

Review of habitat management for wintering
dabbling ducks in manmade impoundments and
proposed plan for private landowners around
Lake Mattamuskeet, North Carolina

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Introduction

Mattamuskeet National Wildlife Refuge is home to North Carolina's largest natural lake (USFWS 2014). Established in 1934 in Hyde County and adjacent to the Pamlico Sound, the refuge totals approximately 50,000 acres. The lake, occupies approximately 40,000 acres, while the remaining 10,000 acres consists of freshwater wetlands, cypress-gum impoundments, moist-soil units and crop land (USFWS 2015). Located in the heart of the Atlantic Flyway, Mattamuskeet NWR's diverse waterfowl habitat and shallow waters, averaging two feet in depth, attract hundreds of thousands of wintering waterfowl every year (USFWS 2014). The refuge has historically been considered as one of the most important wintering habitats for waterfowl in the Atlantic Flyway (Save Mattamuskeet Lake 2015). Long term data indicates that 25% of all green-winged teal, 60% of all northern pintail and 30% of all tundra swans in the Atlantic Flyway winter at Mattamuskeet NWR (USFWS 2014).

According to Mattamuskeet NWR, local citizens and interest groups, the valuable waterfowl habitat on the refuge has been declining since the early 2000's (USFWS 2014; Save Mattamuskeet Lake 2015). Agricultural lands that benefit waterfowl along with 1900 acres of moist soil units have been overrun by woody vegetation with little waterfowl food value (Save Mattamuskeet Lake 2015). Moist-soil and submerged aquatic vegetation has deteriorated by 87 percent in some parts of the lake and nearly 3,000 acres of fresh water marsh is now dominated by invasive phragmites or common reed (Kozak 2014; Save Mattamuskeet Lake 2015). Refuge mis-managements by USFWS, channelization of major drainage canals, maintaining lower lake water levels, salt water intrusion from the Pamlico Sound, and nutrient loading from adjacent farm lands have all been cited as contributing factors plaguing the refuge ecosystem (Kozak 2014; USFWS 2014).

Due to lack of state and federal funding, little long term data exists concerning low water levels, water quality, salinity and sources of nutrients to suggest a clear culprit (Kozak 2014). In 2012 the U.S. Fish and Wildlife Service partnered with the U.S Geological Survey to install two automated water quality monitoring stations to better understand what is causing the declining vegetation (USFWS 2012). On December 6, 2014 the U.S Fish and Wildlife Service and the North Carolina Wildlife Resources Commission issued a collaborative memorandum to establish funding for research and guidelines to conserve fish and wildlife and their habitats on Mattamuskeet NWR (Dohner and Myers 2014). The refuge staff will continue to control the spread of invasive vegetation in moist soil units and freshwater marshes when funding is available (Kozak 2014; Save Mattamuskeet Lake 2015). Until this research identifies a clear cause, the U.S. Fish and Wildlife Service can do little to prevent the further loss of aquatic vegetation and reduce salt water intrusion. The refuge is required to carry out the mandates of the National Wildlife Refuge Improvement Act (NWRIA) and current Comprehensive Conservation Plan (CCP). Under the NWRIA and CCP, no activity or management practice may be allowed that could lead the degradation of a refuge's ability to provide for the stated primary purpose, "to protect and conserve migratory birds and other wildlife resources through the protection of wetlands" (USFWS 2014). The NWIA requires long-term compelling scientific evidence to guide any decision to change sound management practices. The current CCP is not scheduled for a required review until 2023 (USFWS 2014).

Over the past decade, there has been an absence of waterfowl observed on the lake from N.C. HWY 94, which divides the lake in half (Kozak 2014; Save Mattamuskeet Lake 2015). This was once a location where tens of thousands of ducks, geese and swans could be observed. While during the same time period, the Wildlife Resources Commission Annual Mid-Winter Waterfowl Survey on Lake Mattamuskeet and Surrounding Farm Fields indicate wintering waterfowl numbers over the past decade are increasing (Howell 2014). Research by the U.S. Fish and Wildlife Service and landowners indicate the increase in waterfowl numbers is due to food and habitat resource provided by thousands of acres of privately owned agricultural impoundments surrounding the refuge (USFWS 2013; Save Mattamuskeet Lake 2015). Although these impoundments provide a high energy food source and habitat that attract waterfowl, agricultural grains do not contain the protein or amino acids needed to sustain waterfowl populations (University of Maryland 2015; USFWS 2007). Studies have shown that waterfowl depend on a diet of plants, seeds, and aquatic invertebrates to meet their energetic and nutritional needs (Delnicki and Reinecke 1986). The purpose of this paper is to provide a literature review of agricultural and moist-soil waterfowl management practices similar to those used by Mattamuskeet NWR. In addition, I will create a cost effective management plan that reduces nutrient loading to Mattamuskeet NWR, while meeting the nutritional needs of wintering waterfowl within a controlled impoundment.

Wetland Habitats Common to Mattamuskeet National Wildlife Refuge

There are 12 habitat types found on the Lake Mattamuskeet National Wildlife Refuge. Of these habitat types, wintering waterfowl most commonly use moist-soil units, cypress-gum impoundments, fresh water marsh, cropland and open water to meet energetic and nutritional demands of migration and maintenance (U.S. Fish and Wildlife Service 2014). The lake, surrounding impoundments and wetlands are vital wintering habitat for regional waterfowl. The refuge attracts the majority of the green winged teal, northern pintails and tundra swans that winter along the Atlantic Coast. Tens of thousands of tundra swans, geese and wading birds, and hundreds of thousands ducks utilize the refuge during fall, winter, and spring migrations (U.S. Fish and Wildlife Service 2014).

