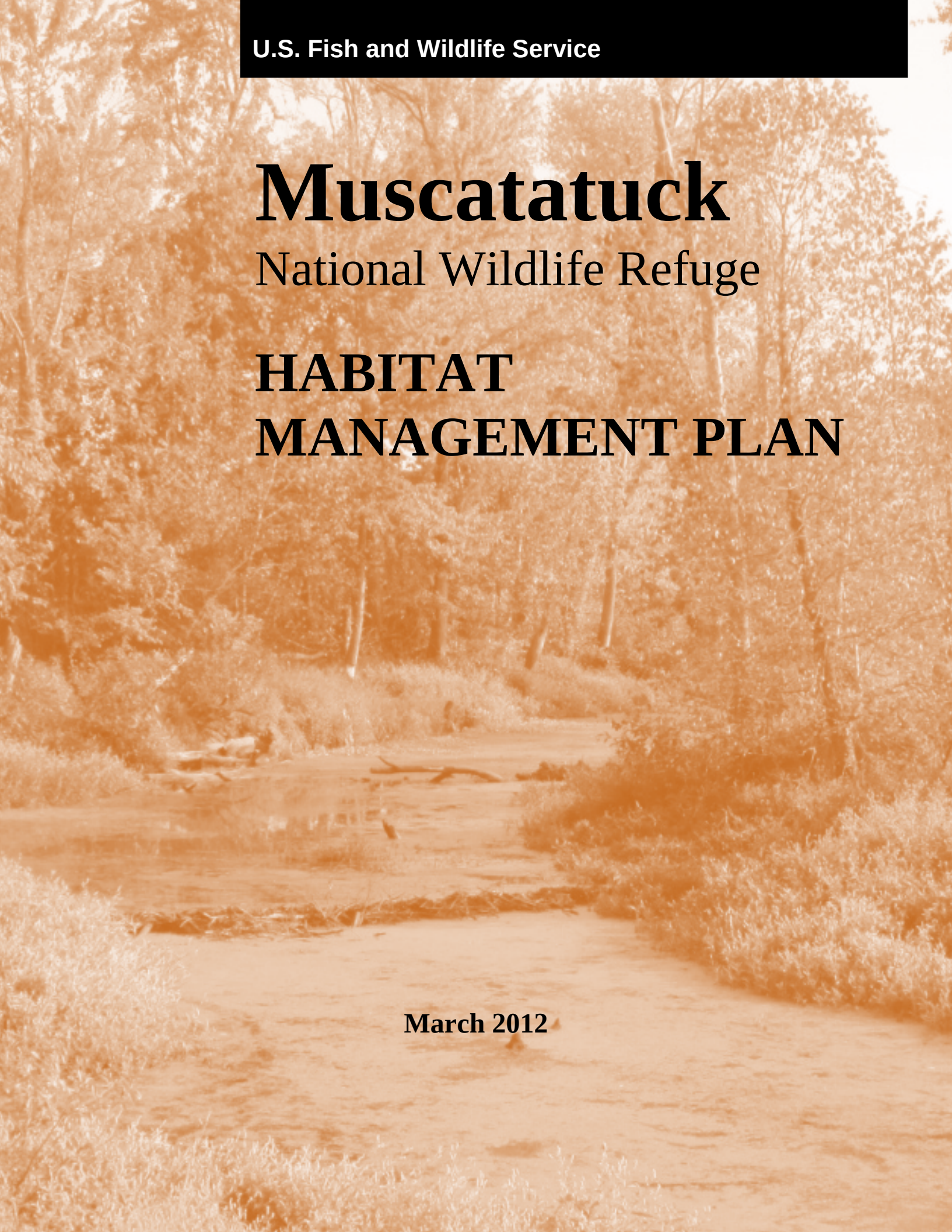
U.S. Fish and Wildlife Service

Muscatatuck
National Wildlife Refuge

HABITAT MANAGEMENT PLAN



March 2012

Muscatatuck

National Wildlife Refuge

Habitat Management Plan Approval

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3-30-12

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This blue goose, designed by J.N. "Ding" Darling, has become a symbol of the National Wildlife Refuge System.

The U.S. Fish & Wildlife Service is the principal federal agency responsible for conserving, protecting, and enhancing fish and wildlife and their habitats for the continuing benefit of the American people. The Service manages the 93-million acre National Wildlife Refuge System comprised of more than 535 national wildlife Refuges and thousands of waterfowl production areas. It also operates 65 national fish hatcheries and 78 ecological services field stations. The agency enforces federal wildlife laws, manages migratory bird populations, restores nationally significant fisheries, conserves and restores wildlife habitat such as wetlands, administers the Endangered Species Act, and helps foreign governments with their conservation efforts. It also oversees the Federal Aid Program which distributes hundreds of millions of dollars in excise taxes on fishing and hunting equipment to state wildlife agencies.

The mission of the U.S. Fish & Wildlife Service is working with others, to conserve, protect and enhance fish, wildlife, and plants and their habitats for the continuing benefit of the American people.

The mission of the National Wildlife Refuge System 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.

Habitat Management Plans provide long-term guidance for habitat management decisions; they identify resources of concern, the needs of those resources, and then set forth goals, objectives, and strategies needed to accomplish Refuge purposes and habitat requirements for the identified resources. Necessary management actions are outlined within the plan; however, implementation may be limited by funding and staff availability.

Muscatatuck National Wildlife Refuge
Habitat Management Plan
January 2012

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Chapter 1: Introduction

A. Scope and Rationale

In order to clarify the contributing role of Muscatatuck National Wildlife Refuge (Refuge) in conservation of wildlife at the local, regional, and ecosystem levels while preserving biological integrity, diversity, and environmental health of the National Wildlife Refuge System, Refuge staff have devised a Habitat Management Plan. The Plan is intended to be a dynamic document providing a decision-making process and guidance for the management of Refuge habitats.

The Habitat Management Plan (HMP) was a process by which the most appropriate management direction or best use of Refuge lands was evaluated. This Habitat Management Plan (HMP) addresses the general habitats and management principles of the Refuge overall for the benefit of endangered species, migratory birds, and resident wildlife. Much of the land acquired for the Refuge has been impacted by agriculture, road and levee construction, unnatural flooding, and other anthropogenic influences and requires recovery. This HMP intends to fulfill the Service mission and other mandates and will address habitat needs, goals and management efforts. This plan is needed to address current management issues, provide long-term management direction for the Refuge, and to satisfy Service policies 602 and 620 FW 1, which require the preparation of a HMP for all National Wildlife Refuges.

In the evaluation process, the Refuge's contribution to biological integrity, diversity and environmental health was examined from several landscape scale perspectives. The Refuge's role in addressing conservation issues within the region was assessed. Priority species and species groups were developed during the evaluation process. Species were elevated to priority when the Refuge played an obvious role in accomplishing population and habitat objectives for a particular species as outlined in various landscape scale conservation plans. These priorities were then used to guide us in the development of habitat objectives based on priority species needs and finally, in the development of implementation strategies to achieve objectives. The Plan provides a vehicle by which Refuge staff use key historical Refuge data, scientific literature, expert opinion, and staff expertise to make habitat management decisions.

B. Legal Mandates

In the early 1960s there was a prominent interest among Indiana Department of Conservation, state-wide sportsmen, conservation organizations, business leaders and civic leaders for a national wildlife Refuge in the southern Indiana region known as

Mutton Creek Bottoms. With the approval of the Governor and support by local elected representatives, the Service presented the proposal for the Muscatatuck NWR to the Migratory Bird Conservation Commission on June 7, 1966. The Refuge was purchased with funding from Duck Stamp sales under the Authority of the Migratory Bird Conservation Act. Acquisition for 7,922 acres to provide duck breeding and migration habitat was approved by the Migratory Conservation Commission on June 7, 1966. Lands for the Refuge were acquired under eminent domain. The Refuge was officially established by the acquisition of the first tracts on October 6, 1966. By April 24, 1973, acquisition was considered complete with 7,724 acres acquired; interest in a remaining in-holding had waned by 1979 because the asking price was too high. The 78-acre Rustle Unit in Monroe County was acquired through a donation in 1991. The Refuge also manages nine conservation easement areas. The purpose of the easements, "... for conservation ...," derives from the Consolidated Farm and Rural Development Act. The Service administers the easements as part of the National Wildlife Refuge System.

The Refuge purpose "for use as an inviolate sanctuary or for any other management purpose for migratory birds" derives from the Migratory Bird Conservation Act and corresponds to the current use and potential for an increase of migratory waterfowl during spring and fall migrations. The Muscatatuck National Wildlife Refuge also serves as an excellent recreational facility for the public. The Refuge staff considered past vision statements and emerging issues and drafted the following vision statement as the desired future state of the Refuge:

> "As the land of winding waters, treasured for generations, Muscatatuck National Wildlife Refuge honors its heritage and connects visitors with the natural environment by conserving a rich mosaic of sustainable habitat for a diversity of wildlife and plants."

We derive our statutory authority from the National Wildlife Refuge System Administration Act of 1966 (Refuge Administration Act), as amended by the National Wildlife Refuge Improvement Act of 1997 (Refuge Improvement Act), 16 U.S.C. 668dd - 668ee. Section 4(a) (3) of the Refuge Improvement Act states:

> "With respect to the System, it is the policy of the United States that each Refuge shall be managed to fulfill the mission of the System, as well as the specific purposes for which that Refuge was established".

Section 4(a) (4) states:

> "In administering the System, the Secretary shall monitor the status and trends of fish, wildlife, and plants in each Refuge".

> "The mission of the National Wildlife Refuge System 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" (National Wildlife Refuge System Improvement Act of 1997).

There are currently over 540 National Wildlife Refuges encompassing more than 100 million acres of lands managed by the U.S. Fish and Wildlife Service (USFWS). Muscatatuck NWR is administered under the National Wildlife Refuge System and thus, part of a larger national landscape conservation plan set forth by the USFWS. It is a component for the conservation and management of fish, wildlife, and plant resources within the National Wildlife Refuge System.

The Refuge Improvement Act provides the Service authority to establish policies, regulations, and guidelines governing habitat management planning within the System. In addition to the acquisition authorities of the Refuge, and the National Wildlife Refuge System Improvement Act of 1997, several federal laws, executive orders and regulations govern its administration. Appendix E of the CCP contains a partial list of the legal mandates that pertain to Refuge management and guided the preparation of this plan.

The habitat management goal for Muscatatuck NWR is to:

> "Maintain a dynamic mosaic of vegetation that includes an expanse of upland and flood plain deciduous forest similar to that historically present along with lakes, marshes, and moist soil units."

C. Relationship to Other Plans

The HMP is consistent with and directly related to existing threatened and endangered species recovery plans, Ohio River Valley Ecosystem (ORVE) plans, IDNR wetland conservation plans, North American Waterfowl Management Plan, Flyway management plans, and National/regional shorebird plans relevant to the Refuge.

North American Bird Conservation Initiative (NABCI)
This initiative brings together the landbird, shorebird, waterbird, and waterfowl plans into a coordinated effort to protect and restore all native bird populations and their habitats in North America. It is intended to reduce redundancy in the structure, planning and implementation of conservation projects by using a common spatial language and ecological framework to identify priority habitats and sites shared among birds of

different taxonomic groups. Bird Conservation Regions (BCRs) are used to guide landscape scale, science-based approaches to conserving birds and their habitats.

Muscatatuck NWR lies within BCR24, Central Hardwoods Region. The Partners in Flight Bird Conservation Plan for The Interior Low Plateaus (Physiographic Area 14), a BCR 24 conservation plan, the individual plans listed below, as well as the other plans and information sources in the six subsequent paragraphs were used by the Refuge to identify focal species and habitat management goals and objectives for the Refuge.

-Partners In Flight Landbird Conservation Plan: Physiographic Area 15: Lower Great Lakes Plain
-U.S. Shorebird Conservation Plan: Upper Mississippi Valley/Great Lakes Regional Shorebird Conservation Plan.
-Upper Mississippi Valley / Great Lakes (UMVGL) Waterbird Conservation Plan
-Upper Mississippi River and Great Lakes Region Joint Venture Implementation Plan
-North American Waterfowl Management Plan
-Indiana Bat Recovery Plan
-Copperbelly Watersnake Recovery Plan
-Ohio River Valley ecosystem plans
-IDNR Wetland Conservation plan
-Flyway Management Plan

National Audubon Society Important Bird Areas Program and Indiana Bird Conservation Areas

The Important Bird Areas (IBA) program is an international bird conservation initiative to identify the most important places for birds, and to conserve them. IBAs are identified according to standardized scientific criteria through a collaborative effort among state, national, international non-governmental conservation organizations, state and federal government agencies, local conservation groups, academics, grassroots environmentalists, and birders. IBAs link global and continental bird conservation priorities to local sites that provide critical habitat for native bird populations. Indiana's IBA program began in 1998 and has identified 41 IBAs including the Muscatatuck NWR. The American Bird Conservancy has identified the Refuge as a Continentally Important Bird Area; designation occurred in June of 1998 and was based on accumulated Christmas bird count data and the presence of wintering Canada geese from the James Bay Population.

Fire Management Plan

Muscatatuck NWR's Fire Management Plan (FMP) was completed in 2011 and will guide all fire program activities on the Refuge (USFWS 2011). The plan was largely put together by Fire personnel at Big Oaks NWR. Service policy requires a FMP "for each Refuge that conducts prescribed burning or on which wildfire may occur." The highest

priority of the Refuge's FMP is the protection of life, property, and natural resources from fire. Prescribed fire may be used as a habitat management tool to maintain grasslands, moist soil units, and to restore degraded forested habitats.

Other Plans

The Refuge has developed or is in the process of developing several other "step-down" plans that at times have some bearing on habitat management. These include Nuisance animal control (2010), Visitor Services (in development), Inventory and Monitoring (in development), Integrated Pest Management (in development), Forest Management (1994/soon to be revised), Hunting (rev. 2003/soon to be revised), Fishery management (1988), Cropland/Grassland Management (1995/soon to be revised), Spill Prevention, Control, and Countermeasure and Control (2002, rev. 2005 and 2009), and Disease Prevention(now called the Disease Contingency Plan;1986).

U.S. Fish and Wildlife Service Migratory Bird Program Strategic Plan

The Migratory Bird Program completed a 10-year strategic plan in January 2004 (USFWS 2004). The strategic plan seeks to conserve and manage migratory bird populations and their habitats. Two strategies to achieve these goals are bird population monitoring and habitat management. Refuges provide high quality habitat for many migratory birds and are currently conducting biological surveys and managing habitat. The Muscatatuck NWR Habitat Management Plan will use, to the maximum extent practicable, standardized monitoring protocols and habitat assessments, thus contributing to region-wide assessments of population trends and effects of habitat management on migratory birds.

Indiana Comprehensive Wildlife Conservation Strategy

In fall 2001, Congress established a new "State Wildlife Grants" (SWG) program that provided funds to state wildlife agencies for the conservation of fish and wildlife and their habitats. Each state was charged with developing a Comprehensive Wildlife Conservation Plan or Strategy by October 2005. State fish and wildlife agencies evaluated which species and habitats are in greatest need of conservation (SGNC) while also addressing the full array of wildlife. The Indiana Comprehensive Wildlife Conservation Strategy (CWCS) is available at http://www.in.gov/dnr/fishwild/files/CWS_MANUSCRIPT.pdf

The Indiana Department of Natural Resources contracted out the preparation of the Plan; it was created by D.J. Case and Associates. The list of SGNC pertinent to the Refuge was included in the Refuge's comprehensive list of resources of concern (see Chapter 3) and the complete list is available at http://www.in.gov/dnr/fishwild/files/fw-Indiana_Species_of_Greatest_Conservation_Need.pdf

Muscatatuck National Wildlife Refuge Comprehensive Conservation Plan

The Muscatatuck NWR Comprehensive Conservation Plan (USFWS 2009) provides management direction for each portion of the Refuge by identifying important groups of wildlife and their associated habitats to be emphasized for management.

This Habitat Management Plan for the Muscatatuck National Wildlife Refuge is a step-down plan of the Comprehensive Conservation Plan and the Environmental Assessment for the restoration and enhancement of the Refuge. The purpose of this plan is to guide the management, protection, and restoration of wildlife habitat on the Refuge while integrating goals and objectives with other pertinent landscape scale plans. This long-range plan will be evaluated after ten years but may be updated earlier as better management information is developed, or resource priorities change.

The mission of Muscatatuck National Wildlife Refuge is to: *provide the feeding, breeding and resting habitat for migratory birds and other wildlife while maintaining the natural diversity of plants and animals native to region.*

To fulfill the Refuge mission, the goal for the habitat program at Muscatatuck National Wildlife Refuge will be to provide a spatial and temporal distribution of habitats to meet breeding, feeding and resting needs for species using the Refuge with an emphasis on priority species.

D. Time Period

April 30, 2012 to April 30, 2022.

Chapter 2: Background

The Muscatatuck National Wildlife Refuge, established in 1966, manages 7,802 acres in Jackson, Jennings, and Monroe Counties of Indiana (USFWS 2004). The Refuge also administers eight conservation easements, totaling 105.5 acres in four Indiana counties. The Refuge consists of wetland, grassland and woodland communities which provides habitat for a variety of wildlife species.

The diversity of wildlife at the Refuge is astounding and is in large part due to the diversity of habitat types found on Refuge lands. Over 280 species of birds have been seen at the Refuge, and the Refuge was recognized as a "Continentally Important" bird area in 1998. Although the majority of birds that use the Refuge are migrants, the breeding of at least 121 species of birds has been confirmed at Muscatatuck. The Refuge is well known for the spring and summer migration of songbirds in May, especially warblers. The Refuge was a stopover site for the Whooping Crane Eastern Partnership (WCEP) Whooping Cranes led by ultra-light planes from 2001-2009. At the end of 2009 the WCEP changed the travel route and the Refuge was no longer used as a stopover. In 2010, nine Whooping Cranes led themselves to the Refuge and took advantage of Refuge habitats for nearly six weeks. Sandhill Cranes use the Refuge by the thousands as stopover, feeding, and resting habitat.

More than 40 species of reptiles and amphibians have been documented and include state listed species such as the copperbelly watersnake, Kirtland’s snake, and the four-toed salamander (Latin names of all species referred to in this HMP can be found in Appendix A). The Refuge supports some of the highest known densities of copperbelly watersnakes and is an important location for research of this species. A total of 85 species of fish, have been documented on the Refuge and include several state listed species including the bigeye chub, northern studfish, and the eastern sand darter. The eastern sand darter is a Region 3 priority species and is imperiled through much of its historic range.

