This image was provided by BlueGreen Water Technologies in correspondence with the North Carolina Department of Environmental Quality on January 10, 2023, and is provisional and subject to change.

Figure 3: A map of the 20 water sampling stations monitored by the University of North Carolina Institute of Marine Sciences. Red and white lines denote proposed project areas with two sampling stations within each project area. The two sites closest to the road dividing the lake are located at the U.S. Geological Survey monitoring stations (Hall & Paerl 2023).

Table 1: Lake Guard® Oxy dosage is dependent on cyanobacteria cell density and biomass; this chart illustrates the changes in dosage as the cell density changes. The chart was provided by BlueGreen Water Technologies in correspondence with the North Carolina Division of Water Resources on February 3, 2023.

Lake Guard Oxy® Dosage Instructions			
Cyanobacteria cell density (cells/mL)	**Cyanobacteria biomass (Chl-a, µg/L)**	**Dose amount (lbs/acre)**	**Dose amount (mg/L or ppm)**
5,000-20,000	10	0.5-5	0.18-1.85
20,000-100,000	10-50	5-30	1.85-11.10
>100,000	>50	30-98	11.10-36.26
Significantly exceeds 100,000	Significantly exceeds 50	>98 (but treat only half of water body area)	>36.26 (but treat only half of water body area)

Appendix C - Monitoring Plan

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1/19/2023

Proposed Monitoring Plan for Assessing the Efficacy of Peroxide Treatment of Cyanobacteria in Lake Mattamuskeet

Currently, Lake Mattamuskeet is hypereutrophic with an average chlorophyll a concentration of 95 μg/L, nearly 2.5 times the 40 ug/L NC State water quality standard. The phytoplankton community is dominated by thin filamentous cyanobacteria that do not produce highly visual surface scums. The primary use impairments associated with the excessive cyanobacteria biomass in Lake Mattamuskeet are decreased light penetration for submerged aquatic vegetation (SAV) (Moorman et al. 2017) and toxin production that may accumulate in blue crabs that are fished for human consumption (Moorman 2018). Experimental treatments of isolated areas on both the east and westerns sides (east and west of HWY 94) of Lake Mattamuskeet are proposed to reduce cyanobacteria biomass to levels, improve water clarity, and reduce cyanotoxins. We expect that treatments will occur during spring of 2023 and 2024. We propose to monitor the phytoplankton community, optical water quality constituents, zooplankton community, and toxin levels prior to the treatment to establish a robust baseline. Intensive monitoring immediately following the treatment will capture rapid changes in the phytoplankton assemblage, toxin levels, zooplankton community, and water clarity that result from the treatment but will also capture any negative side effects such as drops in dissolved oxygen or acute changes in zooplankton community structure. Monitoring will continue, on a less intensive basis, for the remainder of the year following treatment to quantify the longevity of the treatment's impact on reducing cyanobacteria and to document other longer-term changes in conditions (e.g. improved water clarity). Four treatment areas and four control sites will be equally distributed between the east and west sides of the lake and will be isolated from the rest of the lake using turbidity curtains. By comparing before and after and the inclusion of replicated control and treatment areas, this project design fulfills the design requirements for a before/ after/ control/ interrupted (BACI) experimental design, the "gold standard" for environmental experiments.

Monitoring Schedule

Monthly monitoring for winter (2023) will be increased to twice monthly during spring leading up to treatment in April 2023. High frequency, approximately daily, monitoring will be conducted immediately following treatment by resumption of twice monthly sampling for the summer after treatment and monthly monitoring for fall and winter. (Table 1).

Table 1. Sampling schedule

Month	# Sampling Trips
Jan	1
Feb	1
Mar	2
Apr	8
May	2
Jun	2
Jul	2
Aug	2
Sep	2
Oct	1
Nov	1
Dec	1

Monitoring sites

Eight project areas will be assigned as four control and four treatment areas with two controls and two treatment areas on each side of the lake (Figure 1). Two monitoring stations will be established within each project area. One of these monitoring stations will be equipped with continuous monitoring capabilities for temperature, conductivity, turbidity, pH, dissolved oxygen, chlorophyll a fluorescence and phycocyanin fluorescence (see continuous monitoring description below). Both stations will be sampled on each sampling trip to provide duplicate observations from each area. Representativeness of these project areas will be gaged by comparison against four main lake stations that will include the USGS real time monitoring locations in both the east (EM) and west (WM) sides of Lake Mattamuskeet (Figure 1).