Moist-soil Units

In the late 1960s and early 1970s moist-soil units were constructed on 2,505 acres on the southern edge of Lake Mattamuskeet. Water management in the moist-soil units is used to promote the growth of moist-soil vegetation that produce food and cover for waterfowl. Units are drawn down at different times throughout the growing season to create a diversity of moist-soil vegetation and habitat. During the spring and early summer some units are drained to implement burning, disking, and planting that foster moist-soil plant growth and control perennial weeds. Intensive monitoring and proper management determines the success of the vegetation within the units. Monitoring and management decisions continue during the growing season and moist-soils are maintained through the summer. Water may be pumped into moist-soil units to enable growth of moist-soil plants during periods of drought. The units are gradually flooded in the early Fall in preparation for migrating waterfowl (U.S. Fish and Wildlife Service 2014).

Cypress-Gum Impoundments

Cypress-Gum Impoundments are located adjacent to moist-soil units and occupy a total of 572 acres which are flooded semi-permanently to function as a saturated cypress-gum swamp comprised of open water, freshwater marsh, and moist-soil plants. These impoundments offer breeding habitat for wood ducks and wintering habitat for green wing teal and ring neck duck. These forested impoundments are drawn down every few years to enhance moist-soil plant distribution (U.S. Fish and Wildlife Service 2014).

Freshwater Marsh

Freshwater marsh occupies the majority of the 2,046 acres that borders the southern rim of Lake Mattamuskeet. The marsh is an important source of food and cover for American black ducks. Freshwater marshes require burning every few years to reduce stands of dead grass and to promote the growth of sedges, rushes and wildflowers. Much of the marshes have not been burned in the last fifty years and lack species diversity. Only a few species of marsh grasses occupy the unburned upper and lower marshes. As a result of infrequent fire, 1400 acres of marsh are now dominated by invasive shrubs and common reed. Fire, mowing, flooding, and herbicides are required to control invasive species (U.S. Fish and Wildlife Service 2014).

Open Water

Mattamuskeet is a 40,276-acre freshwater lake with an average depth 2-3 feet and a pH from neutral to slightly acidic. Rainfall and surface runoff from adjacent agricultural land are the main water sources for the lake. The submerged aquatic vegetation such as wild celery, redhead grass, and musk grass is an important habitat component for wintering waterfowl in the open water habitat (U.S. Fish and Wildlife Service 2014).

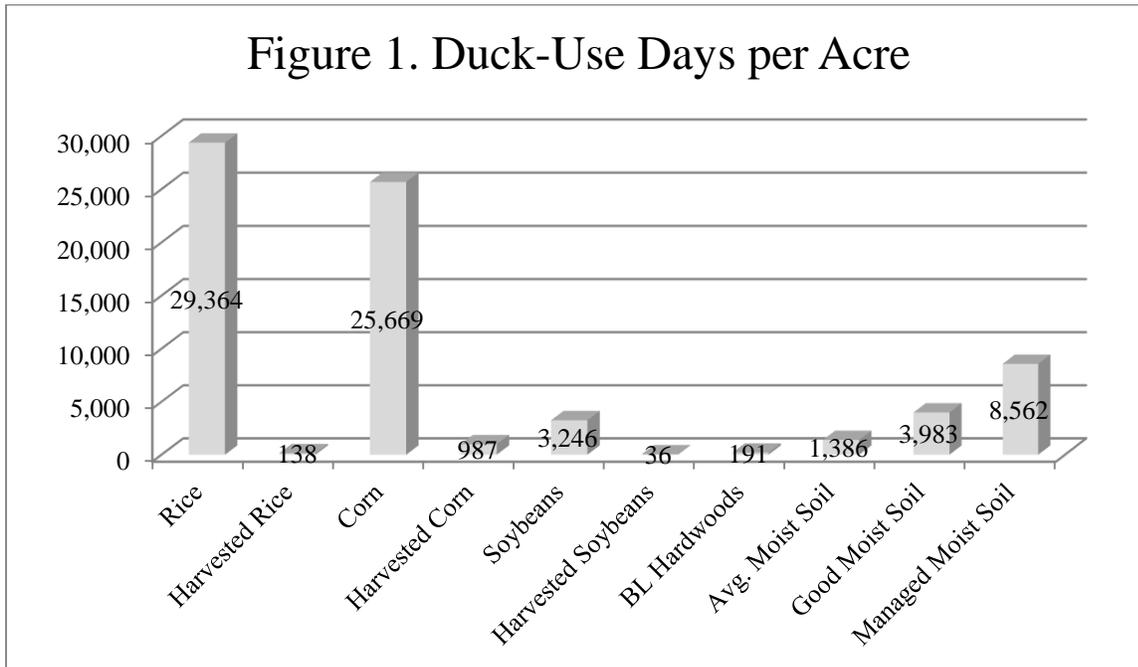
Crop Land

191 acres of crop land is located adjacent to moist-soil units and is planted in corn, a high energy food source. Daily disturbance is minimized to help meet the needs of waterfowl. The harvesting of grain crops reduces the availability of high energy foods during critical weather events creating a limiting factor for waterfowl in North Carolina. The refuge cropland is leased to farmers who leave part of the crop in the field as payment. After harvested, approximately 95 acres of corn is left in standing for waterfowl. Private crop lands surrounding the refuge are an important role in providing waterfowl habitat, but cropland on the refuge provides consistent and long-term habitat (U.S. Fish and Wildlife Service 2014).

Duck-Use Days

Biologists and managers often use the term duck-use days, (DUD) when comparing the volume and quality of food accessible to waterfowl among different habitat types. DUD is the number of

ducks that could be sustained per day by one acre of habitat type (U.S. Fish and Wildlife Service 2007).



Source: U.S. Fish and Wildlife Service 2007

It is clear that unharvested rice and corn provides forage for many ducks per acre. Once harvested, the ability of corn and rice fields to support ducks is lower than average moist-soil. Well managed moist-soil areas have the ability to yield close to 11,000 to 14,000 DUD/acre. Biologists have also discovered that when food densities drop below 45 lbs. /acre, ducks will abandon a feeding location and move to areas with higher feeding opportunities (U.S. Fish and Wildlife Service 2007).