Thirty-eight species of mammals are known to occur on the Refuge. The mammals include the federally endangered Indiana bat and State endangered evening bat, and the white-tailed deer a species popular for hunting and wildlife viewing. Occurrence of the Indiana bat, including lactating females, on the Refuge was confirmed in 1995 and reaffirmed in 2007 by telemetry studies that found that the Indiana bat is a summer resident on the Refuge (Whittaker 1995; Carter 2007) and it may be more abundant than was generally thought. These bats are also known to form maternity colonies on the Refuge; one maternity roost was studied and its coordinates recorded in 2007 (Carter 2007). Another notable mammal is the river otter, once extirpated from the state of Indiana. Reintroduction efforts for the state of Indiana began in January, 1995 with 25 otters released at MNWR. This has resulted in numerous otters using the Refuge; three

confirmed otter litters were produced in 1996. The reintroduction in Indiana has been successful and river otters are no longer considered state endangered (Johnson et al. 2007).

Wetlands cover 69 percent of the Refuge and much of this land floods annually. The majority of wetland habitat is bottomland hardwood forest and managed impoundments that include moist soil units, brood marshes, green tree reservoirs, and Stanfield, Moss and Richart Lakes. Most of the wetland infrastructure was built 1979-1982 with Bicentennial Land Heritage Program funds. The Refuge also has over 70 other small ponds and wetland areas including several seeps. The Muscatatuck Seep Spring Research Natural Area is an acid seep spring that has only been documented in seven other locations in Indiana, one of which was destroyed, making it extremely rare in the state.

Inventory and Description of Habitat

A recent definition of habitat states it is “the physical [space] within which an animal lives, and the abiotic and biotic entities (e.g. resources) in that space”, (Morrison and Hall 2002). The following information is provided as the physical and ecological factors, that when assimilated, describe the habitat of the Refuge.

Location

The Muscatatuck National Wildlife Refuge (MNWR) is located in south-central Indiana in Jackson and Jennings counties, three miles east of Seymour, IN (Fig. 1). Indianapolis is approximately 55 miles to the north and Louisville, KY is approximately 50 miles to the south. The Vernon Fork of the Muscatatuck River (VFMR) forms the southern boundary of the Refuge, U.S. Highway 50 runs along the northern boundary, U.S. 31 defines the western boundary and Jennings CR 900W constitutes the eastern boundary. The Refuge was established in 1966 by the Migratory Bird Conservation Commission and today consists of 7,724 acres in Jackson and Jennings counties, as well as the 78-acre Rustle Unit located north of Bloomington in Monroe County.

Management Units

The Refuge supports a number of diverse plant and animal assemblages in a mosaic of upland and bottomland forests, freshwater marshes, seasonally flooded impoundments, ditches, streams and their riparian corridors, permanent lakes and ponds, ephemeral ponds, croplands, grasslands, and other habitat types.

The Refuge wetland management units include 13 moist soil management units, over 70 farm ponds, two 100-acre reservoirs, four green tree reservoirs, three marshes, and the

Moss Lake Unit (Fig. 2). Hydrologic cells, described on page 20 of this plan (Figure 2), differ from moist soil units as they refer to hydrologic boundaries of the larger landscape. At Muscatatuck NWR, County Road (CR) 500N, CR400W, and the Moss Lake Dam are serious impediments to flow and essentially divide the Refuge into four hydrologic "cells" (compartments) in the portion of the Refuge west of County Line Road and a fifth "cell" encompassing the portion of the refuge east of County Line Road. These cells are interdependent and connected, affecting the drainage of Refuge lands and private property to the north and west of the Refuge.

Terrestrial management units were divided into three forested units and six grassland units (Fig. 4). Forest unit 1, 2, and 3 all consist of a mixture of different age classes of both upland and bottomland forest and includes reconverting farmlands and hardwood plantations. Grassland units 1-5 include current agricultural lands, grasslands, and emergency spillway areas for Richart and Stanfield Lake and hayfields (Fig. 5). However, each of these units within the near future (<5 years) will transition into open grasslands as farming is phased out of existence at Muscatatuck NWR.