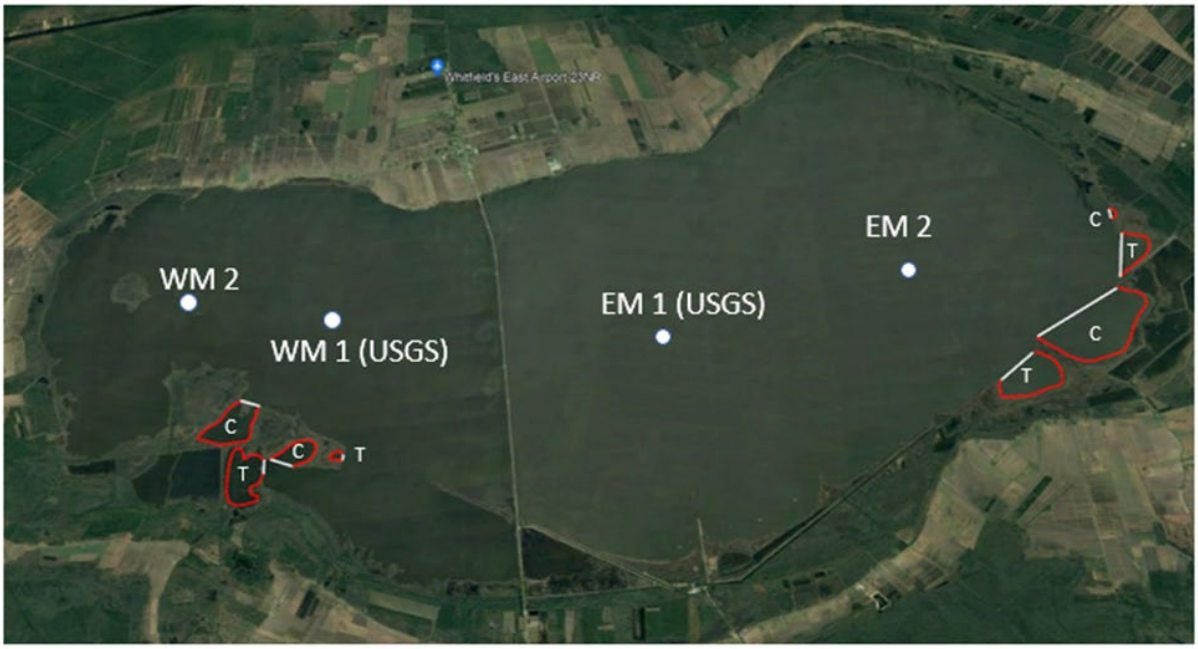

Figure 1. Map showing the planned set of four treatment and four control project areas to assess treatment efficacy. Red lines outline the project areas and white lines indicate the turbidity curtains that will isolate these areas from the rest of the lake. Representativeness of these project areas will be gaged by comparison against four main lake stations that will include the USGS real time monitoring locations in both the east (EM) and west (WM) sides of Lake Mattamuskeet.

Parameters: Discrete sampling, unattended continuous data collection, and remote sensing will be used to measure a broad range of water quality and habitat characteristics to provide a comprehensive assessment of the treatment impacts on the phytoplankton community, and habitat suitability for fish and submerged aquatic vegetation in Lake Mattamuskeet. Table 2 shows a list of proposed parameters and their utility for the project.

Continuous measurements: Aqua Real Time Algae Tracker © continuous in vivo fluorescence sensors will be deployed within the project areas and the main lake by Blue Green Water Technologies to measure total phytoplankton biomass as chlorophyll *a* fluorescence, cyanobacterial biomass as phycocyanin fluorescence, and suspended sediments as turbidity. Data from these sensors will be made available to UNC-IMS via an online dashboard. Dissolved oxygen, pH, temperature, and salinity will be monitored continuously at one centralized station within each of the project areas using an In situ Aqua Troll 600 multiparameter sonde. Our intent is to have the In situ probes collocated with one of the Algae Trackers. The USGS real time instruments will continuously monitor pH, dissolved oxygen, temperature, and salinity within the main lake. Continuous dissolved oxygen and pH measurements will be used to evaluate any potential negative side effects such as sags in dissolved oxygen or pH that result from the mortality of high levels of cyanobacterial biomass. Temperature and salinity data will be used as fundamental habitat information for phytoplankton, SAV, and fish, and also to help evaluate circulation features during the course of the study. For example, salinity intrusions from Pamlico Sound may cause changes in cyanobacteria biomass and monitoring salinity will allow those events to be detected. Additionally, spatial gradients in salinity may be used to indicate the degree to which turbidity curtains are able to isolate treatment and control project areas from the surrounding lake water.