Dabbling Ducks

Dabbling ducks “tip up” when feeding and inhabit shallow water wetlands (Bellrose 1976). They are marked with brightly colored wing feathers and have feet located in the middle of their body, allowing them to easily walk on land. When flushed from the water, dabbling ducks jump straight up in the air when taking flight (University of Maryland 2015). The following is a table of dabbling ducks, geese and swans found on Mattamuskeet National Wildlife Refuge:

<p>Table 1 Dabbling Ducks Commonly Found on Mattamuskeet NWR</p>

Common Name	Scientific Name
American Black Duck	<i>Anas rubripes</i>
American Green-winged Teal	<i>Anas creacea carolinensis</i>
American Wigeon	<i>Anas americana</i>
Blue-winged Teal	<i>Anas Discors</i>
Canada Goose	<i>Branta Canadensis</i>
Gadwall	<i>Anas strepera</i>
Mallard	<i>Anas platyrhynchos</i>
Nothern Pintail	<i>Anas acuta</i>
Northern Shoveler	<i>Anas clypeata</i>
Snow Goose	<i>Chen caerulescens</i>
Tundra Swan	<i>Cygnus columbianus</i>
Wood Duck	<i>Aix sponsa</i>
Source: U.S. Fish and Wildlife Service (2014)	

Nutritional Requirements of Dabbling Ducks

Diets of wintering waterfowl are diverse and include aquatic invertebrates, moist-soil plant seeds, and agricultural grains (Delnicki and Reinecke 1986). Nutritional requirements of waterfowl change during the winter and their needs determine the habitats they select (Weller 1985). The physical demands of migrating from northern breeding areas to winter habitats exhausts much of their energy and fat reserves. Upon their arrival at the wintering grounds, they need to replenish these reserves by feeding on high energy foods and proteins. Once their energy and fat reserves are restored, the fall season is not a generally stressful period. Temperatures remain mild and there is an abundance of available food sources. During the remainder of the fall season, waterfowl build reserves in preparation for the severe weather during the winter months (University of Maryland 2015). Severe weather conditions, especially cold temperatures, are known to cause stress and affect the movements of waterfowl during winter (LeFebvre and Raveling 1967, Cain 1973, Bennett and Bolen 1978, Prince 1979). During these periods, the number of feeding flights is limited, and more time is spent resting to conserve energy (Fredrickson and Rein, 1988). When feeding does occur, waterfowl prefer high energy agricultural grains such as corn, milo and millet that can be quickly easily obtained (University of Maryland 2015).

After winter pair bonding takes place, female dabbling ducks begin to molt, replacing worn feathers with brightly colored breeding plumage. Waterfowl require high protein content foods on order to replace feathers, which are mostly composed of proteins (University of Maryland 2015). To meet these demands, ducks will change to a diet of invertebrates which contains more protein than vegetation and grains (Kaminski and Prince 1981).

Before the spring migration and breeding season, waterfowl feed to store energy and build nutrient reserves. These reserves will be crucial for females during egg production and incubation. Females need to forage heavily on proteins, fats, and minerals from moist-soil plants and seeds, agricultural grains and invertebrates, in order to prepare for the reproductive cycle

(University of Maryland 2015). The majority of waterfowl that breed in the northern United States and Canada consume these nutrients on their wintering grounds and on migration habitats (Gray et al. 1995).

Moist-soil Management for Food and Habitat

In the 1940s, Frank Bellrose introduced the idea of “moist-soil” plant production. The term referred to plant species that grew on exposed wetland soils after surface water has diminished in the growing season (Fredrickson and Taylor 1982). Bellrose discovered that waterfowl gathered in large numbers on these sites and consumed natural vegetation and seeds (Bellrose 1976). As wetland acreage continues to decline in the United States (Dahl 1990), it is important to focus on intensive management of remaining moist-soil wetland habitat and waterfowl needs (Reid et al. 1989).

Managed moist-soil habitats are shallow-water areas impounded by dikes. These dikes contain pumps and riser board structures that allow flooding during fall and draining during the growing season. Flooding of moist-soil impoundments provides feeding habitat and cover for many different species of wintering waterfowl (Fredrickson and Taylor 1982; Reid et al. 1989; Reinecke et al. 1989). Drawdowns (draining to bare soil conditions) encourage the growth of moist-soil plants, such as barnyard grasses, panicums, American bulrush, squarestem spikerush, smartweeds, redroot flatsedge, and beggarticks.

(Hindman and Stotts 1989; Low and Bellrose 1944; Fredrickson and Taylor 1982). These moist-soil plants produce diverse food sources of aquatic invertebrates, seeds, tubers, and vegetation for waterfowl (Reinecke et al. 1989; Krapu and Reinecke 1992). Most moist-soil management is often conducted within man made impoundments (Fredrickson and Taylor 1982), but natural wetlands with disturbed or degraded habitats can be enhanced. Enhancement provides increased value for waterfowl by implementing moist-soil management techniques (Reid et al. 1989). Sites too wet for establishing agricultural row crops or upland vegetation, but too dry for the management of aquatic vegetation, are ideal for development of moist-soil impoundments (Fredrickson and Taylor 1982). Mattamuskeet National Wildlife Refuge and several others in eastern North Carolina have been using moist-soil management along with submerged aquatic vegetation and agricultural row cropping to improve waterfowl habitat.

Vegetation Management

The objectives of moist-soil management are to maximize production of desirable vegetation, control growth of undesirable vegetation and provide the required habitat to increase wetland productivity and waterfowl use on wintering grounds (Fredrickson and Taylor 1982; Bolen et al. 1989; Kadlec and Smith 1989). Techniques to manipulate hydrology and succession are used to manage moist-soil impoundments and should be included an overall management plan (Fredrickson and Taylor 1982).

Vegetation is important to waterfowl for producing seeds, tubers, and tender vegetation; providing nest areas; and habitat for invertebrates. For example, a “hemi-marsh” is the emergent marsh phase with a 50:50 ratio of vegetation cover to open water (Kaminski and Prince 1981). The hemi-marsh phase produces a diverse group of wetland vegetation which attracts the most species and greatest number waterfowl. In addition, it provides good vegetation for nesting

cover, as well as habitat and organic material for invertebrates. The ratio of cover to water is important in attracting waterfowl (Hagy and Kaminski 2013). Manipulation of vegetation through mowing, disking and water levels is a commonly used management tool to create hemi-marsh conditions (Fredrickson and Reid 1988).