Figure 1: General Location of Muscatatuck NWR within Indiana

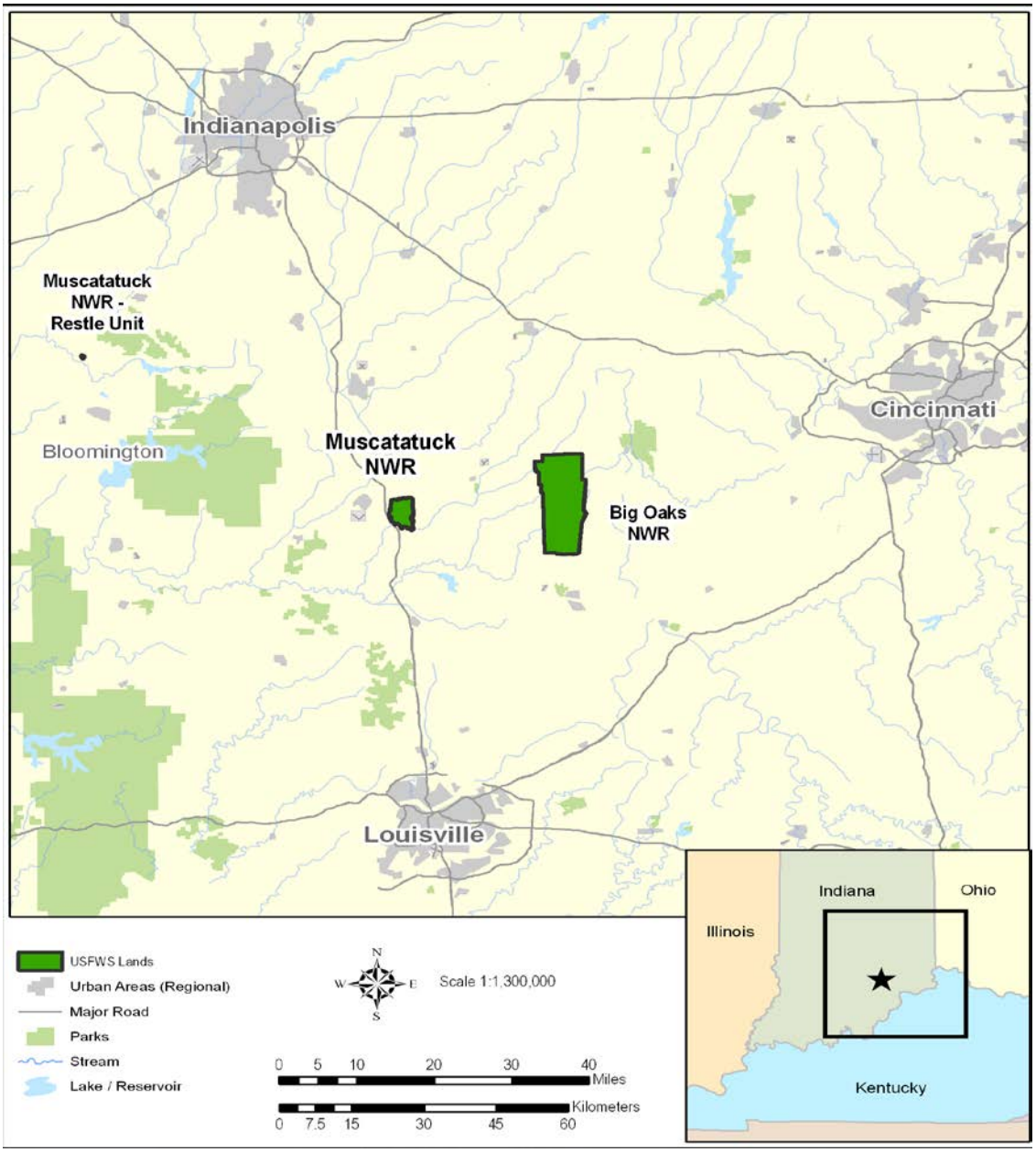


Figure 2: Location of Hydrologic Cells and Major Streams at Muscatatuck NWR

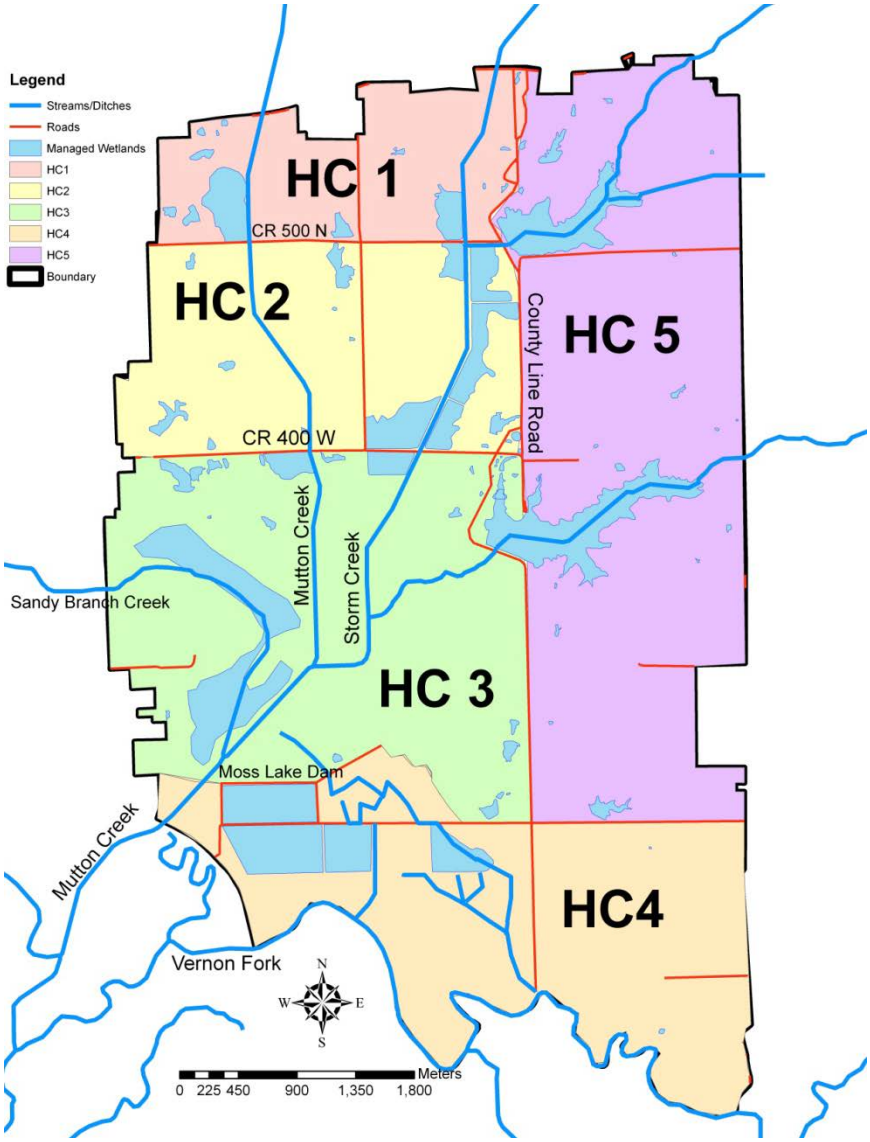


Figure 3: Location of Managed Wetland Units at Muscatatuck NWR

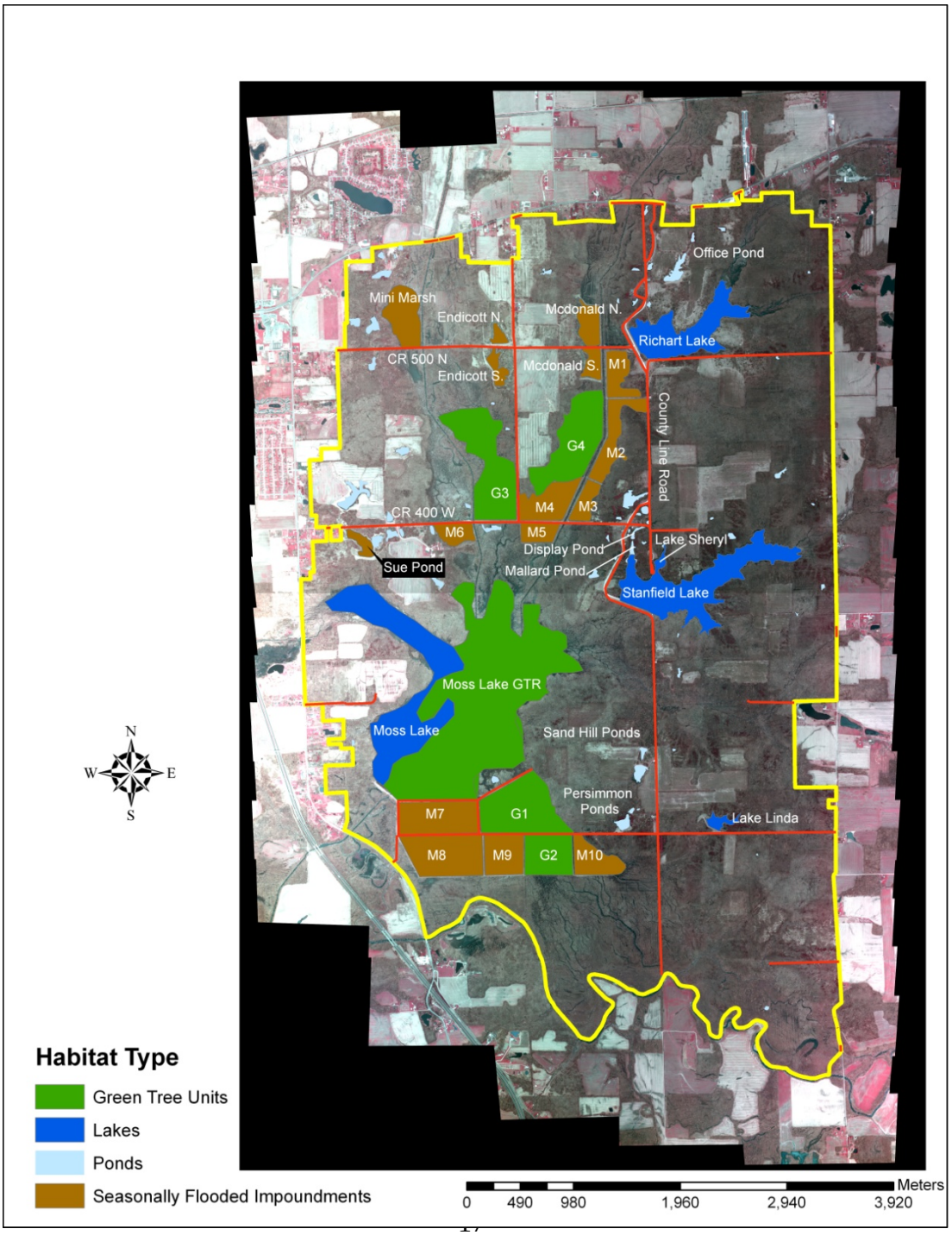


Figure 4: Location of Forest Management Units at Muscatatuck NWR

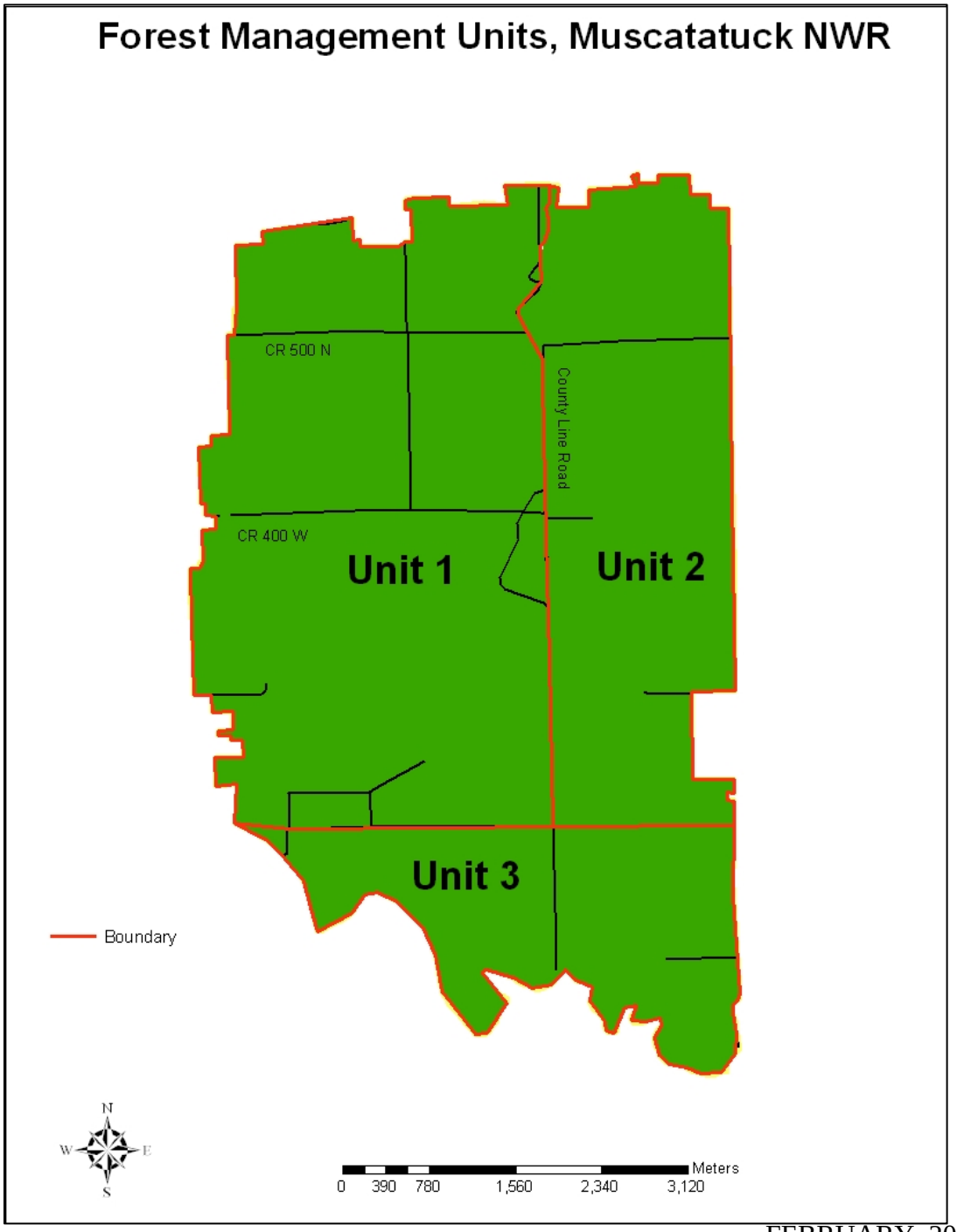
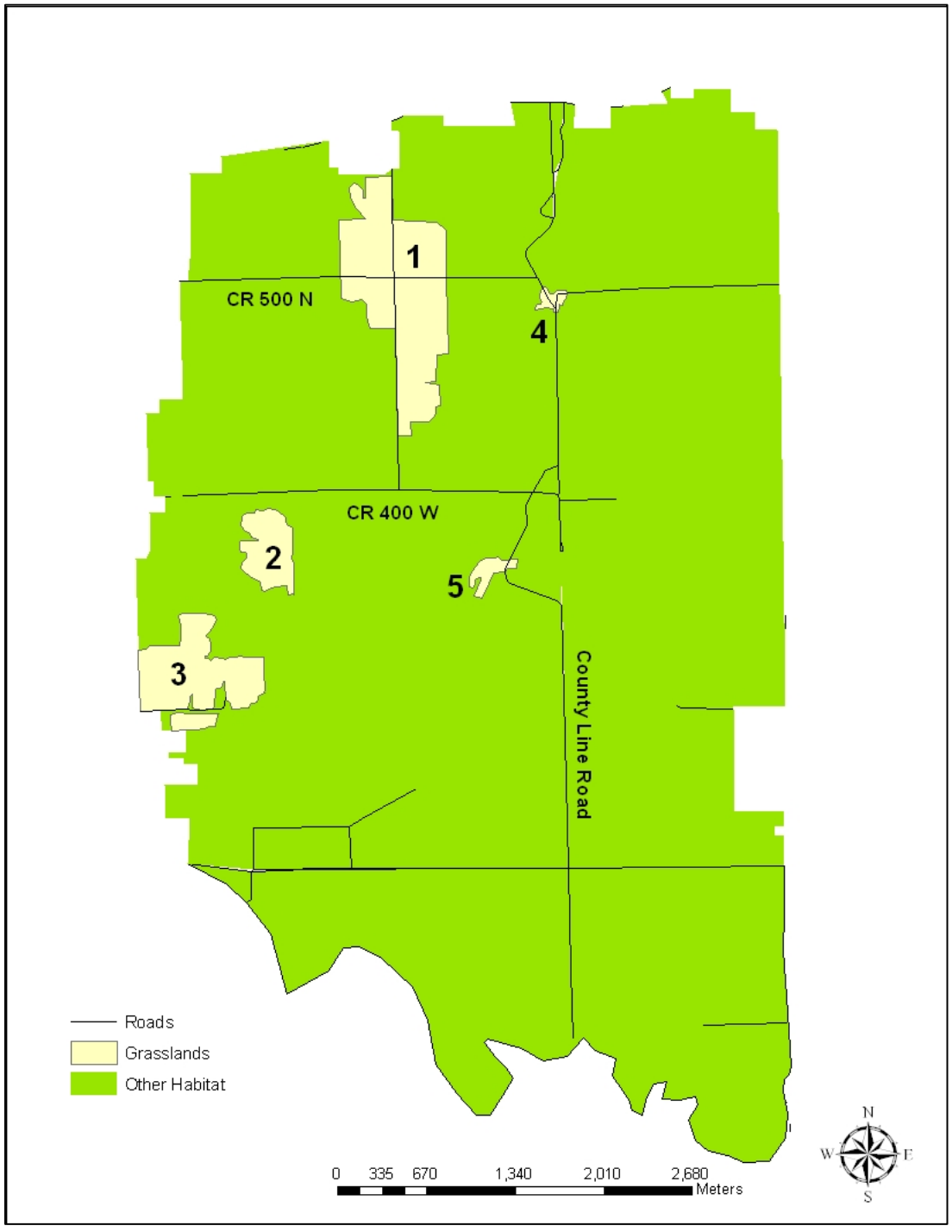


Figure 5: Location of Grassland Management Units at Muscatatuck NWR



Wetland Management Unit Descriptions:

Hydrologic Cells (HC)

Hydrologic Cell 1 (HC1) consists of the area south of Hwy 50 at the Refuge's northern boundary south to CR500N. The cell stretches west from Hwy 31 to the east where County Line Road marks the eastern boundary. Mutton and Storm Creek flow into the cell under the bridges at Hwy 50 and are bordered by private lands to the north of the highway. HC1 is relatively unconstrained compared to the other cells; runoff flows south to CR500N where it "stacks up" and discharges over two low water crossings during high flow conditions, under the Mutton and Storm Creek Bridges (MSCBs) during low and high flow conditions, and also from the culvert at what was formerly known as Grader Marsh. The cell contains Mini Marsh, North Endicott Marsh, McDonald North, portions of Mutton and Storm Creeks, and several smaller ponds and sloughs.

Hydrologic Cell 2 (HC2) consists of the areas south of CR500N and north of CR400W. Hwy 31 is this cell's boundary to the west and County line road marks the eastern boundary. Mutton and Storm Creek flow into the cell from HC1 via the two low water crossings, MSCB's on CR 500N, the structure at McDonald North, and the culvert at Grader Marsh. Inputs are also received by this cell from discharges of Richart Lake which is just outside of the cell to the northeast. The cell drains into HC3 during low and high flow conditions only via the MSCB's on CR400W, from Judy Pond. The cell contains Endicott South, McDonald South, M1, M2, M3, M4, the unit formerly designated Green Tree Unit 3, the green tree unit north of M4, the Muscatatuck Seep Spring Research Natural Area, Judy Pond, portions of Mutton and Storm Creeks, and several smaller ponds and sloughs. Portions of the old meanders of Storm and Mutton Creeks are still present on the landscape within this cell, although the straightened channels generally confine waters within the constructed Mutton and Storm Creek Ditches except during high flow conditions or when beaver dams, Moss Lake, or a combination of both, elevate water levels such that over bank flow is possible.

Hydrologic Cell 3 (HC3) consists of Moss Lake, Sandy Branch, portions of Mutton and Storm Creeks, and the other areas south of CR400W to CR475 S. County line road marks the eastern boundary of the cell. Waters flowing into HC2 can only be discharged into Cell 3 via the MSCBs on CR400. When water reaches HC2, CR400 acts as a dam and water builds up 1.5 -2.5 ft. higher than in HC3. Water then enters Cell 3 which consists of Moss Lake and its surrounding forested habitats and is restricted by the Moss Lake dam that stretches across the basin. All waters from a 67 sq. mi. watershed discharges there from a 6-bay stop log structure with the exception of limited discharge capabilities through the small water control structures at G1 and M7. During extremely high flows waters from HC3 can also be discharged over the Moss Lake dam into M7 and G1. Water

from Sandy Branch enters the cell on the west side of the Refuge through a box culvert on Hwy 31. Several smaller streams enter the cell from Hwy 31 via ditches and their associated road culverts. Discharges from Stanfield Lake and its associated tributaries contribute to the inflows within this cell. Water can also enter the cell from G1 and M7 from Myers Branch, which stretches from its beginnings within HC4 into HC3 through M10 to G2 to G1 and dumps into Moss Lake. However, the outlet of Myers Branch leading into Moss Lake appears to be filled with sediment and thus it cannot completely drain through Moss Lake. Water from overbank flows from the Vernon Fork can occasionally backflow and also enter the cell from the south. HC3 contains all of Moss Lake, portions of Sandy Branch, Mutton, and Storm Creeks, portions of Myers Branch, M6, M5, Sue pond, Persimmon Ponds, Sand Hill Ponds, and several smaller ponds and sloughs.

Hydrologic Cell 4 (HC4) consists of all areas south of the Moss Lake dam south to the Refuge's boundary, the Vernon Fork of the Muscatatuck River. Discharges from HC3 generally are confined to those which exit the 6-bay water control structure within the Moss Lake dam although limited discharge capabilities exist from Moss Lake into M7 and G1. The cell contains M7, M8, M9, M10, G1, G2, and portions of Myers Branch, Mutton Creek Ditch, the Vernon Fork of the Muscatatuck River, and several smaller ponds and sloughs. With the exception of the managed units and Myers Branch, the habitat within HC4 is self-sustaining and is managed passively from natural fluctuations of the Vernon Fork.

Hydrologic Cell 5 (HC5) consists of all areas east of County Line Road and north of CR475S to the eastern boundary at CR900 in Jennings County. The cell drains primarily agricultural lands, private residences, and a few commercial properties to the east of the Refuge. The majority of inflows to HC5 enter the Refuge as tributaries to Richart and Stanfield Lakes. Richart Lake discharges to HC2 via a constructed ditch that empties into Storm Creek just south of CR500N. Stanfield Lake discharges into HC3 via constructed outlet channel which leads into what was likely the natural stream channel that once drained the ephemeral streams that feed Stanfield Lake.

Seasonally Flooded Impoundments/Moist Soil Units

Muscatatuck NWR actively manages 341 acres of moist soil units through water and vegetation manipulation. Moist soil management on Muscatatuck NWR focuses on providing ample food, nesting, and resting resources and habitats for all three major waterbird guilds, waterfowl, shorebirds, and wading birds. This focus generally includes promoting annual grasses and sedges and other beneficial moist soil plants over a large portion of the managed acreage to provide an abundance of annual seeds for fall and spring migrant waterfowl. It also includes providing mudflats and concentrating

invertebrates for shorebirds during all three peak migratory periods. Management also focuses on providing ample feeding habitat for wading birds by drawing down and concentrating fish, amphibian, and invertebrate populations during peak use periods. There are innumerable secondary benefits of moist soil management that indirectly benefit many other species of wildlife on the Refuge.

Moist Soil Unit 1 (M1) has maximum pool acreage of 22 acres. The maximum pool elevation is 549.50 Mean Sea Level (MSL), the maximum field elevation is 548.16 MSL, the minimum field elevation is 546.66 MSL and the outlet floor elevation is 544.11 MSL. The dominant vegetation changes annually, although the desired state is one of early succession moist soil plants. The unit receives water for irrigation and flooding via gravity flow from an inlet water supply at the northeast corner of the unit leading from Richart Lake. The outlet screw gate in the southwest corner of the unit, adjacent to the stop-log structure, empties excess water into the Storm Creek ditch from the southwest corner of the unit; however, this same screw gate can be opened to flood the unit during high flow situations from the Creek. The stop-log structure controls outlet flow into Moist soil unit 2 (M2) and in some instances water stored in M2 can be diverted up the slope to provide a limited amount of water to M1.

Moist Soil Unit 2 (M2) has maximum pool acreage of 20 acres, the maximum pool elevation is 547.50 MSL, the maximum field elevation is 546.68 MSL, the minimum field elevation is 544.68 MSL and the outlet floor elevation is 541.07 MSL. The dominant vegetation changes annually, although the desired state is one of early successional moist soil plant, however, the unit is currently dominated by dead timber, snags, buttonbush, willows, and a range of perennial vegetation. The main water supply is gravity flow from Richart Lake through M1 into the northwest corner of the unit; however, when circumstances allow, water can be gravity fed from Storm Creek into the unit also via the screw gate. Two drainage options exist for the unit; a screw gate in the southwest corner of the unit that flows into the Storm Creek Ditch and a stop-log structure that drains into M3.

Moist Soil Unit 3 (M3) has maximum pool acreage of 17 acres, the maximum pool elevation is 545.46 MSL and the outlet floor elevation is 539.08 MSL. The unit is dominated by woody species, snags, and perennial aquatics; most notably willow, buttonbush, cattail, and perennial smartweed. The main water supply is gravity flow from Richart Lake through M1 and M2 into the northwest corner of the unit where the inlet pipe is located. However, when circumstances allow, water can be gravity fed from Storm Creek into the unit also via a southwest stop log structure that is also the main drain site for the unit. The unit is not a functional moist soil unit due to the vegetation that is currently present, specifically, downed timber, standing dead timber, and live trees including willow, cypress, sycamore, and cottonwood. The unit is in need of restoration

including tree removal, mowing, and disking.

Moist Soil Unit 4 (M4) has maximum pool acreage of 37 acres, the maximum pool elevation is 545.44 MSL, the maximum field elevation is 544.90 MSL, the minimum field elevation is 543.60 MSL and the outlet floor elevation is 539.08 MSL. The dominant vegetation is usually a mix of moist soil plants and has been dominated by millets and sedges in recent years. There are multiple water sources for M4. A WCS exists at the northeast corner of the unit that allows water to enter M4 via Storm Creek ditch, the green tree reservoir to the north, or from gravity flow from Richart through M1 and M2 through a pipe that runs under Storm Creek ditch. Water can flow in from Storm Creek through the southeastern stop log structure during high flow conditions, and occasionally the ditch backflows into the unit by overtopping the dike. The outlet stop-log structure is in the southeast corner of the unit and flows into Storm Creek ditch and is the primary means of discharge. A plastic 12 inch culvert connects the unit directly to an old meander of the original Storm Creek that exists within the previously unnamed Green Tree Reservoir 4.

Moist Soil Unit 5 (M5) has maximum pool acreage of 13 acres, the maximum pool elevation is 543.92 MSL, the minimum field elevation is 541.29 MSL and the outlet floor elevation is 539.06 MSL. Trees, mostly cypress and willow, cover approximately 16% of the unit and desirable moist soil vegetation is intended on the remaining portions of the unit; however, past management plans indicate soil related issues that have reduced this unit's capacity for moist soil plant production. In 2010, the unit showed signs of promise with the growth of several acres of sedges. M5 receives and discharges its water from and to Storm Creek ditch via a stop-log structure. Currently no backflow prevention mechanism is in place on the WCS and therefore the unit generally fluctuates directly with Storm Creek ditch water levels during periods of high flow.

Moist Soil Unit 6 (M6) has maximum pool acreage of 14 acres, a maximum pool elevation of 544.34 MSL, a maximum field elevation of 542.74 MSL and an outlet floor elevation of 541.86 MSL. The dominant vegetation is a mixture of beneficial moist soil plants and a small section of permanently wet scrub shrub habitat on the southwest corner of the unit. Mutton Creek serves as the water supply and enters via a stop-log structure on the southeast corner of the unit. The WCS has a back-flow prevention component installed in 2009; drainage occurs via this stop-log structure.

Moist Soil Unit 7 (M7) has maximum pool acreage of 52 acres, a maximum pool elevation of 543.0 MSL, a maximum field elevation of 540.60 MSL, a minimum field elevation of 538.30 MSL and an outlet floor elevation of 534.36 MSL on the WCS at the northwest corner of the unit. Four water control structures are either in or lead to the unit. One at the northwest corner as previously mentioned, one at the southwest corner leading

to M8, one at the northwest corner leading from Moss Lake into M7, and one on the northeast corner that drains from G1. The dominant vegetation species are millets and sedges and other beneficial moist soil plants. Since four WCS exist for the unit water supplies and drainage options include moving water into or out of each of those structures and Vernon Fork backwater flooding can impact the unit as can high flow headwaters from Moss Lake and the ditches.

Moist Soil Unit 8 (M8) has a maximum pool acreage is 64 acres although only 32 acres are available for moist soil management with the remainder existing as a green tree reservoir. The maximum pool elevation is 543.28 MSL, the maximum field elevation is 542.90 MSL, the minimum field elevation is 541.40 MSL and the outlet floor elevation is 536.53 MSL. The unit consistently produces an abundance of beneficial moist soil plant, specifically duck potato and millets and sedges. However, due to the complexity of managing half of the unit as a green tree reservoir, buttonbush and willow are consistently problematic. M8 has an inlet pipe from M9 in the northeast corner of the unit and an inlet pipe from M7 in the northwest corner of the unit. M8 has a stop-log structure in the northwest corner of the unit that drains into a ditch on the west side of the unit that is connected to the portion of Mutton Creek south of the Moss Lake dam. Water is generally supplied to the unit from multiple sources including: direct precipitation, moving water from Moss Lake into M7 and into the unit, moving water from M10 through M9 to the unit, or via overbank flows from the Vernon Fork.

Moist Soil Unit 9 (M9) has maximum pool acreage of 32 acres, a maximum pool elevation of 543.78 MSL, a maximum field elevation of 543.51 MSL, a minimum field elevation of 542.21 MSL and an outlet floor elevation of 539.26 MSL at the northwest WCS. The dominant vegetation species are millets and sedges and other beneficial moist soil plants. The southern 30-40% of the unit exists at an elevation that is often too high to keep flooded in the spring and early summer. Willows and cottonwoods are continually invading this portion of the unit, shading out beneficial moist soil vegetation. Mowing of this portion in the summer generally releases millets and sedges. M9 has an inlet pipe from G2 in the northeast corner of the unit and in the northwest corner of the unit from G1. M9 has a stop-log structure outlet that drains into M8 in the northwest corner of the unit. Water is generally supplied to the unit from multiple sources. These include: direct precipitation, moving water from Moss Lake into M7 to M8 and into the unit, moving water from M10 into M9, or via overbank flows from the Vernon Fork.

Moist Soil Unit 10 (M10) has maximum pool acreage is 25 acres, the maximum pool elevation is 544.37 MSL and the outlet floor elevation is 550.50 MSL. The dominant vegetation species have been smartweed, buttonbush, trees and cattail, however, the woody vegetation was removed in 2010 with the use of a Fecon machine. Significant portions of the unit contain forested habitat at the higher elevations. M10 has a stop-log

structure that directs water into G2 on the northwest corner of the unit. M10 receives its water supply from the Myers Branch that flows from overbank flows from the Vernon Fork. This water can be diverted to Moss Lake by routing water through G2 to G1 or water can be moved from M10 through G2 and back out to the Vernon Fork.

McDonald North (McDN) is 20 acres of which only approximately 11 acres is manageable as moist soil. Maximum field elevation is 549.18 MSL, minimum field elevation 545.18 MSL, and the maximum pools elevation is 553.32 MSL. A large portion of the unit contains dead snags and downed trees which prevent soil manipulation. The unit has in the past been dominated largely by yellow cow lily, primrose, and perennial smartweed. An 8" PVC pipe that runs underground from Richart Lake was severed and capped in 2010 when the bridge at Grader Marsh was removed. A two-bay stop-log structure exists in the southwest corner of the unit and drains into McDonald Marsh South and has an outlet floor elevation of 547.82. A small stop log structure on the southeast corner of the unit drains into the Storm Creek ditch; this structure will allow limited inflows during high flow periods but is restricted by a small diameter pipe. Water supplies are generally received from Storm Creek ditch overflows, direct precipitation, and runoff from a small watershed to the west and northwest.