Discrete sampling: As described above, a total of 20 stations for discrete sampling will established with 2 stations in each of the 8 project areas and 2 stations in each of the east and west sides of the main lake area. Discrete sampling stations will be co-located with unattended monitoring instrumentation to provide the maximum capacity for data comparisons and post calibration of the continuous data streams. A total of 25 sampling trips are planned for each project year to provide adequate information on pre and post treatment conditions in the treatment, control, and main lake areas. The temporal frequency of sampling trips throughout the year will be varied to achieve higher resolution during the period when treatments occur and during summer when cyanobacterial bloom activity is most likely (Table 2).

Table 2. Parameter list	
Parameters	**Assessment Purpose**
Chlorophyll *a*	Total phytoplankton biomass
Phycocyanin	Cyanobacterial biomass
Accessory pigments by HPLC	Taxa-specific phytoplankton biomass
Phytoplankton species-microscopy	Cyanobacterial species
Chlorophyll *a* fluorescence	Continuous total phytoplankton
Phycocyanin fluorescence	Continuous cyanobacteria biomass
Nutrients (N and P)	Limit algal growth
Cylindrospermopsin	Primary cyanotoxin in Lake Mattamuskeet
Microcystin	Most common cyanotoxin in NC coastal waters
BMAA	Emergent toxin of concern in eastern NC
Dissolved oxygen	Fish habitat
pH	Fish habitat
Zooplankton biomass/ community structure	Fish habitat/ ecosystem health
Turbidity	Light availability for SAV
Colored dissolved organic matter	Light availability for SAV
PAR attenuation	Light availability for SAV
Salinity	Fundamental habitat information
Temperature	Fundamental habitat information

On each sampling event, measurements of chlorophyll *a* and accessory pigments determined via high pressure liquid chromatography and phycocyanin via in vitro fluorometry will provide robust estimation of the total and class-level changes in phytoplankton biomass emphasizing cyanobacteria. An aliquot of each sample will be preserved in 1% Lugol's iodine and selected samples will be microscopically examined to assess changes in the abundance of known toxin producers (e.g. *Cylindrospermopsis raciborskii*) and determine how the abundance of toxin producers relates to measurements of cyanotoxins. Dissolved and particulate nitrogen and phosphorus concentrations (nitrate+nitrite, ammonium, total dissolved nitrogen, dissolved organic nitrogen, particulate nitrogen, o-phosphate, and total P) will be measured from every sample to provide information on how the peroxide treatment affects dynamics between the phytoplankton and nutrient pools. These nutrient data will be critical for understanding changes in community composition, and the efficacy of the treatment in achieving long-term water quality improvements.

On each sampling event, depth profiles of chlorophyll *a* and phycocyanin fluorescence, turbidity, pH, dissolved oxygen, conductivity, and temperature will be measured using an Exo II multiparameter data sonde. Depth profile data will be used to understand the vertical distribution of these parameters and the near surface values will be compared against the continuous, real-time data collected by the Algae Tracker and Aqua Troll 600 instruments as a

quality assurance measure. Vertical profiles of photosynthetically active radiation (PAR) will be measured to quantify how changes in the phytoplankton community impact light availability for SAV. Chlorophyll *a*, turbidity and colored dissolved organic matter are the primary indicators for light attenuating substances in water. These substances will be measured at each sampling event to enable modeling PAR attenuation to tease apart their contributions to PAR attenuation and isolate the impact due to changes in cyanobacterial abundance.

Zooplankton biomass and community structure will be monitored during the period immediately before and after treatments to assess positive or negative impacts to the zooplankton community which supports the lake's fishery. Similarly, cylindrospermopsin, microcystin, and BMAA cyanotoxins will be measured from discrete sample collected prior to and immediately after treatment.

Remote sensing:

Blue Green Water Technologies plans to use remote sensing to provide data necessary for determining their treatment strategy. They have agreed to share their remotely sensed data products with the UNC-IMS research team. The UNC-IMS team will evaluate the remotely sensed data products and will use those data as additional information on treatment efficacy if we feel the data strengthen our assessment capacity.