Wetland vegetation in moist-soil areas are categorized as either desirable or undesirable based on their value to waterfowl. Desirable plants for waterfowl provide habitat, energy, or meet nutrient requirements. Undesirable plants are those that quickly progress toward monocultures and hinder growth of desirable plant species (Fredrickson and Taylor 1982). Each plants species should be evaluated on its direct or indirect value for waterfowl. In order to make timely decisions to manage moist-soil vegetation, managers must be able to identify plant species, their seedlings and how they used by waterfowl (Fredrickson and Taylor 1982).

Encouraging Desirable Vegetation

The successional stage of an impoundment influences plant species and seed production. Moist-soil plant communities are generally in early successional stages and composed of annual grasses and sedges (Van der Valk 1981). Succession evolves to later stages once a moist-soil impoundment has been managed for more than four years with similar water management and minor soil disturbances (Fredrickson and Taylor 1982). Early successional stages result in plant species with high seed production. In later successional stages, annuals are taken over by perennial plant species (Reid et al. 1989). Once perennials become established, seed production declines, undesirable species become more abundant, producing monocultures and woody species begin to develop. In order to maintain habitat quality and high seed production, measures to set back succession must be implemented (Fredrickson and Taylor 1982).

Water manipulation and mechanical disturbances are the most common managements practices used to set back succession (Reid et al. 1989). Perimeter dikes allow shallow flooding of large areas with little water and are effective control of undesirable plants (Fredrickson and Taylor 1982). Deep flooding can be used to remove stubborn stands of undesirable plants and set back succession (Payne 1993). Mowing and disking are the most widely used mechanical practices to set back succession (Reid et al. 1989). Disking is the most common soil disturbance practice used in moist-soil impoundments. The impoundment should be drained in order for the soil to dry enough to allow for machinery and implements. To stimulate seed production of annuals and control woody growth, impoundments should be disked once every few years based on the presence of perennials and woody vegetation (Fredrickson and Taylor 1982).

At Noxubee National Wildlife Refuge in north Mississippi, tilling was shown produced the greatest seed yields, plant species variety, and occurrence of annual grasses (Gray 1995). Aquatic invertebrate populations were 1.3 to 3.5 times higher in tilled impoundments and disking yielded the second greatest response (Gray et al. 1995). When used in large management projects, disking is more economical and effective than tilling. Mowing prior to disking will allow for greater soil disturbance (Gray 1995). To ensure maximum waterfowl use, large areas or strips can be mowed then disked to provide a 50:50 ratio of emergent vegetation to open water after flooding (Kaminski and Prince 1981).

Controlling Undesirable Vegetation

Undesirable plant species can be managed by using similar practices to encourage growth of desirable vegetation (Reid et al. 1989). Frequent inspections are required to determine plant species established within an impoundment and make management decisions to control undesirable vegetation (Fredrickson and Reid 1988).

Disking and re-flooding is required in impoundments with large stands of undesirable vegetation. Undesirable plants that cannot be controlled by disking or flooding often require applications of herbicides as an alternative to mechanical disturbances and water manipulations (Fredrickson and Taylor 1982). Chemicals can be costly and are strictly controlled in aquatic environments. Care should be taken to follow label instructions when applying herbicides as some chemicals can be harmful to wildlife and deter growth of desirable vegetation (Fredrickson and Reid 1988).

Soil Seed Banks

Soil seed banks, dormant seeds within buried in the soil, define the type of wetland vegetation that establish moist-soil sites (van der Valk and Penderson 1989). Most wetland soil seed banks contain many species of moist-soil plant seeds native to a certain location. These seeds can lay dormant in the soils years. Under appropriate environmental conditions, seeds can germinate and yield stands of moist-soil vegetation. Seed may remain viable in the soil even if agricultural cropping was a prior land use (van der Valk and Davis 1978). The type of moist-soil species and amount of seeds in the soil is linked to prior species at a given site. Consequently, a moist-soil site dominated by desirable vegetation should produce the same desirable vegetation the following year under similar environmental conditions. The same likelihood relates to undesirable vegetation. It is important to prevent their germination and reproduction in order to promote desirable moist soil varieties (Fredrickson and Taylor 1982).

Moist-soil plant seed banks may be insufficient or absent at disturbed sites. For example, sites where topsoil has been stripped or buried under fill and wetlands that have been flooded for many years may have inadequate seed banks to produce moist-soil vegetation (Weller 1990). In sites that lack soil seed banks, they can be established by seed, transplanting seedlings, cuttings, tubers, rootstocks and sprigs. In extreme cases, soil seed banks can transferred from other wetland sites (Payne 1993). When establishing a soil seed bank, care should be taken to avoid impacts within wetlands. Federal, State, or local permits may be required to remove and transplant plant propagules from natural sites (Payne 1993). Commercial sources of wetland plant propagules can be found in the U.S. Army Engineer Waterways Experiment Station (1992).

Drawdown and Flooding

The timing and length of yearly drawdowns (draining) impact moist-soil plant species variety, concentration, and seed production (Reid et al. 1989). Timing is the period when water is drained out of a moist-soil impoundment. There are three time periods; early, mid, and late. Drawdowns

before May 15th are considered early; drawdowns from May 15th to July 1st are mid-season; and late drawdowns occur after July 1st (Fredrickson and Taylor 1982). Drawdown dates and vegetative responses are linked to length of the growing season and differ in geographic area. Early drawdowns promote higher seed production and species diversity (Fredrickson 1991). Early drawdowns produce smartweeds, rushes, and common barnyard grass. Mid-season drawdowns stimulate production of millets, panic grasses, beggarticks, rice cutgrass, crabgrass, and common burhead. Late-season drawdowns promote dense stands and greater species diversity and also result in panic grasses, hairy crabgrass, beggarticks, sprangletop, barnyard grass, and redroot flatsedge (Fredrickson 1991).