McDonald South (McDS) is 12 acres although only 9.1 acres is manageable as moist soil. The minimum field elevation is 543.69 MSL, maximum field elevation 548.77 MSL, and maximum pool elevation is 551.57 MSL. The unit historically has been managed in a static state and was dominated by water lilies. However, in 2010 the unit experienced its first draw down in many years, possibly since its creation, and the moist soil vegetation response was tremendous with millets and sedges produced on nearly the entire acreage. McDonald Marsh South is fed by the inlet pipes from the two-bay WCS at McDonald Marsh North. There is a stop-log structure that drains into Storm Creek ditch at the southeast corner of the unit.

Sue Pond (Sue) is approximately 13 acres and has an approximate maximum pool elevation of 556.0 MSL. The maximum field elevation is 553.63 MSL and the minimum field elevation is 545.94 MSL. The unit is managed via a stop log structure in the middle of the south levee. The unit receives its water from direct precipitation and from overflows from Judy Pond to the north of the unit. This unit has affected private property to the west of the unit when beaver or debris plugs the structure. Sedimentation of the unit near the pipe is extreme and required excavation of approximately two feet of sediment to find the outflow pipe in 2010. Dominant vegetation in the unit consists of primrose and sedges. Soil manipulations in 2010 may set the stage for increased production of beneficial moist soil plants in 2011. The unit has a dense stand of reed canary grass existing on its perimeter and within the inflowing drainages to the north.

Lakes/Reservoirs

Richart Lake has an approximate 4.5 square mile watershed to the west that is largely private property consisting of small farms and rural residences and is a 90 acre pool. The maximum stop log elevation is 555.50 MSL. The outlet floor elevation leading to Storm Creek is 547.7 and the outlet floor elevation leading from the screw gate to M1 is 550.85 MSL. Richart Lake was artificially constructed in the 1980s and filled via precipitation and runoff from small ephemeral streams that enter the Refuge from the east. The streams that feed Richart contribute heavy sediment loads to the lake and drastically increase turbidity during periods of high flow. The screw gate is located on the western wall of the WCS which is located on the west side of the Lake in the constructed dam. There is also an 8" outlet PVC pipe that runs underground and connects to the McDonald North unit; the pipe was cut and capped in 2010 to facilitate replacement of an old dilapidated bridge at Grader Marsh. The primary function of the Lake is to act as a reservoir; water can be discharged directly to M1 and indirectly to M2, M3, and M4. Water from the Lake can be used to raise water levels within Moss Lake and Mutton and Storm Creek ditches, which can also aid in flooding M6, M5, and the southern waterfowl units.

Stanfield Lake has a drainage area of 2.7 square miles to the west that is largely private property consisting of small farms and rural residences. The Lake receives its water from precipitation and runoff from small ephemeral streams that enter the Refuge from the east. The streams that feed Stanfield contribute moderate sediment loads and increase turbidity during periods of high flow. The full pool acreage of the Lake is 125 acres. The stop-log weir elevation is 555.16 MSL and the maximum weir elevation is 559.10 MSL. The outlet water structure is a screw gate that opens into a large culvert that outflows into Moss Lake via a half mile meandering stream. Stanfield Lake can be used to raise water levels in Moss Lake and ultimately Mutton and Storm Creek ditches. The same waters can then be used to flood impoundments in the southern waterfowl area and can aid in flooding M5 and M6.

Moss Lake has a drainage area of 67 square miles. During the winter the pool can be over 1,000 acres; summer pool acreage is between 90 and 175 acres. Maximum pool storage capacity is 7,244 acre-feet. A concrete drop inlet water control structure with six 4-foot wide stop log bays and two 10-foot long fixed crest weirs is located in the middle of the western 1/3rd of the Moss Lake dam. The minimum stop log weir elevation is 537.82 MSL and the maximum stop log weir elevation is 546.1 MSL. Moss Lake directly impacts its surrounding cropland and floodplain forest. It has a stop-log structure in the southwest corner that drains into M7. There is a second stop-log structure in the southeast corner that drains into G1. Myer's Creek flows northwest from M10 into G2 to G1 and ultimately into Moss Lake where it fades into the topography and becomes undistinguishable before reaching Mutton Creek. Historically, the two creeks likely

conjoined somewhere slightly north and east of the large water control structure. However, over time, siltation coupled with beaver activity has apparently shifted the drainage channel multiple times to the point that one single main channel outlet is no longer distinguishable as the channel seemingly dead ends on the eastern side of Moss Lake. Mutton Creek ditch also flows through the center of Moss Lake and continues until it merges with the North Vernon Fork in the southwest corner of the Refuge. Sandy Branch Creek enters Moss Lake on the northwest side and Storm Creek ditch runs through Moss Lake, entering in the northeast corner. Several seeps exist around the boundary of the unit at the base of the ridges on the east and west sides. A beaver dam, nearly 1/10th of mile long, maintains a deeper/wetter portion on the northwestern side of the unit where Sandy Branch enters the Refuge. The old Moss Lake remains impounded even when water levels are below the outlet floor elevation. Another pocket of water exists in the northeastern section just east of Storm Creek and impounded due to beaver dams along the cuts in the Storm Creek ditch. Beaver dams are common problems within the ditches inside of the Moss Lake unit. On average three to nine feet of water is being staged by beaver dams within Moss Lake by the end of spring each year; since 2008 the Refuge has been aggressively attacking this management problem to protect the stressed and highly degraded forested systems within the unit.

Green Tree Reservoirs

Green Tree Unit 1 (G1) is 76 acres, the maximum pool elevation is 545.41 MSL, the maximum field elevation is 542.24 MSL, the minimum field elevation is 540.30 MSL and the outlet floor elevation is 537.51 MSL. G1 is fed by the Myer's Creek Branch that flows to Moss Lake and waters can backflow from Moss Lake via the stop-log structure in the northwest corner of the unit. G1 has a second stop log structure in the northwest corner that flows into M7 and a third in the southwest corner leading to M9. There is also a 36" culvert that leads to/from Green Tree Unit 2. The unit has suffered severe flood damage from approximately 15 years of deep impoundment well into the growing season. Active impoundment of the unit ceased in 2007 and the unit fluctuates with the water levels in Moss Lake and is inundated by Vernon Fork overbank flows. Approximately 40-50 acres of the forested habitat has completely shifted to an emergent marsh or scrub/shrub habitat following the complete mortality of almost all trees. These trees are almost all soft snags or case-hardened; as such they provide abundant cavity nesting opportunities.

Green Tree Unit 2 (G2) has maximum pool acreage of 40 acres, the maximum pool elevation is 543.76 MSL, the maximum field elevation is 543.76 MSL, the minimum field elevation is 542.35 MSL and the outlet floor elevation is 539.90 MSL. G2's water supply comes from an inlet pipe from in the northeast corner from M10. There is a 36" diameter culvert to the west of the inlet pipe from M10 that allows water to move into G1

from G2; during high headwater conditions when the Vernon Fork is not out of its banks water can also move from Moss Lake to G1 into G2 and out the diversion ditch into the Vernon Fork. There is also a stop-log structure in the northwest corner that drains into M9. G2 has suffered some damages from extended flooding and impoundment although the impacts are minimal relative to those described in G1. In 2009 and 2010 regeneration was documented in the unit and consisted primarily of ash, maple, sycamore, and cottonwood; limited oak regeneration was also noted.

Green Tree Unit 3 (G3) receives its water from the Mutton Creek ditch. The concrete water control structure was removed in 2007, although the metal culvert still remains and has been plugged and covered with earthen fill. Dikes exist as CR1250 E to the east, CR400 N on the south, and the Mutton Creek ditch levee on the west. The maximum pool acreage is unknown, the maximum pool elevation is 544.0 MSL, the maximum field elevation is 544.0 MSL, and the minimum field elevation is 542.0 MSL.

Green Tree Unit 4 (G4) receives its water from overflows from Storm Creek Ditch or from Storm Creek Ditch via the water control structure (WCS) at the southeast corner of the unit. Water can be discharged in multiple directions from this WCS; it can drain into Storm Creek Ditch, M4 or into M2 if water levels are low enough. No information is currently available with regard to pool acreages or field elevations.

Moss Lake Green Tree Unit is described above in the Moss Lake section. The unit was described in past water management plans as being approximately 400 acres in size with 200 acres as green tree and 200 acres as seasonally flooded impoundment to benefit wood duck broods and migrant waterbirds. This was thought to be the best compromise to meet waterfowl objectives and protect the forested systems within the unit. However, from 1994 to 2007, water was held two feet higher than recommended in the management plans. These deeper water levels led to reduced storage capacity during rain events and led to the death of approximately 750 acres of bottomland forest, stressed approximately 200-300 more acres of forest, and increased the size of the unit from 400 acres to approximately 1000 acres. This problem began to be investigated and addressed in 2008; those investigations are ongoing and continue today. The green tree forest portion of Moss Lake no longer exists as forest and the community type now present is scrub/shrub, emergent marsh, or moist soil vegetation.

Marshes

Endicott Marsh North has a stop log water control structure located on the southern dike and water supplies are received via direct precipitation and runoff from the north. The water control structure empties onto the lower portion of the dike where water free flows down the dike and under CR500 westward to Endicott Marsh South through a stone

bridge that was likely constructed prior to the Refuge's existence. The unit is approximately 8 acres in size. The outlet floor elevation is 551.46 MSL, the maximum field elevation is 556.46 MSL and the minimum field elevation is 551.25 MSL.

Endicott Marsh South has a stop log water control structure located on the southwest portion of the unit and empties into a channel that leads into G3. The outlet floor elevation is 545.03 MSL, the maximum field elevation is 549.28 MSL and the minimum field elevation is 544.09 MSL. Water is supplied to the unit via discharges from Endicott Marsh North and from runoff from the farm fields and grasslands to the east.

Mini Marsh currently has no water control structure; however, it is likely that one will be installed either in 2011 or 2012. The outlet floor elevation will be set at approximately 544.0 – 544.4 MSL. The maximum field elevation is 547.45 MSL and the minimum field elevation is 542.97 MSL. The unit currently has an earthen dam that prevents discharges from the unit under CR500 North via a concrete box culvert. That box culvert is slated for removal due to safety concerns at which time a water control structure and outlet pipe should be installed. The dead timbered areas to the north may be directly related to a lack of management of the unit. Historically the earthen dam was removed and drawdowns conducted; however the unit has not undergone a drawdown for many years. The problems with hydrology have been under investigation since 2009. However, due to the treacherous nature of the habitat, i.e. deep beaver runs, dead standing and downed timber, and large dense patches of dead multiflora rose bushes, reconnaissance missions are very difficult to conduct.

Ponds

Over 70 small ponds exist on the Refuge; of these ponds only those that are fished will be addressed specifically within this plan. Figure 2 depicts the locations of most of these ponds; they are shaded in the light blue color, except for Lake Linda and Lake Sheryl which are dark blue. The ponds that are managed for fishing include: Sand Hill Ponds, Persimmon Ponds, Lake Linda, Lake Sheryl, Mallard Pond, Display Pond, and Office Pond.

Ditches/Creeks

During high flow periods Storm and Mutton Creek ditches are restricted and sheet flows inhibited by Highway 50, CR 400 West, Moss Lake dam, and to a lesser extent by CR 500 North which contains two high water/emergency spillways that allow waters to discharge following significant rainfall events (Fig. 2). Bridges exist at each of the roads; however, they are undersized and cause impoundment of the hydrologic cells. A discussion of this issue can be found on pages 20 and 21 within the description of the

hydrologic cells. Mutton and Storm Creek ditches have levees on both banks that are covered in trees, buttonbush (*Cephalanthus occidentalis*), multiflora rose (*Rosa multiflora*), and other vegetation. While most of the ditch is only traversable by foot, dense trees, vegetation, beaver and muskrat runs and bank lodges, and deep cuts within the levee make travel extremely dangerous and difficult. It is common to find beaver dams and log jams spanning the width of the ditches. Over 130 dams were removed from Storm Creek, Mutton Creek, and Sandy Branch from 2007 to 2010; this has greatly reduced the duration of flood events within the riparian systems along these ditches. Nearly the entire watersheds on and adjacent to the Refuge of all three creeks are directly affected by the impoundment of water within the Moss Lake area. Staging water within Moss Lake in the past has led to significant losses of forested acres on the Refuge, including that seen within the Muscatatuck Seep Spring Natural Research Area and affecting the farm grounds to the north of Highway 50. Contaminants are serious concerns within each of these waterways, most notably are issues with poisonous strains of *Escherichia coli*. These streams each carry large sediment loads that build up behind log jams and beaver dams.

Storm Creek Ditch runs in a general northeast to southwest direction, although, within Moss Lake the Ditch turns at a ninety degree angle to the west just before its convergence with Mutton Creek Ditch. The total length of the Ditch is approximately 6.5 miles, although only 3.3 miles occur on Refuge property. The Storm Creek Ditch watershed is approximately 29 square miles and drains primarily agricultural lands to the north. Residential and forested lands also drain into this watershed.

Mutton Creek Ditch runs in a general south to southwest direction until exiting Moss Lake via the main water control structure. The Ditch continues beyond the Refuge boundary and travels southwest until it empties into the Vernon Fork. The total length of the Ditch is approximately 15 miles, although only 6.3 miles occur on Refuge property. The Mutton Creek Ditch watershed is approximately 31 square miles and drains primarily agricultural lands to the north. Residential and forested lands also drain into this watershed including the Mutton Creek subdivision.

Sandy Branch Creek originates near the city of Seymour, Indiana and flows southeast into the Refuge through Moss Lake, merging with Mutton Creek approximately 1/3 of a mile prior to leaving the Refuge. Sandy Branch Creek drains approximately 9 square miles of urban and agricultural land. A small portion of the creek, at its entrance to the Refuge, was dredged and straightened in the past. In 2010, over 17 beaver dams were located and removed within the first half mile of the waterway.

The combined drainage of the ditches/creeks accounts for twenty percent (69 square miles) of the drainage area of the Vernon Fork. (Master Plan-MNWR, 1982)

Terrestrial Management Unit Descriptions

Forest units

Forest Unit 1 (F1) encompasses approximately 4,010 acres. Although many managed impoundments, ponds, and portions of the creeks and roads fall within the boundary of this unit, they will not be considered within the context of the forest management goals, objectives and strategies of this unit. Not considering the acreage of the aforementioned areas the unit is primarily bottomland hardwood forests approximately 2,400 acres in size. Due to the complexities and severe hydrologic issues that confound management of the Muscatatuck Seep Spring Research Natural Area, it will be considered as a compartment within F1. It has special management needs, independent goals, objectives, and strategies that are described and considered within the overall context of management of the forested unit.

Forest Unit 2 (F2) is in transition from fragmented upland and bottomland forest to a relatively contiguous 2,130 acre block of hardwood forest representative of pre-settlement conditions. The boundary of the unit encompasses approximately 2,310 acres (Fig. 4). However, that acreage includes Richart, Stanfield, portions of Grassland Unit 4 and Grassland Unit 5, portions of CR500N, service roads, and several smaller ponds which will not be considered within the context of the forest management goals, objectives and strategies that will be outlined for this unit.

Forest Unit 3 (F3) is primarily bottomland floodplain forest that is strongly influenced by the Vernon Fork's natural pulsing hydrology. The boundary of the unit, as depicted in figure 4 on page 11, encompasses approximately 1400 acres. However, that acreage includes M8 through M10, Green Tree Unit 2, portions of County line road, service roads, and several smaller ponds which will not be considered within the context of the forest management goals, objectives and strategies that will be outlined for this unit. This unit is a relatively contiguous 1,250 acre block of bottomland hardwood forest.

Grassland units

GU1 consists of warm season grass plantings that surround Endicott South, mixed grassland habitat that surrounds Endicott North, former agricultural land north of CR500N and east of CR1250E, and current agricultural land south of CR500N and east of 1250E (Fig. 5). Woody encroachment within a large portion of this unit has been a concern in recent years; approximately 70 acres of woody vegetation was removed from GU1 in 2009 and 2010. The unit is approximately 230 acres although that acreage is not contiguous and is intersected by CR500N and CR1250E.

GU2 is adjacent to the maintenance area just to the south of CR400W and southeast of Sue Pond (Fig. 5). This unit was still managed within the farming program and in 2010 the unit was farmed in corn. GU2 is approximately 50 acres.

GU3 is located along the western boundary of the Refuge to the east of Hwy 31. The unit abuts portions of Moss Lake and Sandy Branch Creek and is largely surrounded by bottomland forest (Fig. 5). A portion of the unit is currently reconverting to trees and this trend may cause that portion to be removed from consideration within the context of grassland management. Total acreage of the unit is approximated at 121 acres.

GU4 is the emergency spillway at Richart Lake and is approximately 7 acres in size; the dominant vegetation is tall fescue (Fig. 5).

GU5 is the emergency spillway at Stanfield Lake which is approximately 12.5 acres in size and is dominated by tall fescue. The SW section of unit has reverted to trees and is dominated by pole sized timber (Fig. 5).

