Where has the *Grass* *Gone?*

FACTORS IMPACTING SUBMERGED AQUATIC VEGETATION BRING TOGETHER PARTNERS AT MATTAMUSKEET NATIONAL WILDLIFE REFUGE

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THE GRASS HAS ALL BUT DISAPPEARED FROM LAKE MATTAMUSKEET, THE CENTERPIECE OF THE U.S. FISH AND WILDLIFE SERVICE'S (USFWS) MATTAMUSKEET NATIONAL WILDLIFE REFUGE (REFUGE). THE "GRASS," OFTEN REFERRED TO AS SUBMERGED AQUATIC VEGETATION (SAV), INCLUDES BEDS OF AQUATIC PLANTS LIKE WILD CELERY, REDHEAD GRASS, SAGO PONDWEED, SOUTHERN NAIAD, EURASIAN MILFOIL, MUSKGRASS AND NITELLA.

Located on the Albemarle-Pamlico Peninsula in eastern North Carolina, the Refuge was established to promote and maintain wetlands for migratory bird populations, specifically wintering waterfowl, as well as habitat for other wetland-dependent wildlife. Many of the Refuge wildlife and habitat conservation goals, outlined in its Comprehensive Conservation Plan, are supported by having grasses in the lake, as well as emergent vegetation around the lake shore. This vegetation provides key food resources for migratory birds, particularly waterfowl, as well as habitat for fish, crabs and other aquatic organisms.

Just how important is Lake Mattamuskeet and the Refuge to wintering waterfowl? Its strategic location along the Atlantic Flyway makes it a vitally important annual stopover site for hundreds of thousands of wintering ducks, geese and swans. Sportsmen and wildlife viewers alike, from all parts of the state and country, visit the Refuge and local area each year to hunt, fish, crab and observe wildlife — activities that provide a vital economy to the region.

Why is the grass disappearing? The sudden decline of SAV on the east side of the lake, and the potential impact these declines could have, particularly to waterfowl, fish, and crabs, has alarmed natural resource managers from the USFWS and the North Carolina Wildlife Resources Commission (NCWRC).

"In 2014, a memorandum of understanding was signed by the USFWS and NCWRC to create the Mattamuskeet Collaboration Team for the purpose of co-managing more than a dozen projects aimed at addressing the health of Lake Mattamuskeet's ecosystem, identifying and prioritizing monitoring and research needs and opportunities for habitat restoration, as well as projects designed to increase the recreational value of the lake," said USFWS Southeast Region Director Cindy Dohner.

Since establishing the collaborative agreement, USFWS, NCWRC and other partner agencies and researchers have been studying the ecology of Lake Mattamuskeet in order to better understand why SAV has declined.

"This collaborative agreement has allowed the two agencies to leverage more resources and accomplish much more than they could if they were addressing this difficult conservation challenge of restoring Lake Mattamuskeet alone," NCWRC Executive Director Gordon Myers said.

As part of the Mattamuskeet Collaboration Team, the Mattamuskeet Technical Working Group was formed and tasked with ensuring that the best available science is used for habitat restoration on the lake and surrounding watershed. The Mattamuskeet Technical Working Group is a multi-disciplinary team consisting of members from USFWS and NCWRC who have specific and extensive expertise in wildlife and fisheries management, water quality and environmental contaminants.

Based on results from an assessment of water-quality trends, we have concluded that significant increases in nutrients and suspended sediments in the lake since the 1980s have caused an increase in harmful phytoplankton and a reduction in water clarity (eutrophication). As a result, the grass has declined from the deepest to the shallowest areas of the lake. Many of the last beds of SAV are currently located in the calmer waters along the shallow, southern shores of Lake Mattamuskeet.

FIGHTING PHYTOPLANKTON

Lake Mattamuskeet is the largest naturally formed lake in North Carolina, with a surface area of approximately 40,000 acres. It is also very shallow, with an average depth of just 2 feet. It is not the only shallow lake that has lost its grasses; other large, shallow lakes share similar histories. In theory, shallow lakes generally have two ecosystem states — one where phytoplankton is dominant or one where macrophytes dominate.

Phytoplankton are mostly microscopic, single-celled photosynthetic organisms that live suspended in the water, and include algae, diatoms and cyanobacteria. Macrophytes are aquatic plants (that include SAV) and grow in or near water and are either emergent, submerged or floating. Phytoplankton and macrophytes are considered primary producers because they use the process of photosynthesis to produce their own food while serving as food sources for animals further up the food chain.

Whether a lake is dominated by phytoplankton or SAV is important to resource managers because of the negative impacts that can occur. Dense communities of phytoplankton often result when there is too much sediment and too many nutrients like nitrogen and phosphorous in a water body. The combination of excess sediment and phytoplankton reduces water clarity, which reduces the amount of light in the water column available to SAV for photosynthesis. This causes the health and abundance of SAV to decline until the grass eventually disappears.