Table 2. Plants Resulting from Drawdowns in Wetlands Managed for Moist-Soil Vegetation in North Carolina		
North Carolina	February to March	Redroot, smartweed, panic grass, flatsedge
	Spring	Dwarf spike rush, smartweed, panic grass, millet, flatsedge
	Summer	Smartweed and millet
Source: Johnson and Montalbano (1989)		

Slow and fast duration drawdowns produce different vegetation distribution and diversity. Slow drawdowns, 2 weeks or more, create diverse soil conditions within an impoundment. Fast drawdowns drain impoundments within days, creating uniform soil conditions within an impoundment (Fredrickson and Taylor 1982). Slow drawdowns early in the season promote better vegetation diversity, while fast drawdowns produce uniform stands of monotypic vegetation (Fredrickson 1991). In late summer, more dense and diverse vegetation can result from slow drawdowns. Soils around the edges of the impoundment remain moist longer providing optimum conditions for seeds to germinate. Fast drawdowns in late summer tend to cause dry soil conditions and inhibit seed germination, giving way to establishment of less desirable vegetation (Fredrickson and Taylor 1982).

When desirable plant species reach 4 to 6 in. tall, impoundments can be flooded during the growing season. Rapid growth of newly established barnyard grasses, sedges, and smartweeds can be stimulated with a shallow flooding of 1 to 2 in. Panic grasses, crabgrasses, and beggarticks, which establish drier soils, are less tolerant of flooding (Smith et al. 1994). Complete submergence of plants should be avoided to prevent disease and inhibited growth. Flooding can be slowly increased to depth of 6 to 8 in. as plants grow. Water levels are likely too deep if plants turn a light-green color and should be lowered as soon as possible to prevent damaging plant health (Fredrickson and Taylor 1982).

Fall flooding of impoundments should coincide with the arrival of early migrating waterfowl. Blue-winged teal and Pintail are usually the earliest waterfowl to migrate (Fredrickson 1991). Impoundments flooded in early fall should contain plant species with mature, smaller seeds (Reinecke et al. 1989). Water depths of 8 in. are best for most dabbling ducks but should not exceed 12 in. As new species arrive and waterfowl populations increase, additional units should be flooded to provide foraging habitat. During the peak waterfowl migration, generally 85

percent of a moist-soil unit should be flooded to a foraging depth 8-10 in. (Fredrickson and Taylor 1982; Fredrickson 1991).

Other Waterfowl Foods

Agricultural Foods for Waterfowl

Agricultural effects on North American waterfowl have been mostly detrimental. Agriculture is responsible for the widespread loss of wetland habitat, conversion of nesting grasslands to cropland and the application of pesticides that poison waterfowl. Though not all agricultural by-products are negative, waste grains, left after harvest are the one of the most widely utilized foods by waterfowl (Ringleman 1990). Due to the loss of natural food resources, many species have adapted to the abundant foods produced by agriculture; particularly corn, rice, wheat and millet. Over the last century, waterfowl migration routes and wintering grounds have shifted to agricultural areas in response to agricultural foods. Many waterfowl populations now rely on agricultural grains as the main source of food on their wintering grounds (Ringleman 1990).

Waterfowl depend on a diet high in protein content during breeding and molting cycles. During these cycles, agricultural foods are seldom consumed because they lack protein and nutrients required for egg laying and feather production. However, agricultural foods are preferred during fall, winter, and early spring when vegetation is a large part waterfowl diets. Corn, wheat, rice, sorghum, rye and millet are commonly planted during the growing season as waterfowl foods during the fall and winter (Ringleman 1990).

Food Quality of Agricultural Grains

Waste grain is a quick, locally abundant and high-energy food source consumed by waterfowl. The nutritional quality of agricultural grains is indicated by a breakdown of their chemical composition. The amount of energy, protein, fiber, fat and ash are markers of food value.

Metabolizable energy content of grains is used as a basis for comparison since waterfowl consume natural foods for a balanced nutritional diet and supplement grains as a high-energy food and their diet with to compensate for deficiencies (Ringleman 1990).

Crop	Metabolizable Energy kcal/g		Percent (dry weight)			
	Mallard	Canada Goose	Protein	Fiber	Fat	Ash
Barley	2.98	3.32	14	5	2	2
Milo	-	3.85	12	3	3	2
Rice	3.34	-	9	1	2	1
Rye	3.14	2.74	14	4	2	2
Soybeans	2.65	3.20	42	6	19	5
Wheat	3.32	3.35	26	19	4	17
Corn	3.60	4.01	10	5	5	2

Source: Ringleman (1990)

Aquatic Invertebrates Important for Waterfowl Production

Consumption of plant material and seeds alone do not supply the energetic or nutritional resources needed by waterfowl. A diverse group of invertebrates is a much needed source of protein for waterfowl during the annual cycle. Dabbling and diving ducks almost exclusively consume invertebrates during egg production and molt periods which require large amounts of protein. Duck species have developed foraging strategies for invertebrates and are equipped with special bill structures for invertebrate consumption (Fredrickson and Reid 1988).

Different groups of invertebrates present in wetlands provide nutrients to waterfowl for many life cycle processes. The northern shoveler and gadwall are dependent on crustaceans, northern pintails and mallards consume midge larvae and earthworms, which are often the most available food in in early spring pregnant waterfowl depend on snails, crustaceans, and insects for protein. Most species of hens rely on calcium from snail shells for egg production and shift from a winter diet of seeds and plant material to a spring diet of invertebrates (Fredrickson and Reid 1988).