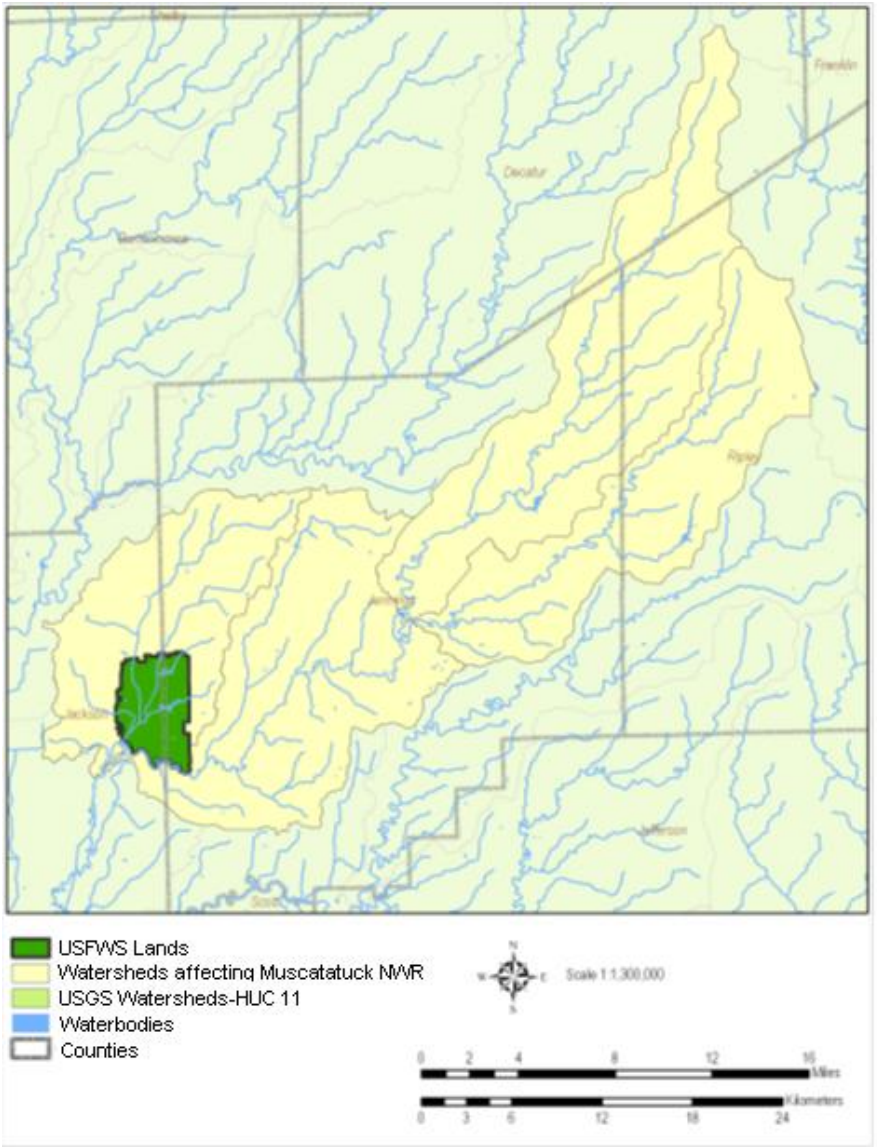
Physical/Geographic Setting

Hydrology

The MNWR lies within the Vernon Fork of the Muscatatuck River (VFMR) watershed (Fig 6). This flat, relatively well-drained area is part of the Wabash River Basin. The river is a meandering, turbid, lowland stream with a channel 10 to 20 feet below the average topographic level of the floodplain. While the VFMR may approach dry conditions at certain times of the year, the annual floodplain of the VFMR extends 2,000 to 3,500 feet into the Refuge along its southern border. Annual floods inundate approximately 2,700 acres of the Refuge. The VFMR drains the Refuge and flows into the Muscatatuck River (MR) just south of Crothersville, Indiana in Jackson County. From there, the MR flows westward and empties, via the East Fork White River, into the Wabash River. Three tributaries run through the Refuge and enter into the Vernon Fork of the Muscatatuck River. Mutton Creek Ditch and Storm Creek Ditch originate north of the Refuge and run parallel to each other as they flow southward and eventually merge in the Refuge area known as Moss Lake, just prior to leaving the Refuge and entering the VFMR. Each drains relatively small watersheds (primarily agricultural) of 31 and 29 square miles, respectively. As their names imply, both creeks were channelized in the early 1900's, altering the pattern of pools and riffles that once existed. The third tributary, Sandy Branch, originates near the city of Seymour, Indiana and flows southeast into the Refuge through Moss Lake, merging with Mutton Creek approximately 1/3 of a mile

prior to leaving the Refuge. Sandy Branch Creek drains approximately 9 square miles of urban and agricultural land. The combined drainage of these 3 streams through the Refuge accounts for twenty percent (69 square miles) of the VFMRs drainage area (USFWS 1982).

Figure 6: Watersheds of Muscatatuck NWR



Ecoregion

According to the U.S. Environmental Protection Agency's Western Ecology Division Ecoregion level I map, MNWR is located in the Eastern Temperate Forest region. The Ecoregion level II map illustrates that the Refuge is in the Central U.S. Plains region and the Ecoregion level III map illustrates a more specific Eastern Corn Belt Plain Ecoregion; these maps can be viewed at http://www.epa.gov/wed/pages/ecoregions/level_iii_iv.htm The Eastern Temperate Forest region has a moderate to mildly-humid climate. The physical description can be best described as limestone-dolomite hills and plains. The surface waters are mostly perennial streams, small areas with high densities of lakes and variety of wetland communities with an array of maritime ecosystems (CEC 1997).

The Eastern Temperate Forests form a dense forest canopy consisting mostly of tall broadleaf, deciduous trees and needle-leaf conifers. Beech-maple and maple-basswood forest types occur widely especially in the eastern reaches of this region, mixed oak-hickory associations are common in the Upper Midwest, changing into oak-hickory-pine mixed forests in the south and the Appalachians. These forests have a diversity of tree, shrub, vine and herb layers. While various species of oaks, hickories, maples and pines are common, other wide-ranging tree species include ashes, elms, black cherry, yellow poplar, sweet gum, basswood, hackberry, common persimmon, eastern red cedar and flowering dogwood. A once common tree species, the American chestnut, was virtually eliminated from the Eastern Temperate Forests in the first half of the twentieth century by an introduced fungus.

Two essentials for wildlife—food and shelter—are relatively abundant in the Eastern Temperate Forests. The region contains a great diversity of species. Mammals of the region include the white-footed mouse, gray squirrel, eastern chipmunk, raccoon, porcupine, gray fox, bobcat, white-tailed deer and black bear. The region has extremely diverse populations of birds, fish, reptiles and amphibians.

Muscatatuck NWR is located within the Ohio River Valley Ecosystem (ORVE). The ORVE is comprised of portions of 9 states and 9 of the designated Partners in Flight (PIF) physiographic regions. The states of Kentucky, Indiana, Ohio and West Virginia make up the majority of the ORVE (USFWS 2002). Most of the land cover within the Ohio River Valley Ecosystem is designated as agriculture. Deciduous forest makes up the second highest percentage of land cover in the ecosystem.

Topography

The Refuge is mainly located within the Scottsburg Lowland physiographic region of Indiana (Schneider 1966). The topography is nearly level to gently sloping in upland areas (Nickell 1976). Streams have dissected the area and have developed broad, level floodplains that are occasionally to frequently inundated by floodwaters.

Elevations on the Refuge range from an estimated 533 ft. MSL (at Ditch bottoms and at the bottom of Moss Lake) to 620 ft. MSL at the top of the ridges. The following table of elevational acreages was developed for use in the Refuge Master plan and likely has changed slightly over the past 40 years.

Table 1: Elevation Acreages at Muscatatuck NWR

Elevation (ft. MSL)	Acreage	Percent of Refuge
536-546	2,127	27%
547-558	1,730	22%
559-570	1,573	20%
571-582	1,608	20%
583-584	833	10%
594-620	145	1%

*Data compiled in 1973

The Refuge has both uplands and river valley areas, causing variations in the depth of the unconsolidated surface soils to bedrock. Slopes over 15% are uncommon and are usually heavily wooded (Table 2).

Table 2: Slope Type Acreages at Muscatatuck NWR

Percent of Slope	Acreage	Percent of Refuge
0-3	3,086	39%
3-5	1,733	22%
5-10	778	16%
10-15	230	10%
15-25	536	7%

*Data compiled in 1973

Orientation of slopes was classified as part of the Master plan process using data compiled in 1973 (Tables 2 and 3). Slopes were classified into three microclimatic regimes. Cool moist slopes were those oriented to the north and northeast; warm dry slopes oriented to the southeast, south, southwest, and west; and temperate slopes which

were those with an east or northeast aspect. All lands with no slope were classified as flat.

Table 3: Orientation Acreages at Muscatatuck NWR

Orientation	Acreage	Percent of Refuge
Cool Moist Slopes	931	12%
Warm Dry Slopes	3,489	39%
Temperate Slopes	1,268	17%
Flat	2,448	32%

*Data compiled in 1973

Soils

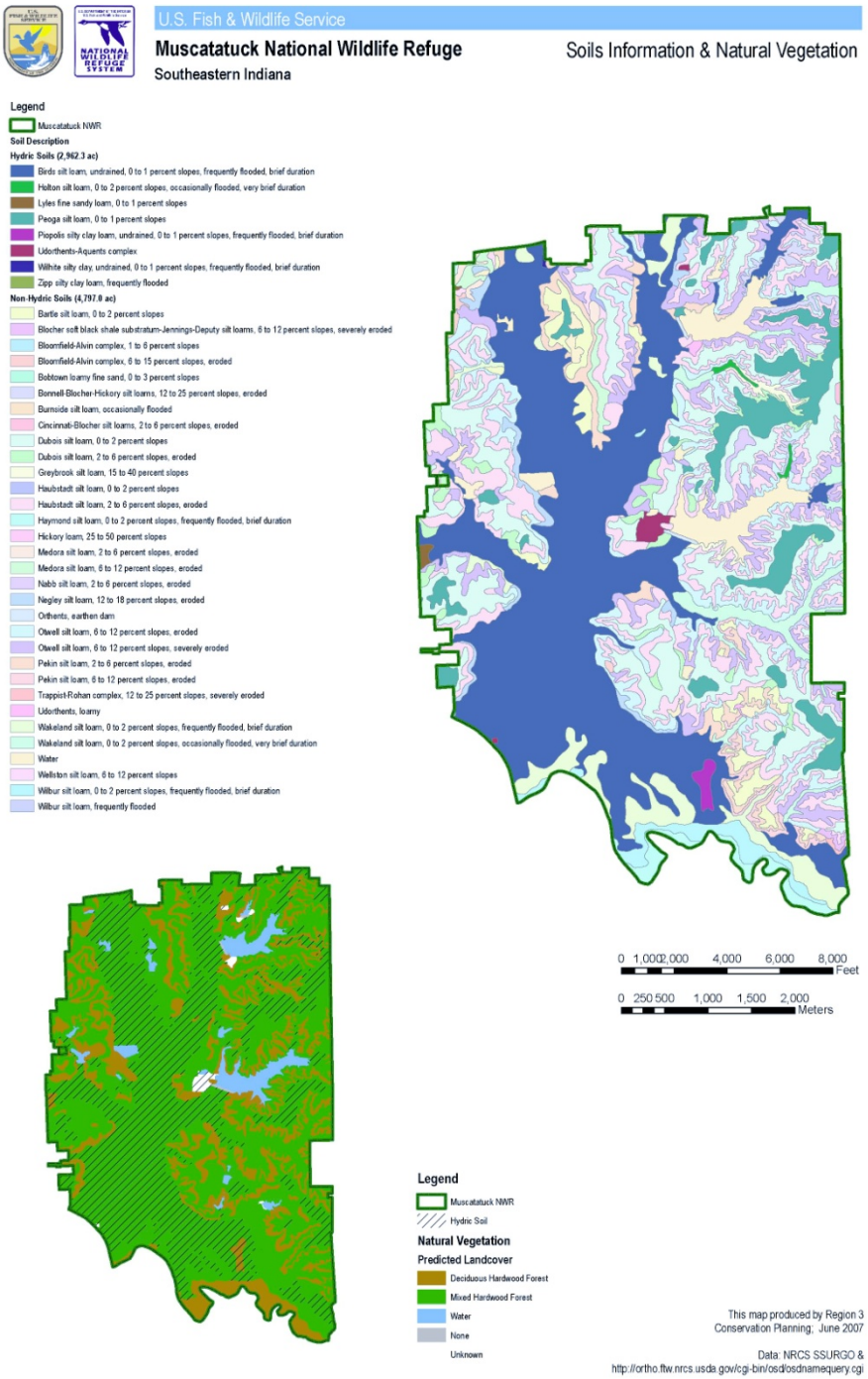
Detailed soil information can be found in the CCP on pages 16-18. Table 4 below lists the soils present at MNWR and their acreage; their extent can be viewed in Figure 7.

Table 4: Soils of Muscatatuck NWR

Soil Type	Acreage	Percentage of Refuge
Birds silt loam	2,381.70	30.44
Holton silt loam	12.02	0.15
Lyles fine sandy loam	9.77	0.12
Peoga silt loam	445.56	5.69
Piopolis silty clay loam	21.88	0.28
Udorthents-Aquents complex	26.43	0.34
Wilhite silty clay	2.33	0.03
Zipp silty clay loam	62.63	0.80
Bartle silt loam	171.26	2.19
Blocher	7.49	0.10
Bloomfield-Alvin complex 1-6%	0.19	0.00
Bloomfield-Alvin complex 6-15%	16.22	0.21
Bobtown	0.01	0.00
Bonnell	81.08	1.04
Burnside	2.32	0.03
Cincinnati	3.89	0.05
Dubois 0-2% slope	1,046.14	13.37
Dubois 2-6% slope	138.67	1.77
Greybrook	31.52	0.40
Haubstadt 0-2%	5.81	0.07
Haubstadt 2-6%	1,108.74	14.17
Haymond	78.54	1.00

Hickory	6.00	0.08
Medora 2-6%	21.57	0.28
Medora 6-12%	42.41	0.54
Nabb	14.03	0.18
Negley	86.21	1.10
Orthents	7.51	0.10
Otwell eroded	443.61	5.67
Otwell severely eroded	464.89	5.94
Pekin 2-6% slope	197.15	2.52
Pekin 6-12% slope	47.67	0.61
Trappist-Rohan	3.80	0.05
Udorthents	10.92	0.14
Wakeland frequently flooded	281.04	3.59
Wakeland occasionally flooded	160.60	2.05
Water	283.75	3.63
Wilbur 0-2% slope	1.52	0.02
Wilbur frequently flooded	105.38	1.35

Figure 7: Soils and Natural Vegetation of Muscatatuck NWR



Climate

Indiana's climate is a temperate-continental and humid climate, which is typical of 30° and 50° latitudes (Jackson, 1997). The Refuge experiences a continental climate of warm, humid summers and moderately cold winters. The area receives moisture from the Gulf of Mexico as air masses move up the Mississippi and Ohio River Valleys. January is the coldest month with a mean temperature of 28 degrees Fahrenheit. July is the warmest month with a mean normal temperature of 74.5 degrees Fahrenheit. April 20 and October 12 are the frost and freeze dates for 32 degrees Fahrenheit with a 50 percent probability. The normal annual precipitation is about 46 total inches. Normal precipitation is distributed relatively evenly across the months of the year with a low normal of 2.84 inches in February and a high normal of 5.01 inches in May (Source: National Climatic Data Center). The normal climograph (Figure 8.) illustrates the normal wet periods in the fall, winter, and spring and the normal dry period in the late spring and throughout the summer. The 2009 climograph (Figure 9) was included to illustrate the extreme conditions that are often present; the entire year was dominated by wet conditions.

Figure 8: Muscatatuck NWR Normal Climograph

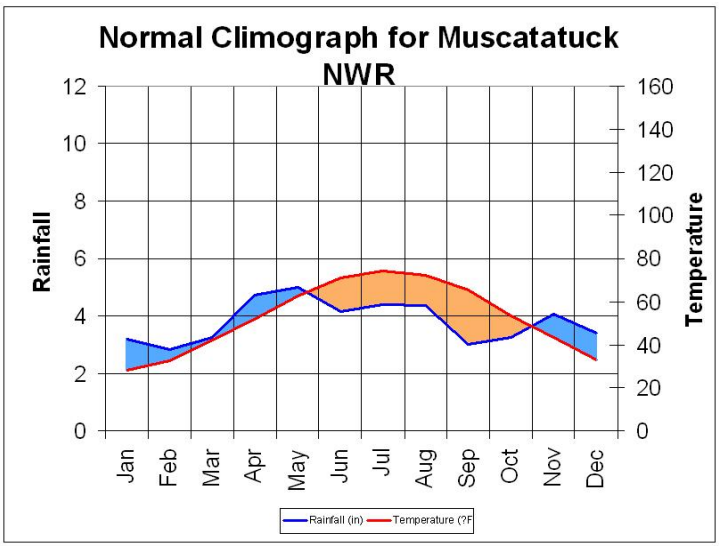
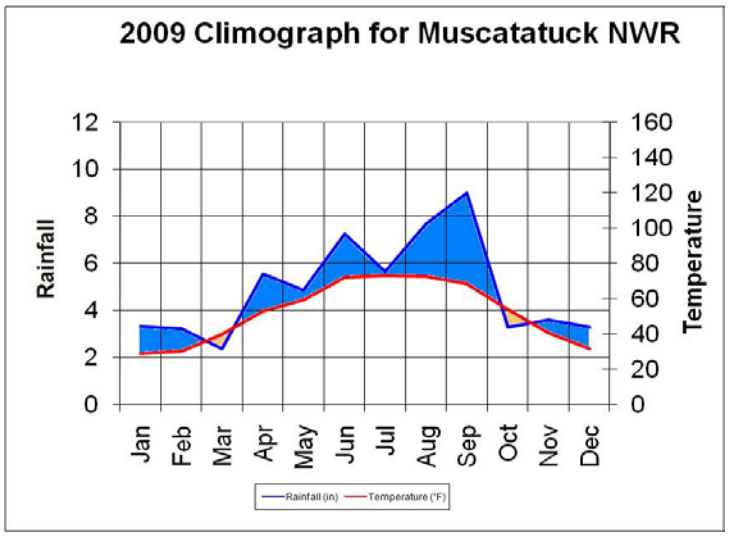


Figure 9: Muscatatuck NWR 2009 Climograph



*Rainfall is in inches and monthly average temperatures are in °F
**The blue shading indicates periods dominated by wet conditions; the tan shading indicates periods dominated by dry conditions

Historical

Historical information regarding anthropogenic influences and use of the Refuge can be reviewed in the CCP.

Vegetative Features

Evidence indicates that Pre-Wisconsinan glaciations had their effect on the Refuge although the area has been extensively reworked by water (Gray 1972). Many of the woody and herbaceous species that are present at the Refuge today were present historically in the mid-tertiary period (Jenkinson 1998) and the forests were transitioning to a mixed deciduous forest as climates became dryer and cooler. Tertiary forests retreated during the Pleistocene glaciations and three tertiary types radiated out following those events and included western mesophytic forests, beech maple forests, and oak hickory forests (Petty and Jackson 1966).

Limited distribution of the western mesophytic forest type occurred on the Refuge but where present contain beech, sugar maple, white oak, red oak, white ash, tulip poplar, pignut hickory, white basswood, yellow buckeye, black gum, shagbark hickory and red maple. The understory contained dogwood, redbud, and blue beech and shrubs such as pawpaw, spicebush, greenbrier, and leatherwood.