Once the grass is gone, lake water quality continues to decline because the grasses are no longer there to anchor sediments to the bottom with their roots and to absorb the excess nutrients in the water and sediment. Dense beds of SAV are desired at Lake Mattamuskeet because grasses maintain relatively clear water, can support fish and crab populations, and are attractive to waterfowl — many of which prefer to feed on aquatic vegetation or the aquatic invertebrates which live there. By contrast, a phytoplankton-dominated lake is not a preferred state because harmful algal blooms can occur and have adverse effects on fish and crab populations. This can also produce toxic cyanobacteria.

A HISTORY OF CHANGES

This isn't the first time in the history of the Refuge that SAV hasn't been present in Lake Mattamuskeet. The lake was refilled and established as Mattamuskeet National Wildlife Refuge in 1934 following a failed agricultural project that drained the lake three times in the early 1900s. At this time, no SAV was present and the lake had poor water clarity. Turbid water conditions prevailed in the lake until the 1950s, attributed to the large number of carp present, which tend to stir up bottom sediments.

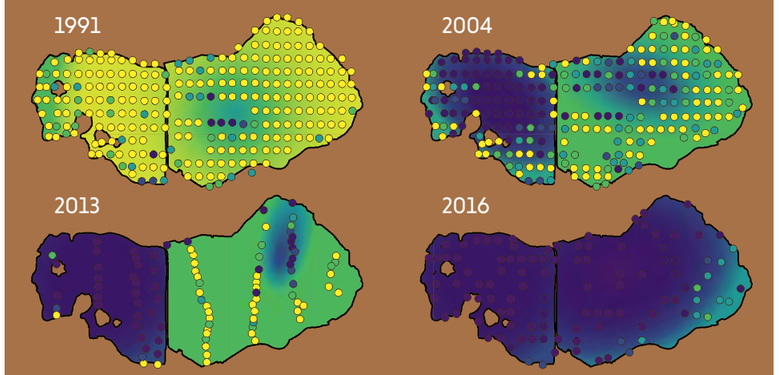
It was presumed that the turbid water conditions prevented growth and survival of SAV. Refuge managers began transplanting SAV and removing carp at this time. Between 1945 and 1960, SAV restoration in Lake Mattamuskeet began to have success with the removal of 2.3 million pounds of carp, 250,000 pounds of catfish and 150,000 pounds of gar, bowfin, gizzard shad and mullet. As SAV began to take hold, water quality continued to improve, which further promoted the establishment, spread and survival of the grasses during this time. Since the 1960s, the lake grasses have been viewed as an important part of the Lake Mattamuskeet ecosystem.

The grass on the west side of Lake Mattamuskeet began to decline during the 1990s, while grass on the east side continued to flourish. In 2009, concerns over those declines sparked research to more fully understand the apparent changes that were occurring. By extracting and examining cores of the lake sediment, researchers concluded that the construction of the Highway 94 causeway in 1940 resulted in a unique shallow lake ecosystem at Lake Mattamuskeet. Highway 94, which bisects the lake from north to south, effectively resulted in two distinct basins, which were only connected by five culverts underneath the causeway. The west basin of the lake was dominated by phytoplankton while the east basin of the lake had better water quality and supported dense beds of grasses. This unique two-state system maintained itself until recently, when the state of the lake changed again.

Monitoring data collected since 2012 indicates that there is presently no difference in water quality between the east and west sides of the lake, and rapid declines in SAV have occurred since 2013. Additionally, increasing levels of harmful cyanobacteria in the lake are producing toxins that could potentially harm wildlife and recreational users if the concentration of toxins in the lake increases. An assessment of water-quality data by the N.C. Division of Water Resources has determined that Lake Mattamuskeet is currently not meeting state water-quality standards, and beginning in 2016, the lake will appear on the U.S. Environmental Protection Agency's list of impaired waters.

GROWING CONCERN

MAPS BELOW SHOW THE ESTIMATED PROPORTION OF SUBMERGED AQUATIC VEGETATION (SAV) COVERAGE IN LAKE MATTAMUSKEET FOR THE YEARS 1991, 2004, 2013 AND 2016. SAV BEGAN TO DIE OFF ON THE WEST SIDE OF THE LAKE BETWEEN 1991 AND 1993 AND HAS BEEN RELATIVELY ABSENT FROM THAT AREA SINCE 1997. IN 2014, SIGNIFICANT DIE-OFFS OF SAV BEGAN ON THE EAST SIDE OF THE LAKE. *(CIRCLES REPRESENT SAMPLING LOCATIONS WHERE COVERAGE OF SAV WAS ESTIMATED.)*