Aquatic Invertebrate Type	Importance to Waterfowl
Oligochaeta (Aquatic and Terrestrial Earthworms)	Important to nesting hens
Hirudinea (Leeches)	Not important as a food source
Anostraca (Fairy Shrimp)	Important to laying hens

Conchostraca (Clam Shrimp)	Important to laying hens
Cladocera (Water Fleas)	Very important to laying hens
Copepoda (Copepods)	Not important as a food source
Ostradoca (Seed Shrimp)	Little Importance as a food source
Amphipoda (Scuds, Side-swimmers, or Freshwater Shrimp)	Little Importance as a food source
Ephemeroptera (Mayflies)	Not important as a food source
Odonata (Dragonflies, Damselflies)	Little Importance as a food source
Hemiptera (True Bugs)	Little Importance as a food source
Trichoptera (Caddis Flies)	Very important to laying hens
Coleoptera (Beetles)	Little Importance as a food source
Diptera (Flies and Midges)	Very Important to hens
Lepidoptera (Butterflies and Moths)	Little Importance as a food source
Gastropoda (Snails)	Very important to laying hens
Source: Eldridge (1990)	

Invertebrate Association with Vegetation Structure

Leaf shape, structure, and surface area of aquatic vegetation influence invertebrate colonization. Aquatic plants with complex leaf structures, such as smartweeds, provide habitat for larger invertebrate groups than plants with more simple leaf structures, such as American lotus (Fredrickson and Reid 1988). The successional stage of moist-soil and aquatic plants influences the composition of invertebrate populations. Undesirable plant communities are modified by disking and other physical treatments (Reid et al. 1989). Shallow disking in late summer, followed by immediate flooding of shredded plant material yields the greatest initial invertebrate response. Rapid invertebrate colonization can be achieved in the spring by cutting emergent vegetation above the water line in winter (Fredrickson and Reid 1988). Undesirable plants should be manipulated so that decomposing vegetation can be used by wetland invertebrates. When followed by shallow flooding, these high protein invertebrates can be consumed by waterfowl (Fredrickson and Reid 1988). The timing of flooding should correspond with the consumption of leaf litter by invertebrates. Invertebrate availability for waterfowl consumption can be achieved by maintaining shallow water levels, drawdowns to expose prey, and extended drawdowns with shallow flooding to increase the size feeding areas (Reid et al. 1989).

Integrated Management Strategy

The site selected for this project is a 40 acre waterfowl impoundment adjacent to the north east side of Mattamuskeet National Wildlife Refuge. The impoundment is currently divided into 2 agricultural units. The southern unit, approximately 19 acres was constructed in 1959 on a non-riverine swamp forest. The northern unit, approximately 17 acres, was constructed 1972 on an agricultural field. Prior to 1972, the southern unit was managed as a moist soil waterfowl impoundment. After the northern unit was completed, both units were and are currently managed as agricultural waterfowl impoundments. Since its inception, the impoundments have provided agricultural food, wintering habitat and attracted large numbers of waterfowl (Floyd 2104). Its proximity to Mattamuskeet NWR, historic waterfowl use, and small size; make the site an ideal location for an integrated moist-soil and agricultural impoundment.

A moist-soil plant community dominated by moist-soil vegetation is an important component of a diversified moist-soil management program. The moist-soil vegetation provides waterfowl with a high quality food source throughout the fall and winter. These plant species produce numerous seeds that provide vitamins, minerals and carbohydrates to waterfowl (Kaminski and Prince 1981). In addition, they have complex leaf structure, which support excellent populations of aquatic invertebrates when flooded. Invertebrates are consumed by waterfowl to obtain protein for life processes (Fredrickson and Reid 1988). Reeds, sedges, rushes and other emergent species add structural diversity and provide important cover for waterfowl. Moist-soil impoundment units having dominant stands of target vegetation, in combination with cover plants, receive heavy usage by dabbling ducks (Smith et al. 1994).

Agricultural grains, left after harvest, are the one of the most widely utilized foods by waterfowl (Ringleman 1990). Due to the loss of natural food resources, many species have adapted to the abundant foods produced by agriculture; particularly corn, rice, wheat and millet. Over the last century, waterfowl migration routes and wintering grounds have shifted to agricultural areas in response to agricultural foods. Many waterfowl populations now rely on agricultural grains as the main source of food on their wintering grounds (Ringleman 1990). Agricultural foods are preferred during fall, winter, and early spring when vegetation is a large part waterfowl diets. Corn, wheat, rice, sorghum, rye and millet are commonly planted during the growing season as waterfowl foods during the fall and winter (Ringleman 1990).

Southern Unit - Moist-soil Impoundment

Size: Approximately 19 acres

Soil Type: Belhaven muck, Engelhard loamy very fine sand (both frequently flooded)

Management Practice: Moist-soil Hemi Marsh (50% emergent vegetation, 50% open water)

Target Vegetation: Flatsedge, panicum, smartweed, spikerush, and wild millet

Target Waterfowl Protein: Aquatic invertebrates and insects

Timing of Spring Drawdown:

March 15 – April 1

Management Strategy:

There are two important factors that influence target vegetation, timing of spring drawdown and the stage of succession (Reid et al. 1989). Smartweeds, wild millets, and flatsedges require relatively high soil moisture for germination while spikerushes and panicums require drier soil conditions (Smith et al. 1994). All species are associated with spring drawdowns, with the exception of Duckweed. Duckweed is a free floating aquatic plant that germinates on shaded surface waters and ditches (USFWS 2007). Target vegetation can be maintained in moist-soil impoundments for several years if water management coincides with growth requirements and periodic soil disturbance (Reid et al. 1989). Most of these species are considered pioneer plant

species because they colonize recently disturbed wetland sites. If not properly managed, competition from other wetland plants, such as cattails, reeds and bulrushes, will become the dominant undesired vegetation. Disking should occur when target vegetation abundance decreases substantially (Fredrickson and Reid 1982).

Establishment:

Flatsedge, panicum, smartweed, spikerush, and wild millet seeds are present in the soils seed banks of wetlands surrounding Lake Mattamuskeet, which eliminates the need for supplemental planting (USFWS 2013). Chufa, beggartick, flatsedge and millet seeds are also found in the local wetlands (USFWS 2015). Although corn has been the predominant crop in recent years, soil seedbanks containing these viable seeds should still exist (Fredrickson and Taylor 1982). Deep disking of 12 in. to 18 in. in mid to late March of the first year should be implemented in order to expose the seedbanks for spring germination. Once target vegetation is established, it is important to conduct frequent assessments to identify and control undesirable vegetation (Reid et al. 1989).