Beech-maple forests likely dominated the Refuge's habitats and evolved from the mixed mesophytic forest type following glacial recession. Dominant species shifted to beech and maple which accounted for approximately 50-80% of the canopy. Beech was considered the dominant species and maple as co-dominants in the canopy. Other principal species include tulip poplar, white ash, American elm, slippery elm, cork elm, white oak, bur oak, red oak, basswood, black burn, black walnut, black cherry and mockernut hickory. Selective cuttings of high grade species such as walnut, oaks, poplar, and ash apparently shifted beech into the more dominant position and the openings created by the disturbance resulted in sassafras, black cherry, tulip poplar, and walnut establishing higher densities as well (Jenkinson 1998).

Oak-hickory forests, in the 19th century, were most closely associated with upland sites where water retention was reduced and are often associated with southwest facing slopes. Dominant species included a mixture of oaks including white, black red, swamp white, chinquapin, bur, and chestnut oaks, as well as pignut, shagbark, and mockernut hickories, American elm, slippery elm, black gum, sugar maple, white ash, and American beech.

The bottomland areas adjacent to the streams and in the Moss Lake basin were likely dominated by a mixture of more mesic species including elms, ash, pin oak, swamp white oak, other oak species, sycamore, cottonwood, willow, elm, hackberry, and beech. Little data exists within these lowland areas as surveyors often avoided the wetter conditions.

Two forested types are described by Parker and Ruffner (2004) based on General Land Office surveys and include the lowland-depression forests and floodplain forests. Lowland-depression forests are dominated by elm, ash, sweet gum, oaks, hickories, and red and silver maples; these forests occur on low lying terraces. The floodplain forests are characterized by sycamore, elms, ashes, hackberry, and cottonwood found within riverbed margins.

In the middle Holocene, warming temperatures during a period commonly referred to as the Hypsithermal period (9,000-5,000 yrs. B.P) allowed for the expansion of prairie habitat types in Indiana as mesophytic species moved down into bottomland areas and uplands were dominated by oak and hickory forests (Franklin 1994). It is likely that small, localized disturbance events created forest gaps that were largely dominated by a mixture of cool season species such as Canada wild rye, western wheat grass, Kentucky blue grass, needle grass, and Pennsylvania sedge, and warm season species such as big and little bluestem, Indian grass, switch grass, and prairie dropseed. These forest gaps were likely short-lived as tree species swiftly recolonized disturbed areas.

It is important to recognize that climate induced vegetation shifts were commonly accompanied by human induced changes and the interactions between the two likely

shaped the landscape from the period of 8,000 years B.P. to present. It is well known that archaic peoples were relatively adept at managing habitats. These peoples are believed to have significantly altered species compositions within forests through patch clearings (Parker and Ruffner 2004).

Woodland cultures used fire to manipulate their environments and formed what are referred to by Delcourt et al. (1998) as “forest gardens”. During the Mississippian period natives began establishing agricultural sites within bottomland areas that were later settled and farmed by Europeans. Eighteenth century records indicate strong, sustained, anthropogenic influences on plant communities by native peoples; however, their use of fire and agriculture largely subsided prior to the 1700’s. Forested systems recovered due to the massive reduction in Native American populations as a result of disease and genocide brought on by the European settlers.

Fire regimes experienced dramatic changes as European settlers came to dominate the landscape. By the early 1900’s most of the forested areas at the Refuge appear to have been cut and forests were replaced by agriculture and residential sites. Areas too wet to be farmed seemingly reverted to forest and likely experienced multiple periods of timber harvest. From the early 1900’s to present most fires were completely suppressed with the exception of some limited grassland burning by farmers initially and by Refuge staff once the Refuge was established. Fire use as a management tool ceased in the 1990’s.

The 1982 master plan indicated that 370 acres of “reproductive trees”, 252 acres of cut trees, 1,169 acres of pole size timber, 1,390 acres of saw log trees, and 218 acres of mature trees existed on the Refuge. The total forest acreage appears to have been 3,399 acres, roughly 44% of the Refuge. These forested areas predominantly existed within birds silt loam hydric soil series and were the true bottomland forests on the Refuge. They ran in a general north-south direction within the center of the Refuge and are within or surrounding the riparian zones, abandoned channels, oxbows, and low lying depressions associated with Storm, Mutton, and Sandy Branch Creeks; this also includes the Moss lake complex.

Forests were classified in 1973 in three woodland vegetation associations: forested wet sites, floodplain/bottomland forests, and upland forests. Tulip poplar, beech and oak were the most common species dominating nearly 40% of the woodlands. Tulip poplar forests were the most abundant of these dominant species in the forested wet sites, which accounted for 16% of total vegetative area, and were dominated by tulip poplar, hickory, pin oak and white oak, red maple and sweet gum. In the low lying areas along streams, sycamore and river birch were listed as common among the tulip poplar. The bottomland/floodplain forests, accounting for 14% of total vegetative area, were dominated by beech. These forests also contained a mix of sweet gum, red maple, and

river birch; pin, white and chestnut oaks and tulip poplar may also occur. Upland forests were dominated by oak species and these forests comprised 8% of total area. Species found in this forest type were pin, white, and red oak, hickory, sweet gum, sycamore, river birch, red maple, and tulip poplar. Minor woodland types not described in detail were Tulip/Maple, Pin oak, Willow/Sycamore, Beech/Tulip, Sweet gum, River birch, Birch/Gum, Birch Maple and Gum/Oak. Wood land vegetation from 35 years to 100 years of age was dominated by beech, white oak and tulip poplar.

When the Refuge acquisition was completed in 1972, most of the acreage of cropland was not yet removed from active farming. In 1973, ten farmers derived economic gains from cropping a little over 2,480 acres of Refuge land. Approximately 1,700 acres existed and were managed as grasslands which supported high densities of nesting grassland bird species. Small stock ponds existed on the property and the Refuge was engaged in active construction of wetlands across the landscape. Three fishing ponds were created to provide opportunities to local users and other visitors in the mid to late 1970's as were several shorebird and duck management impoundments, although little water control existed. Mini Marsh was created in the 1970's along with several smaller marsh units.

Grassland management declined over the next three decades; the 1,700 acres of grasslands was slowly whittled down to only 80 acres by 2007. Forested habitats changed relatively little from 1973 to 1985 with a few exceptions. The management plan developed in December 1985 outlined that cropland was decreased to only 500 acres, 571 acres of grassland remained, and approximately 2,366 acres of "grow back areas" existed which were in some stage of reversion to forest. Most of this acreage existed on the east side of the Refuge. Croplands were further reduced over the next decade and by 2009 only 310 acres remained.

Tree plantings occurred as early as 1971 and included, in decreasing order of magnitude, white pine, Virginia pine, red pine, bald cypress, black walnut, black locust, tulip poplar, European alder, river birch, dogwood, and autumn olive. Tree plantings and plantings of invasive species occurred annually for many years. It should be noted that early annual narratives and reports indicated that multiflora rose was extensively planted prior to Refuge establishment by private landowners, likely under guidance from state wildlife agencies.

During the time period of 1970 to 1982, significant additions of impoundments dramatically increased the wetland acreages on the Refuge. In the beginning, these wetlands were generally small and averaged half an acre to 6 acres in size. Only a handful were established for fishing purposes while had a primary objective of waterfowl, marsh bird, and shorebird management. The impoundment system was largely developed between 1979-1983 and added Richart and Stanfield lakes, moist soil units 1-

10, green tree reservoirs 1-4 (although G4 was never referenced or discussed in any plan it was simply created), and the Moss lake impoundment. At that time several smaller ponds and marshes existed, as did Mini Marsh which was actively managed. Both McDonald marshes were developed from 1994 to 1996 and Endicott Marsh South was developed in 1981; the development of Endicott Marsh North is unknown at this time.

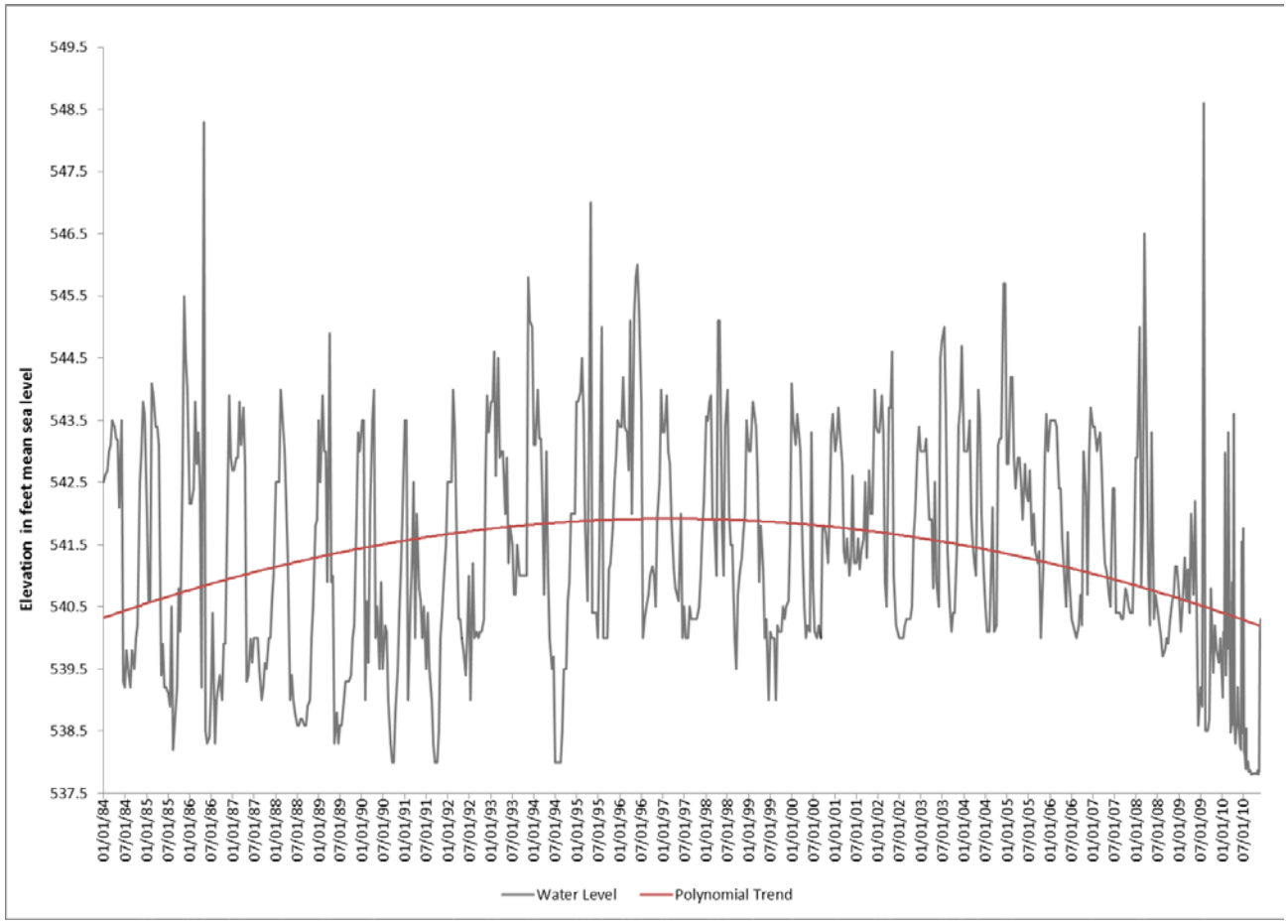
The most significant changes in forested habitats, other than cropland conversion to forest, was what occurred within the bottomland/floodplain habitats, especially those of the Moss Lake complex (MLC) and within the green tree reservoirs. Initial planning efforts within the MLC were quite contradictory among different plans.

The 1982 Master Plan for the MLC indicated managing a 428 acre area. However, a more accurate depiction of the impacts of management of the MLC can be found in the 1978 Environmental Assessment completed prior to the construction of the impoundment system and the one mile Moss Lake Dam. In that EA the impacts of the dam were indicated and the total area of the MLC was described as 725 acres flooded at a permanent depth of 1 to 7 feet. These numbers are marked out by hand in that EA and 428 acres written in and permanent depths of 1 to 7 feet marked out and replaced with semi-permanent depths of 1-5 feet. The EA was completed by an independent contractor and reflects more accurately the true nature of the impacts of that dam. However, the first water management plan completed in 1984 indicates that the intention for the MLC was to be decided within the next couple of years and two alternatives were proposed including: 1) 200 acres of permanently flooded marsh and 200 acres of seasonally flooded green tree areas and 2) 400 acres of semi-permanently flooded marsh. In 1985, management direction within the WMP indicated that it was decided that the best alternative to meet waterfowl objectives and maintain the integrity of the bottomland hardwood forests within the MLC were to manage the area as a 200 acre marsh and 200 acres of green tree area.

In 1982, the MLC contained approximately 90 to 150 acres of permanently flooded land and approximately 850 to 910 acres of mature bottomland forest consisting of tulip poplar, hickory, pin oak, beech, sycamore, sweet gum, birch and willows that ranged from 35 to 75 years of age. The target conservation pool elevation for the MLC in the summer was 539.5 ft. MSL. However, water management of the MLC from 1984 to 1991 usually included complete summer drawdowns (Figure 10).

Throughout all water management plans, a consistent message was indicated that management of the MLC desired to protect the forested system, although it was expected that limited tree mortality would occur. The intended objectives were clear that green tree areas were managed to protect the timber resource while still conferring benefit to waterfowl within the winter. However, limited understanding of the management of

Figure 10: Moss Lake Water Levels: 1984-2010



bottomland forests slowly resulted in greater impacts to those systems. Flooding of bottomland forests was conducted generally in early November following “leaf drop”, although the senescence referred to in these plans likely accounted only for mature trees and not seedlings and saplings as they generally senesce later and are the last to drop their leaves. Drawdowns were planned to coincide with leaf out and in the earlier plans began in late March and early April. The drawdowns were timed too late and flooding occurred too early within the MLC and led to changes in the vegetative community and included some tree mortality across a few hundred acres.

Immediate changes can be seen in the management of water within the MLC (Figure 10) in 1992 resulting in higher baseline levels throughout the year, longer duration flooding, and total drawdowns were no longer conducted with the exception of 1994. This trend continued from 1992 until 2008 and resulted in the loss of approximately 700 acres of mature bottomland forest, reduced overall productivity of the system, and led to relatively steady flooding on approximately 400-500 acres of the MLC. During that period, vegetation shifts within the MLC were evident and most of the bottomland forest was replaced by a snag forest within a scrub/shrub habitat type. Mature trees of all species experienced complete mortality across an additional 450-650 acres not considering the 100-300 acres that died in the previous decade. Two aerial photos and a map produced by Dr. Joseph Robb, as part of his master’s thesis, are included in Figure 11, Figure 12, and Figure 13 as evidence of the change.

Changes in health and community structure were evident within the forested areas of the MLC, the forested areas surrounding the MLC, forested areas to the north of the MLC adjacent to Mutton, Storm, and Sandy branch creeks, and even the forested sections of the Muscatatuck Seep Spring Research Natural Area. Impacts included reduction or complete removal of forest understory and herbaceous layers, severely stressed mature trees across significant portions of the birds silt loam soil series, and complete community shifts in many areas from forest to open water and permanent marsh habitats intermixed with snags. Green tree unit one and the Muscatatuck Seep Spring Research Natural Area area were dramatically impacted; forests were completely destroyed, and increases in flood frequency and duration were also evident.

Within the period of 1992-2007 most moist soil units were managed as open water lakes although management labeled them as “brood marshes”. Many of the units lacked the necessary components described within wood duck HSI models to adequately provide for brood rearing. Dramatic declines in moist soil plant development had resounding impacts on waterfowl and waterbird use of the Refuge. Although resident species such as Wood Ducks and Canada Geese thrived, migrant use experienced significant declines as productivity was reduced and water levels were stabilized (Figure 14). Invertebrate

Figure 11: 1960 Aerial Photo of the MLC

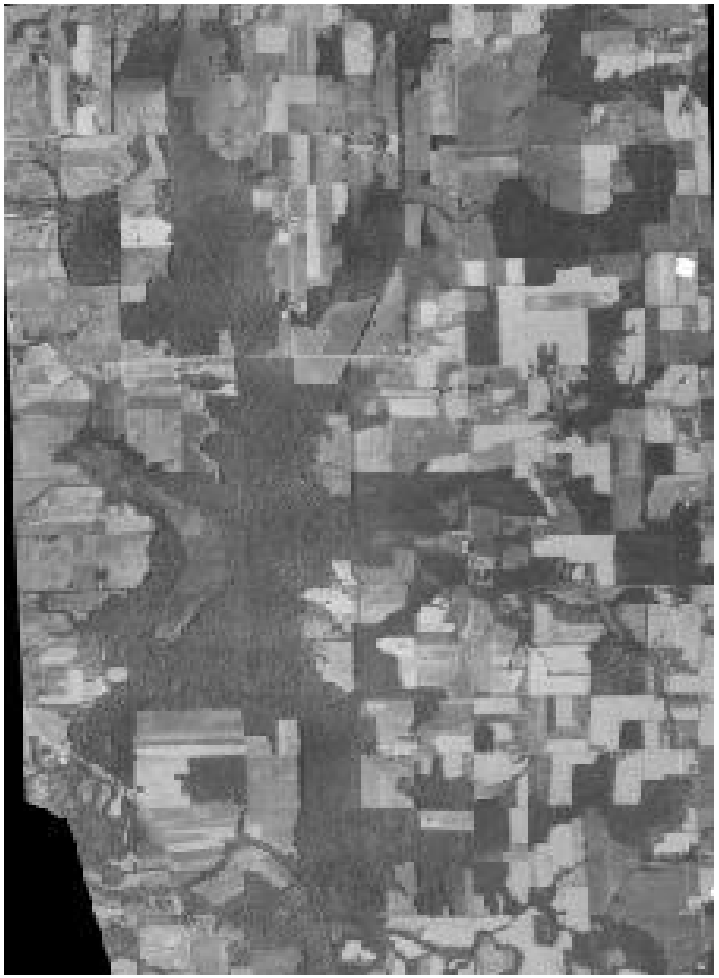


Figure 12: 2006 Aerial Photo of the MLC

Figure 13: Forested Habitats at Muscatatuck NWR: 1984-1985 adapted from the Journal of Mammalogy (Robb et al. 1996)