WORKING ON A SOLUTION

There are likely many sources of increased sediment and nutrients that have resulted in eutrophication in Lake Mattamuskeet, including runoff from the surrounding farm fields and waterfowl impoundments draining to the lake, waterfowl feces and atmospheric deposition of nitrogen. The Refuge currently affects the rate of water outflow from Lake Mattamuskeet to a very limited extent, through flap gates on each of the four canals leading to Pamlico Sound. The one-way flap gates only open and allow water to pass when water levels in the lake are higher than those in Pamlico Sound. When the flap gates are open, winds can accelerate the process of pushing lake water to Pamlico Sound, depending on direction. The flap gates begin to close as Lake Mattamuskeet and Pamlico Sound reach the same level, and completely shut when the water level in the lake drops below that of the Sound, preventing salt water from entering the lake.

Current models suggest that water levels are increasing in the Pamlico Sound at a rate of 2 millimeters per year and that water levels in the Pamlico Sound have increased 9 inches since the early 1900s. This is important because it could impact the rate at which water leaves the lake, increasing the amount of time that it takes excess nutrients and sediments to be "flushed" from the system. Changes in water levels in the Pamlico Sound may play an important role in eutrophication of Lake Mattamuskeet, since even a small rise in sea level directly impacts the amount of time nutrients and sediments reside in the lake. As a result, climate change could increase nutrients and sediments in Lake Mattamuskeet and increase the likelihood that they are recycled and resuspended in the water column by wind and wave action, and grazing fish like carp.

SAV is being used as the indicator for the health of Lake Mattamuskeet to guide current and future monitoring and research efforts led by the USFWS and NCWRC. These efforts will provide the baseline information needed for managers to begin targeting potential strategies that can reduce harmful algae blooms and promote the growth of SAV in the lake, and to develop a long-term restoration plan to improve SAV coverage and overall health of the lake.

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Since September 2012, USFWS has partnered with the U.S. Geological Survey (USGS) and the N.C. Division of Water Resources (NCDWR) to monitor lake water quality. Data collected as part of this project has informed our current understanding of why the grasses have declined at Lake Mattamuskeet. The USFWS, in partnership with Dr. Ryan Emmanuel at North Carolina State University (NCSU) and the National Oceanic and Atmospheric Administration (NOAA), have begun monitoring local water levels, salinity and temperatures in the Pamlico Sound from instruments placed at Bell Island Pier, located on Swanquarter National Wildlife Refuge. Real-time data from both the lake and the Pamlico Sound is publically available. Additionally, USFWS, NCWRC and NCSU are collaborating to understand the abundance and movements of carp and the current impacts these fish have on the increased turbidity in Lake Mattamuskeet.

Several research projects designed to inform restoration strategies for Lake Mattamuskeet began in the summer of 2016. With funding provided through the Wildlife and Sport Fish Restoration Program — excise tax dollars on equipment, gear and motorboat fuel purchased by hunters, anglers and boaters — NCWRC has contracted with Dr. Mike Piehler of the University of North Carolina Institute of Marine Sciences and UNC Coastal Studies Institute to conduct a three-year project which will examine the in-lake factors that may influence the potential for restoration of grasses in the lake.

"This research is especially important since Lake Mattamuskeet has experienced such a fast and dramatic decline in plant coverage," Piehler said. "Two potential limitations on restoration of grasses in the lake are light availability and grazing [like waterfowl, turtles and carp]. We will map the amount of light available in the lake for SAV, conduct transplant experiments that include treatments that exclude grazers, and quantify chemical and physical differences between areas of the lake with and without plants . . . Results from this project will provide answers to questions about where in the lake should be targeted for restoration and what approaches are most likely to lead to sustained restoration success."

Dr. Randall Etheridge, East Carolina University, will begin to assess the sediment and nutrient inputs coming into the lake from various sources. Dr. Daniel Obenour, NCSU, has begun a project that will use existing data for Lake Mattamuskeet to develop a lake hydrologic and water-quality model.

Collectively, these projects have been prioritized as top research needs by the Mattamuskeet Technical Working Group, and will help USFWS and NCWRC determine which restoration strategies may be most successful. From what has been learned from similar restoration efforts, recovering the grass on Lake Mattamuskeet will be complicated, and will also have to focus beyond the bounds of the Refuge itself by including stakeholders in the surrounding watershed, many of which may have direct impacts on lake water quality. An assessment of all the factors impacting SAV growth and survival needs to be completed first, so that any long-term restoration plans can have the greatest chance of success.

Bottom line, the factors which led to the current state of Lake Mattamuskeet did not happen overnight. It's going to take time, and more importantly, continued funding and partnerships to improve the water quality and bring back the grasses to Lake Mattamuskeet. ◆

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