Vegetation Management:

After target vegetation has reached 4 in. to 6 in., a shallow flooding of 1 in. to 2 in. can be used to control the establishment of undesirable vegetation, particularly cattails, phragmites and woody vegetation. (Fredrickson and Taylor 1982). This method is particularly effective within stands of spikerushes, smartweed, millets, barnyard grass, crabgrass and flatsedges. Panicums and beggarticks are adapted to drier soils and are less tolerant of prolonged flooding (Smith et al. 1994). Water level should be lowered if plants show signs water damage or inhibited growth (Fredrickson and Taylor 1982). Shallow flooding can continue until target vegetation is 8 in. to 10 in. in height to prevent the growth of undesirable plants. Generally, water should not cover more than one third of the vegetation. If shallow flooding cannot be implemented and undesirable vegetation becomes dominant, disking of around 4 in. to 6 in. during summer should occur (Smith et al. 1994). Disking reduces plant competition, eliminates undesirable plant germination and prepares the seedbed for improved desirable vegetation (Reid et al. 1989). Periodic summer irrigation or additional shallow flooding may be required if target vegetation show signs of yellowing or stunted growth (Fredrickson and Taylor 1982). 10 ft. wide strips of mature vegetation, the entire length of the impoundment, should be mowed and then disked to create open areas prior to fall flooding (Kaminski and Prince 1981). After fall flooding, shredded and disked vegetation will provide forage for aquatic invertebrates and provide open areas for waterfowl to land. In addition, standing vegetation will provide habitat for invertebrates, cover for wintering waterfowl, moist-soil seeds, roots and tubers for forage (Reid et al. 1989).

Fall Flooding:

Fall flooding should occur prior to the arrival of wintering waterfowl, allowing time for aquatic invertebrates to colonize. In most cases, flooding during late August or early September should provide the time needed for invertebrate colonization (Fredrickson, 1991). Early migrating

waterfowl begin to arrive on Lake Mattamuskeet in mid to late September, followed by the peak migration in December through January (USFWS, 2015). Flooding depth should remain between 6 in. to 12 in. to provide optimum foraging depth for waterfowl (Reinecke et al. 1989). Water levels will need to be manipulated during the winter to provide access to available seeds, vegetation and invertebrates (Reid et al. 1989).

Spring Drawdown:

Water should be held within the unit until late February in order to provide waterfowl to opportunity to forage on protein rich invertebrates needed for breeding and egg laying (Fredrickson and Reid 1988; Reid et al. 1989). Spring drawdown or dewatering should begin around mid-March and end in early April in order to promote a greater diversity of target vegetation species. Slow drawdowns of 2 to 3 weeks allow moist-soil plant seeds deposit evenly and germinate at different soil temperatures required for plant diversity (Fredrickson and Taylor 1982). Fast drawdowns can be completed in a few days but, will result in stands of vegetation with only a few species. Monocultures should be avoided in order to provide the essential carbohydrates, proteins, fats and amino acids needed by wintering and breeding waterfowl (Fredrickson 1991).

Cost:

Table 5. Estimated per acre, per year Operational Cost for Moist-soil Management	
Machinery & Labor	
Land Manager	\$ 10.00
Modify Succession (Mow, Disk)	\$ 65.00
Water Control	\$ 14.25
Pumps	\$ 26.00
Miscellaneous	\$ 9.00
Total cost per acre	\$ 124.25
Source: (Reinecke et al. 1989), adjusted for inflation using (United States Department of Labor 2015)	

Northern Unit - Agricultural Impoundment

Size: Approximately 17 acres

Soil Type: Wysocking very fine sand (rarely flooded)

Agricultural Crop: Corn (10 acres in strips), Japanese Millet (7 acres in strips)

Target Waterfowl Protein: Aquatic invertebrates and insects

Timing of Spring Drawdown:

February 20 – March 1

Establishment:

After the impoundment is drained and the soil is dried, the remaining corn stalks will be harvested; the field will be disked to break up the existing roots and clods and prepared for planting. Alternating strips of corn, Japanese millet and native volunteer grasses will be planted in 15 ft. wide strips, over the entire length of the impoundment. Fertilizer and lime should be applied prior to planting, based on a soil sample analysis. RoundUp Ready corn will be planted between April 1st and May 1st on 38 in. rows, plants will be spaced at 6 in. and planted at a depth of 1.5 in. Since the corn will not be harvested it can be planted as late as June 1st. Corn generally matures within 120 days and should be planted in time to mature before the first frost near the end of October (Floyd, 2014).

Japanese millet has a shorter growing cycle of around 60 days compared to corn at 120 days. It should be planted in mid-August in order to mature before the first frost. A shallow disking of 1 in. to 2 in. will be required to provide a seedbed for successful germination and limit competition. Japanese millet should be seeded at a rate of 20 lbs. /acre and soil amendments are generally not required (Floyd, 2014).

Crop Management:

Corn seedlings will be sprayed with post-emergent herbicide when they reach 6 in. height to control weeds and limit competition. After the initial application of herbicide, natural grasses, such as crabgrass and barnyard grass will be allowed to grow between the rows. The germination and growth of undesirable species will need to be closely monitored and treated as needed. The corn plants will also need to be monitored and treated for insects, worms and fungi throughout the growing season. Depending on soil fertility, the crop may need additional fertilizer application if showing signs of inhibited growth. Irrigation is typically not required within an impoundment due to its landscape position. The perimeter ditches can be pumped full of water from the surrounding canals allowing the soil water table to remain near the root zone. Periodic irrigations may be required in periods of prolonged drought if plants begin to show signs of stress (Floyd, 2014).

After germination, Japanese millet requires minimal management. Monitoring for drought stress and periodic irrigations will follow as listed above. Undesirable species are not generally a factor late in the growing season. Whenever conditions allow, millets can be interspersed within stands of native species to ensure a sustained food supply and increase the waterfowl habitat quality (Floyd, 2014).