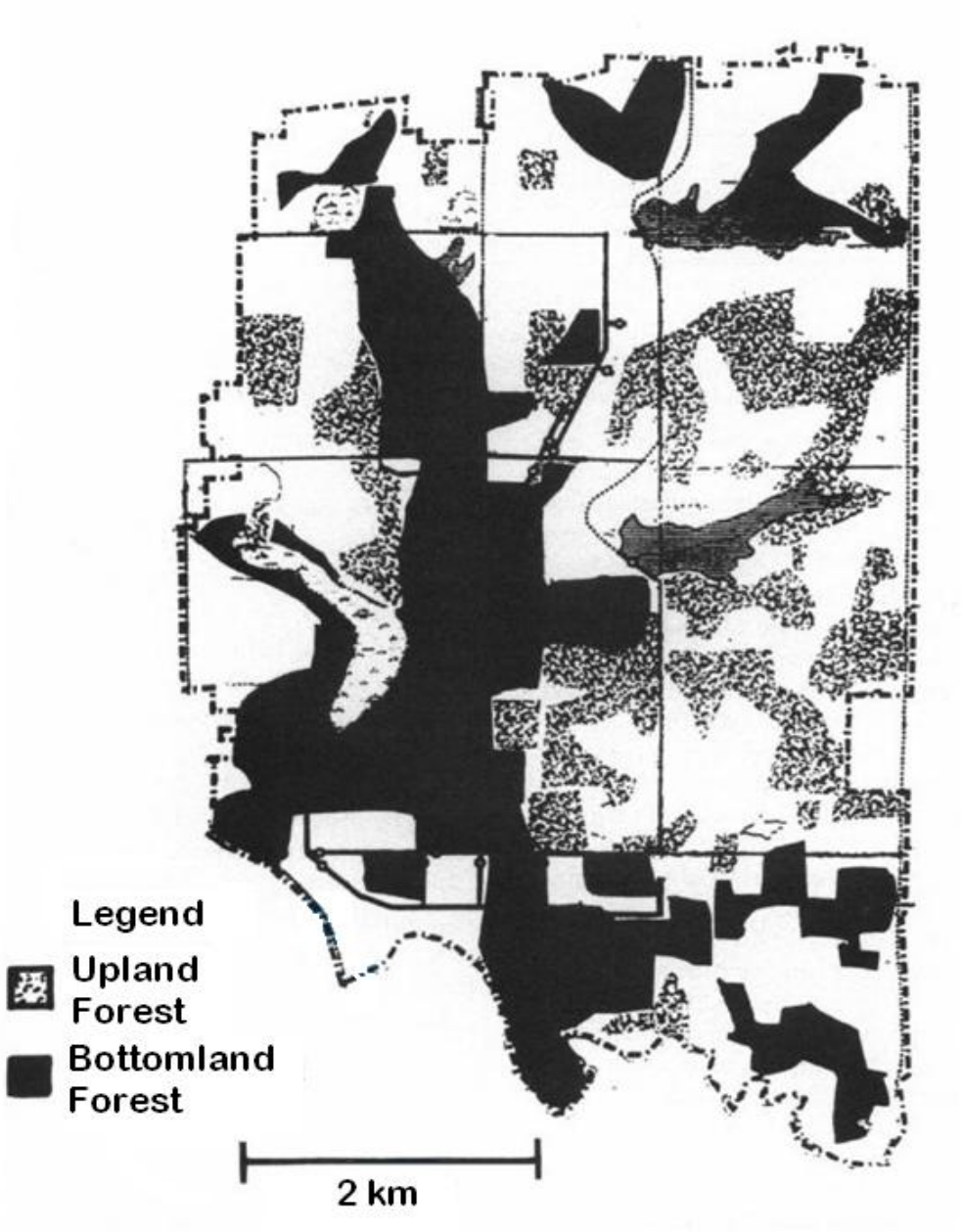


Figure 14: Thirty-eight Years of Total Waterfowl Use Day Data at Muscatatuck NWR

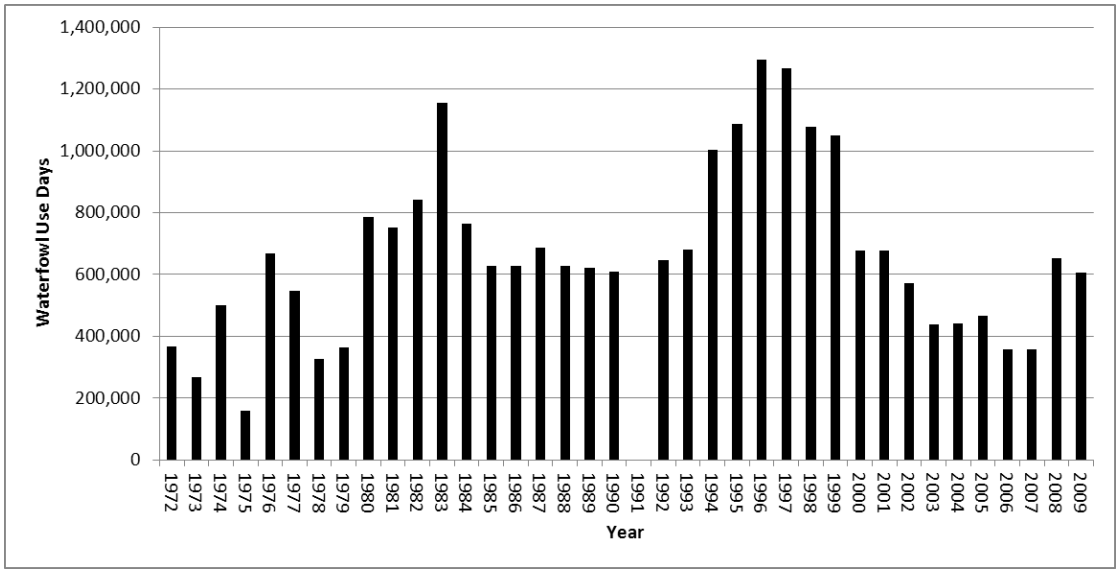
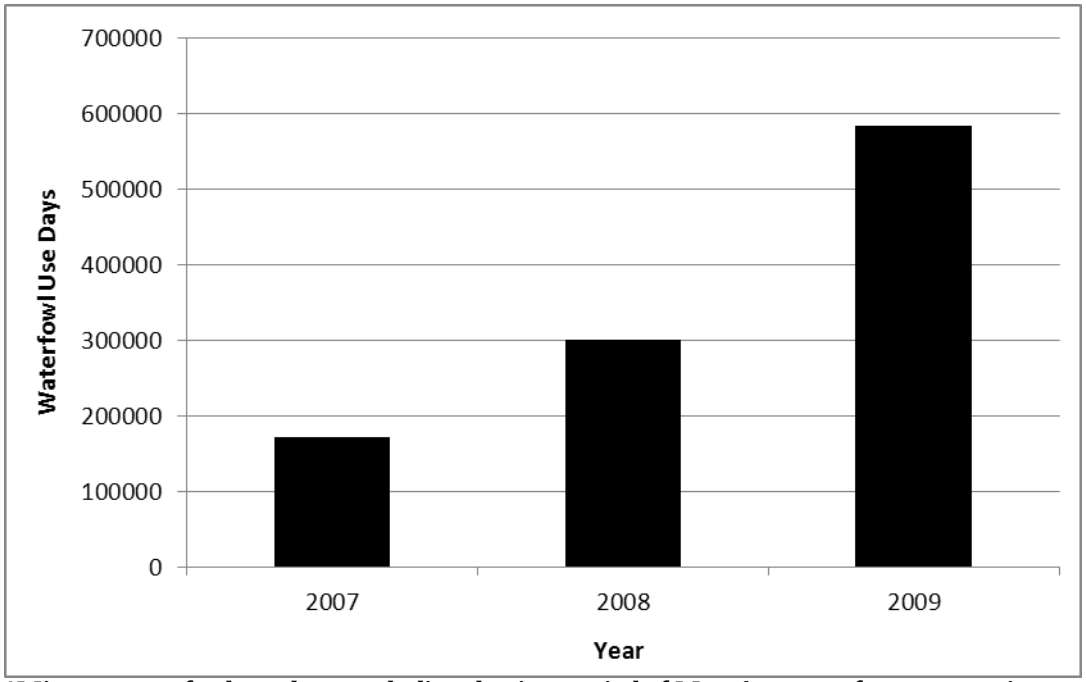


Figure 15: Three Years of Migrant Waterfowl Use at Muscatatuck NWR*



***Migrant waterfowl use days: excluding the time period of May-August to focus comparisons on migrant populations and their response to changes in water management over the three year period and the resulting habitat response**

populations were not monitored; however, based on literature review it can be accurately assumed that they experienced similar significant declines.

As our understanding of wetland management increased, changes in water management ensued. These changes were initiated in 2007 and full force changes were enacted in 2009 and 2010 and a reversal of the previous 17 year trend was fully recognized. These changes increased moist soil plant production (Figure 18 - 20) and migrant waterfowl/waterbird use (Figure 14 and15), while also decreasing water levels throughout the watershed and the negative impacts associated with the higher levels. Overall productivity was enhanced, increased capacities to absorb higher rainfall events were realized, and much needed habitat alterations and restorations proceeded. Two other critical factors played significant roles in the successes of 2009 and 2010, including the commitment to reduce beaver populations and remove beaver dams throughout the Refuge. Direct control efforts removed 129 beaver during those two years and over 130 beaver dams were removed from 2007-2010; some dams were estimated to be as old as 15 years by the size of trees growing from them.

Current Condition

The current condition of the Refuge can best be understood through the use of current landcover maps and the summarization of habitat types, conditions, current management regimes and problems, and other details.

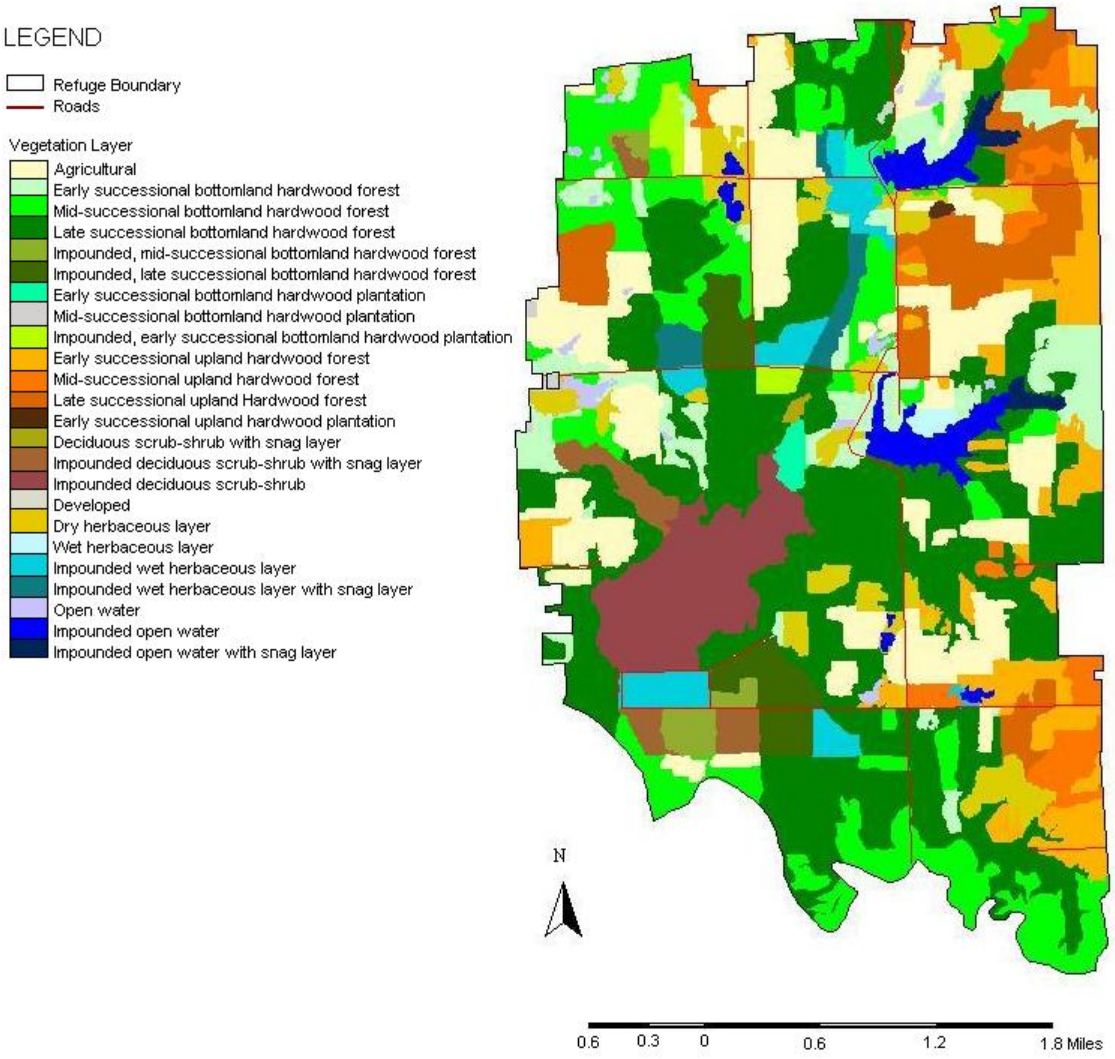
Habitat Types

Data derived and reviewed in the creation of this plan was compiled from multiple sources and included the CCP, professional publications, annual narratives, outdated management plans, environmental assessments, anecdotal data, Refuge staff experience, annual water management plans, miscellaneous research reports, and other documentation. Due to the wide array of sources and the dramatic evolution of wildlife science and habitat classifications during the span of the data reviewed, habitat types are not consistent. In the effort to provide coherency, where possible this plan utilizes habitat classifications and terminology consistent with the CCP.

Landcover

The University of Minnesota, Department of Forest Resources created a high resolution land cover spatial database in 2000 (LCSD) of the Refuge (Figure 16). U.S. Fish and Wildlife Service (USFWS) 1:15000, color- infrared aerial photos were collected in 2000 and vegetation types were classified based on a Refuge-derived system that was cross walked to the National Vegetation Classification System (NVCS). The LCSD was

Figure 16: Land Cover at Muscatatuck NWR for 2001 (UMN 2001)

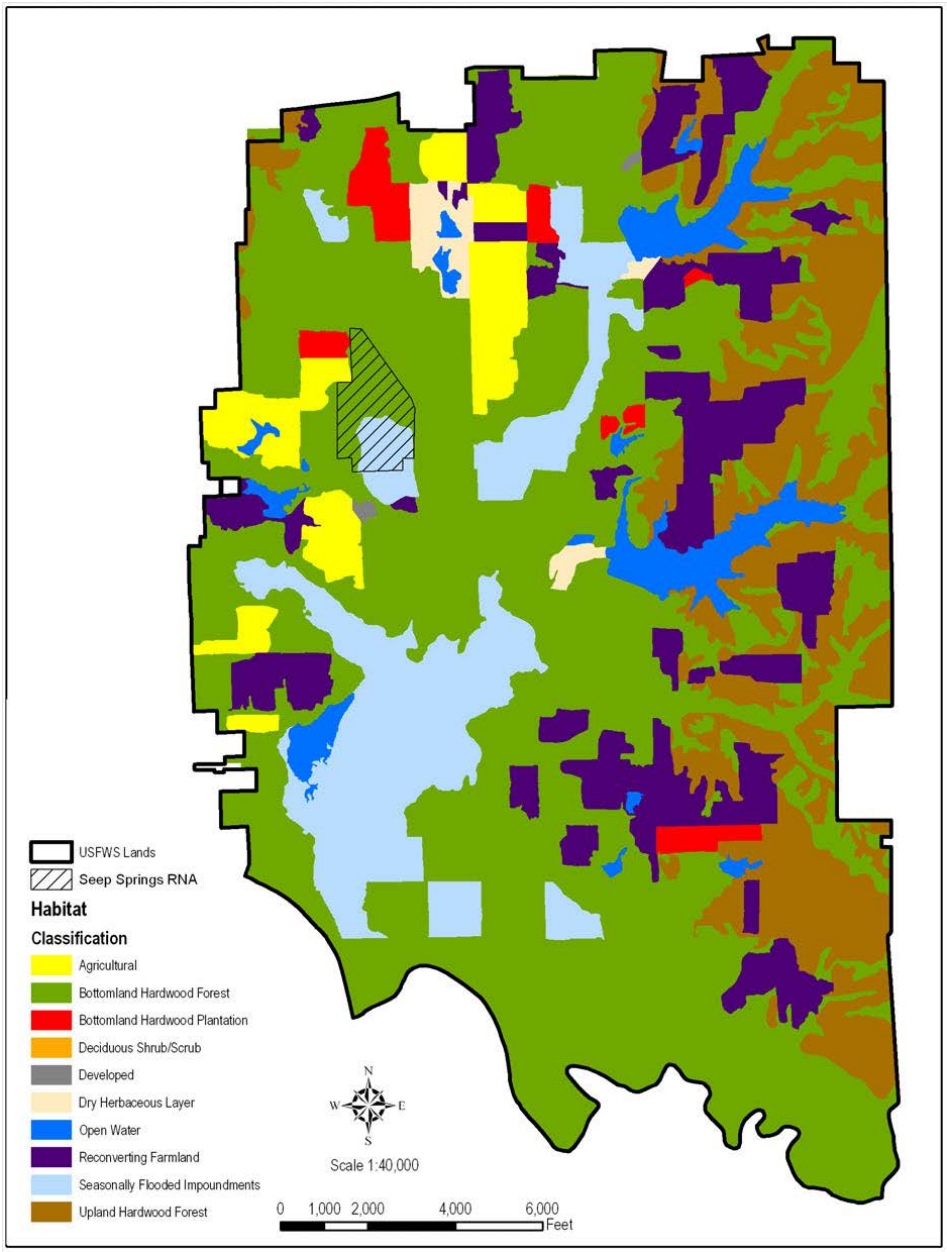


created to provide baseline data that was used in producing the CCP (Sieracki et al. 2002).

Data on vegetation cover types were remotely sensed and aerial photos ground-truthed; the vegetation types were digitized in ArcGIS. The overall accuracy for map classes was 83%. The vegetation cover spatial database is available as a shapefile and ArcInfo export file (Seiracki et al. 2002).

The LCSD is quite complex with 24 cover classes (Fig. 16). These data were further simplified down to 10 cover classes by regional GIS specialists from 2007 to 2009 and these were used to complete the CCP (Fig. 17).

Figure 17: Current Landcover at Muscatatuck NWR (FWS 2009)



The previous map in Figure 17 shows the habitat types present on Muscatatuck NWR as described within the CCP. The acreages of these habitat types are listed in below in Table 5.