Fall Flooding:

The fall flooding schedule will remain the same as the moist-soil impoundment listed above.

Spring Drawdown:

Spring drawdown should begin in early March and completed within a few days to allow the soil to dry for several weeks prior to tillage and replanting. Drawdown time (fast or slow) is not a factor when planting agricultural crops. Water should remain as long as corn is available and waterfowl are using the impoundment. Generally, the majority of the corn has been consumed and waterfowl have begun their northern migration by the end of February (Floyd, 2014).

Cost:

Table 6. Estimated per acre, per year Operational Cost of Corn Production	
Machinery & Labor	
Machinery	\$ 24.00
Pumps	\$ 26.00
Labor	\$ 37.00
Seeds, Soil Amendments, Chemicals	
Roundup Ready Seed Corn	\$ 50.00
Fertilizer (N, P, K)	\$ 92.00
Pelletized Limestone	\$ 64.00
Insecticide	\$ 23.00
Herbicide	\$ 35.50
Miscellaneous	\$ 9.00
Total cost per acre, per year	\$ 368.50
Source: (Floyd, 2014), (Plastina, 2015)	

Table 7. Estimated per acre, per year Operational Cost of Japanese Millet Production	
Machinery & Labor	
Machinery	\$ 24.00
Pumps	\$ 26.00
Labor	\$ 37.00
Seeds etc.	
Japanese Millet Seed	\$ 12.75
Miscellaneous	\$ 9.00
Total cost per acre	\$ 108.75
Source: (Floyd 2014; Plastina 2015)	

Conclusion

Based on the research and literature provided, a management plan utilizing moist-soil and agricultural practices has the potential to meet the required energetic and nutritional needs of wintering waterfowl (Reinecke et al. 1989; Krapu and Reinecke 1992). Corn, moist-soil vegetation and seeds provide waterfowl with high energy carbohydrates, essential nutrients and

amino acids, improving overall winter health (Kaminski and Prince 1981). Both corn and moist-soil vegetation are sources of winter cover and habitat, while aquatic invertebrates associated with moist-soil leaf structure provide waterfowl with needed proteins (Fredrickson and Reid 1988).

There is some uncertainty associated with the proposed management plan. Additional cost may be incurred by the landowner associated with the potential for multiple flooding and drawdowns during the growing season. The success of the plan is highly dependent on the landowner's and/or manager's ability to identify desirable and undesirable vegetation, employ techniques to limit the growth of undesirable vegetation and promote the establishment of desirable vegetation (Reid et al. 1989). In addition, naturally occurring uncertainties will also affect the success of the management plan. Unsuitable nesting conditions on waterfowl breeding grounds, mild winters in northern latitudes, above normal rainfall or drought conditions, and food shortages on wintering habitats are factors that can limit waterfowl population and migrating patterns (NRCS, 2015). Currently, there are no past waterfowl survey records for comparison other than hunting field journals documenting the amount and species of waterfowl taken during past hunting seasons. Some form of annual waterfowl survey method will need to be established to determine the success of the management plan compared to moist-soil and agricultural impoundments at Lake Mattamuskeet NWR, with regard to size.

Under the current agricultural management plan, the total annual operational cost is \$13,266.00 to plant and maintain 36 acres of corn. The current management plan has the potential to provide 25,669 DUD per acre; however, corn is not a nutritionally balanced food source (Floyd 2014; Plastina 2015; Ringleman 1990). Waterfowl will often seek out additional feeding locations to obtain nutrients. The cost to implement the proposed integrated moist-soil and agricultural plan is less than half of the current total annual cost at \$6,417.29. If managed properly, an integrated agricultural and moist-soil management plan can yield an average 15,000 DUD per acre within a controlled impoundment. In addition, the availability of corn, moist-soil vegetation and invertebrates will satisfy nutrients requirements and habitat cover in a single location (Floyd 2014; Kaminski and Prince 1981; Plastina 2015). Although the DUD is reduced under the proposed plan, the actual amount of waterfowl that use the impoundment is subject to the number of waterfowl present in this region during the winter months. DUD simply represents the maximum potential population that could be supported. Currently, this site averages of roughly 5,000 to 7,000 waterfowl during the day and 15,000 to 20,000 at night during peak winter migration. Under the proposed plan, it could be possible that population numbers remain constant. If waterfowl numbers are reduced, 3,000 to 5,000 waterfowl during the day and 10,000 to 15,000 waterfowl at night would be expected. Returning healthier waterfowl back to their spring breeding grounds will increase the ability to produce more and healthier offspring, benefitting the entire waterfowl population.

The proposed plan for the site also requires an average of 73% less fertilizer, insecticide and herbicide than the current plan, significantly reducing the potential nutrient load to Lake Mattamuskeet during spring drawdown periods (Floyd 2014; Plastina 2015). Roughly 12,000 acres of forest, wetland and farm land lies between the refuge boundary and Turnpike Road to the North and West, North Lake Road to the North and East and NC HWY 264 to the South. Of the 12,000 acres, approximately 4,000 acres of privately owned waterfowl impoundments abut Mattamuskeet NWR. The majority of these impoundments are managed under agricultural row

cropping practices. If 30% of landowners/managers adopted the proposed management plan, nutrient requirements would be reduced by nearly 22%. If 50% percentage of landowners implanted the plan, then nutrient reduction would be around 37%. Land owner participation at 60% would yield a nutrient reduction of 44%. If significant nutrient reduction can be demonstrated over time, financial assistance from federal, state or private programs may become a possibility for those who choose to adopt the management plan.

The implementation of an integrated moist-soil and agricultural plan would not require any added impoundment construction or equipment than required for agricultural production. This plan provides landowners and managers the option to provide a diverse, high quality waterfowl food source at a reduced cost while maintaining high population numbers. In addition, the plan should improve the nutritional health of wintering waterfowl while reducing nutrient loading to Lake Mattamuskeet.

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