Table 5: Acreage of Habitat Types at Muscatatuck NWR

Habitat Type	Acreage
Wetlands	5,461
-Bottomland hardwood forest	4,180
-Moist soil units, green tree units, marshes, lakes, and ponds	1,260
-Ditches	21
Upland Hardwood Forest	1,210
Agriculture	267
Grassland	80
Reconverting farmland	700
Administrative	7

Wetlands

Wetlands cover 70 percent of the Refuge and much of this land floods annually. The majority of wetland habitat is bottomland hardwood forest (4,180 acres), and managed water units that include moist soil units, brood marshes, green tree impoundments, and Stanfield, Moss and Richart Lakes (approximately 1,260 acres), which were built 1979-1982 with Bicentennial Land Heritage Program (BHLP) funds (Table 6). The Refuge also has more than 70 other small ponds and wetland areas included in the 1,260 acres referenced above; these were constructed by former land owners to be stock ponds or ponds near residences and are utilized by migratory birds and wildlife.

Several seeps exist the Refuge, however, these areas will be treated as compartments within their associated forests. Forested wetlands will be treated as forest, except as they affect or are managed to effect moist soil and marsh management.

Examples of wildlife that use these wetlands include Wood Ducks and Hooded Mergansers, which nest in the bottomland hardwoods, American Bald Eagle, copperbelly watersnake, river otter and many other species from all faunal assemblages.

Table 6: Acreage of Wetland Management Units at Muscatatuck NWR

Unit Name	**Habitat Type**	**Acreage**
M1	Moist Soil Unit	22
M2	Moist Soil Unit/Marsh	20
M3	Moist Soil Unit/Marsh	17
M4	Moist Soil Unit	37
M5	Moist Soil Unit	13
M6	Moist Soil Unit	14
M7	Moist Soil Unit	52
M8	Moist Soil Unit/Green Tree Reservoir	64
M9	Moist Soil Unit	32
M10	Moist Soil Unit/Marsh	25
Sue Pond	Moist Soil Unit	13
McDonald North	Moist Soil Unit/Marsh	20
McDonald South	Moist Soil Unit/Marsh	12
Endicott North	Marsh	4
Endicott South	Marsh/Moist Soil Unit	8
Mini Marsh	Marsh/Moist Soil Unit	36
Richart Lake	Lake/Reservoir/Marsh/Moist Soil	76
Stanfield Lake	Lake/Marsh/Moist Soil	125
Moss Lake	Lake, Marsh, Moist Soil, Green Tree Reservoir	750-1000
G1	Green Tree Reservoir/Marsh	76
G2	Green Tree Reservoir	40
G3	Green Tree Reservoir (WCS removed)	92
G4	Green Tree Reservoir	32
F1	Bottomland/Floodplain Forest (Impounded)	4010
F3	Floodplain Forest (Natural influence of Vernon Fork of the Muscatatuck River)	1400
Judy Pond	Pond/Marsh	1
Lake Linda	Fishing Pond	6
Persimmon Ponds	Fishing Ponds	3
Sand Hill Ponds	Fishing Ponds	4
Lake Sheryl	Fishing Pond	2
Office pond	Fishing Pond	5
Other Ponds	Woodland Ponds/Marshes	?
Mutton Creek Ditch	Ditch	9
Storm Creek Ditch	Ditch	5
Sandy Branch Creek	Creek/Ditch	3

Moist Soil Units

Moist soil management generally consists of managing seasonally flooded impoundments to produce annual food crops for migrating waterbirds. The current goal of moist soil management on Muscatatuck is to produce food for migrating waterbirds in all units. The first step in this process identified units capable of sustaining moist soil plant production. Currently, M1 and M7 are the only units found to have full capabilities as moist soil units; these two units have nearly year round water supplies for flooding, irrigation, and have independent drainage. Units M2, M3, M4, M5, M6, M8, M9, M10 Sue pond, McDonald Marsh North, and MacDonald Marsh South all have partial management capabilities; obstructed drainages, the lack of an adequate water supply and/or irrigation capability, inability to conduct disturbances, or drainages dependent on other units were the primary determinants in their reduced capability designations. Most of the units with partial capabilities rely entirely on direct precipitation and/or flooding from adjacent creeks to refill in the fall or winter. Also, dead trees, live trees, cypress knees, stumps, buttonbush, and other woody vegetation are serious impediments to moist soil management in units M2, M3, M5, and M10.

Moist soil management requires soil disturbance to maintain the highly productive early successional stages. Delayed disking practices were enacted in the past with poor results which are partly due to drawdown timing the following spring and summer. However, annual plant production declined as disking occurred too late in the growing season (in September and October) and disturbance projects were left incomplete due to the wetter conditions of that time period. In order to manage the units effectively for most resources of concern, including the copperbelly watersnake, June through August disking is recommended as the preferred management alternative. This will promote annual plant production, allow time for seed development, and ensure disturbance projects are completed within the scheduled timeframe.

Topography, depth, duration, timing of flooding and drawdown are some of the most important variables in management of water on the Refuge. Many of the water management issues that are present today are a result of water being held too deep, too long, and at the wrong times in combination with a lack of topographical understanding. The Refuge relied for many years on guesswork and “eyeballing” to set water levels for management. This was combined with a false assertion that the stoplogs structures were designed such that the maximum level was “full for management purposes” and this would provide the maximum benefit/habitat for migrating waterbirds. However, this led to extremely deep water (i.e. greater than 3 feet) in most of the units and subsequent declines in overall productivity and waterbird use. Bathymetric modeling conducted from 2008-2010 helped guide management in recent years by allowing the Refuge to quantify

the amount of habitat available at suitable depths (0 to 10 inches) for feeding and to maximize the optimum habitat within units during peak migration.

Management tactics to reduce impediments to moist soil management were taken during 2008 to 2010. Willows, buttonbush, cottonwood, alder, and other undesirable plants were removed from M1, M4, parts of M5, M7, parts of M8, M9, and M10 from 2008 to 2010. These units were bush hogged and then disked to set the stage for annual plant production. Positive gains in moist soil plant production were realized in each successive year (Figure 18 and 19), culminating in nearly 70% of all moist soil unit acreage producing dense stands of beneficial plants in 2010. The stage for even better production is set for 2011.

Figure 18: Trends in Select Moist Soil Plants at Muscatatuck NWR: 2006-2010

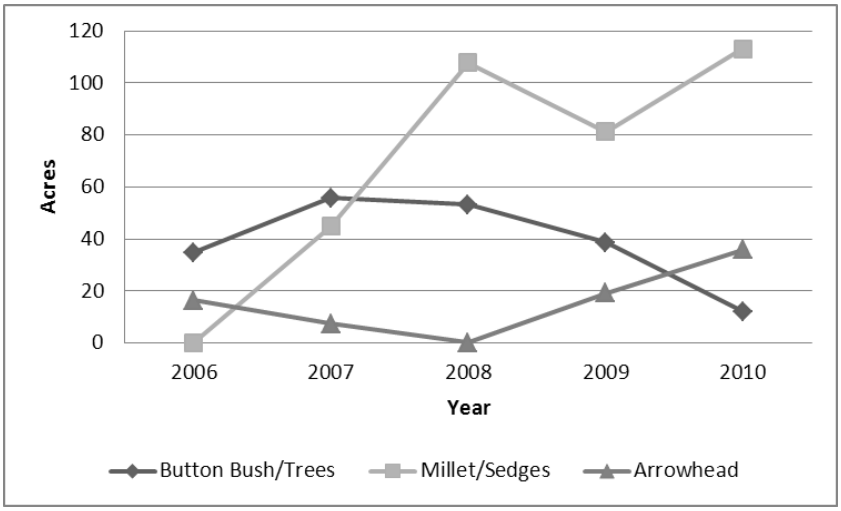
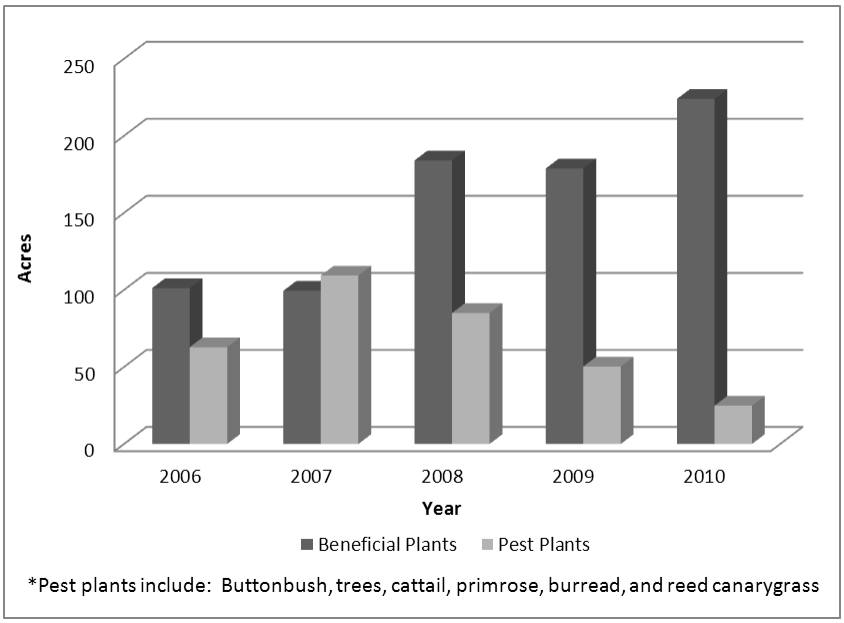


Figure 19: Five Year Comparison of Acreages of Beneficial and Non-Beneficial Moist Soil Plants



Vegetation within the moist soil units varies annually based on timing of drawdowns and reflooding, irrigation or precipitation availability and timing, temperature, successional stage, time since last disturbance, and several other factors. The graph in Figure 20 shows the most current vegetation in a majority of the Refuge moist soil units. Note that Endicott South is not considered a moist soil unit; however, the drawdown of the marsh in 2010 resulted in the production of millets and sedges on nearly 40% of the unit's acreage.

Marshes

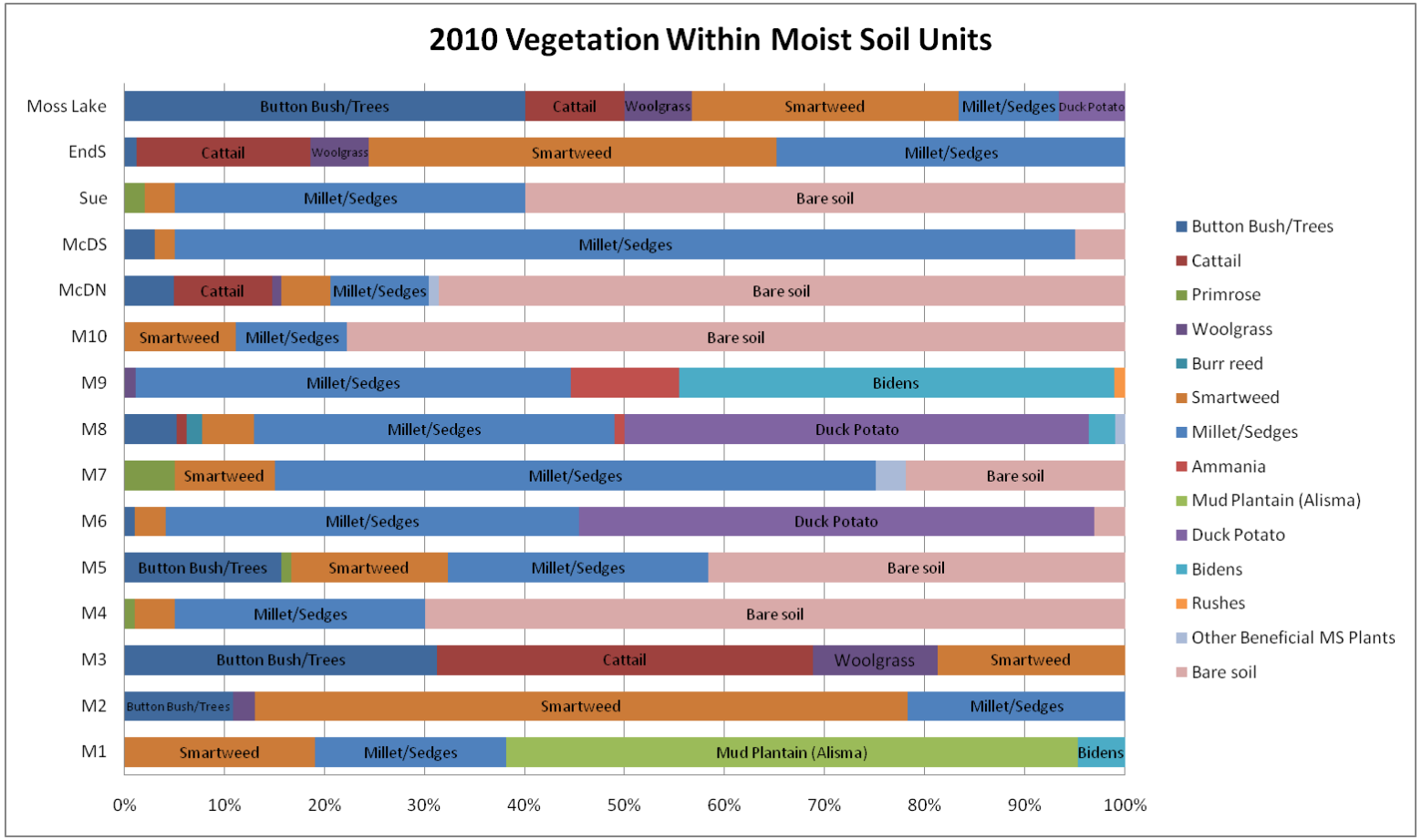
Marshes were created to manage for waterbirds by impounding water from creeks and ephemeral streams of the area. Historically, marshes were not a significant feature on the landscape at the Refuge, and management of man-made marshes has mirrored lake management strategies in the recent past. Water levels were held stable resulting in open water type habitats, the death of flooded timber, and areas dominated by undesirable plant species. However, each marsh has undergone one or more drawdowns between the years of 2009-2011 with water being removed gradually throughout the spring and summer months resulting in most cases in a dense stand of native millets, sedges, and other beneficial moist soil plants. Detailed drawdown and vegetation response information can be viewed in the annual water management plans from that time period. The only unit that is considered purely within the context of marsh management is Endicott North. Only portions of M2, M3, M10, McDonald North and South, Endicott South, Richart, Stanfield, can be managed as marsh habitat.

From 19xx to 2008 water levels were stabilized on McDonald North, McDonald South, Endicott South, M5, and M6 resulting in the dominance of water lilies within these units (Unpublished Refuge water level data). Dynamism inherent within these habitat types has been returned by fluctuating water levels throughout the year. Currently, growth of several desirable species (i.e. millets, sedges, and duck potato) has been increased within most of the units due to the recent drawdowns. Three of these units need further development, most notably McDonald North, Endicott North, and Mini Marsh. Limited vegetative development within the shallow portions of Richart and Stanfield indicate a further need for earlier partial drawdown on each of those lakes.

Green Tree Reservoirs

Green Tree Reservoirs (GTRs) on the Refuge have suffered dramatically as flooding durations were too long and drawdowns were conducted too late in the spring nearly every year since 1984 (Figure 21 and 22). The most significant period of flooding in G1 and G2 occurred from 2000 to 2007 when drawdowns were relatively non-existent. Duration of flooding and timing of drawdowns of these forested units has led to the loss

Figure 20: Current Vegetation Within Moist Soil Units at Muscatatuck NWR



of over 50% of the timber in G1, small portions of G2, G3, and G4 and contributed to the loss of much of the understory in G2, G3, and G4. These trends have been slowly reversing from 2008-2010 and understory development is progressing well within G2 and G3 but progress is not pronounced within G1 and G4. Monitoring of GTRs in 2010 revealed dense recolonization was occurring within the understory of G2 by ash, sycamore, and cottonwood. Regeneration of oaks was observed within G2, although it was extremely limited. G1 had some areas where regeneration of sycamore and ash was occurring but it was not as pronounced as what was observed in G2. The water control structure was removed from G3 in 2007 which has greatly aided in the protection of that unit; however, damages due to prolonged flooding related to the CR400 barrier are still evident. The southeastern portion of G3 and the central portion along the permanently wet slough have experienced some tree mortality and it appears that those dead zones are still increasing in size. Tree stress is evident within a large percentage of all units, mostly in the form of severely swollen trunks, stress cracks, and weeping.

Figure 21: Twenty-six Years of Water Levels in Green Tree Unit One

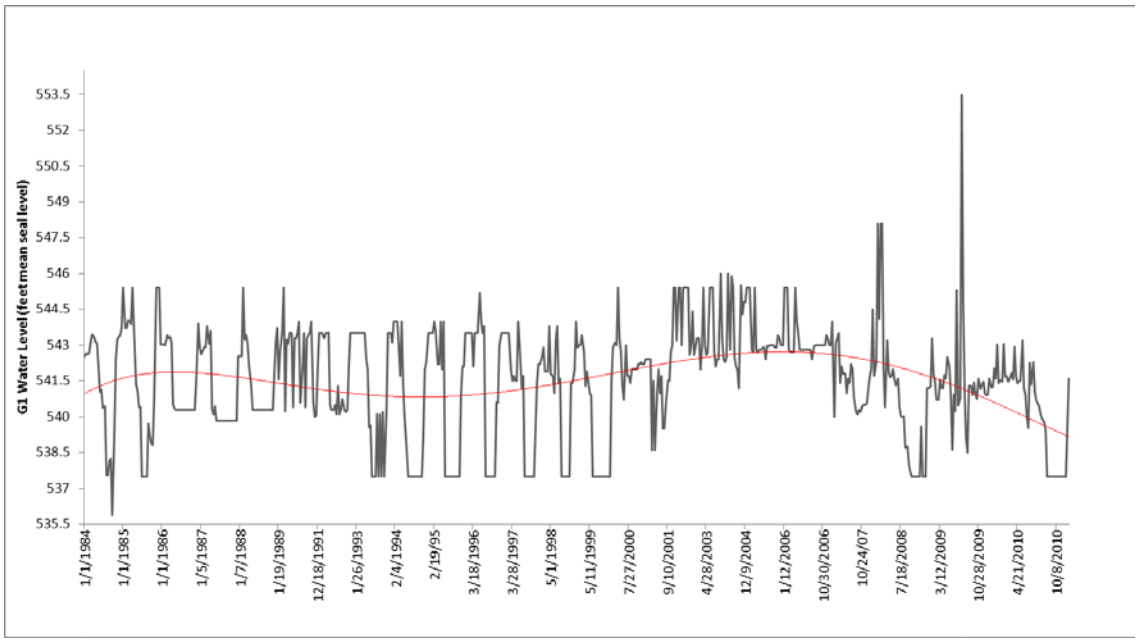
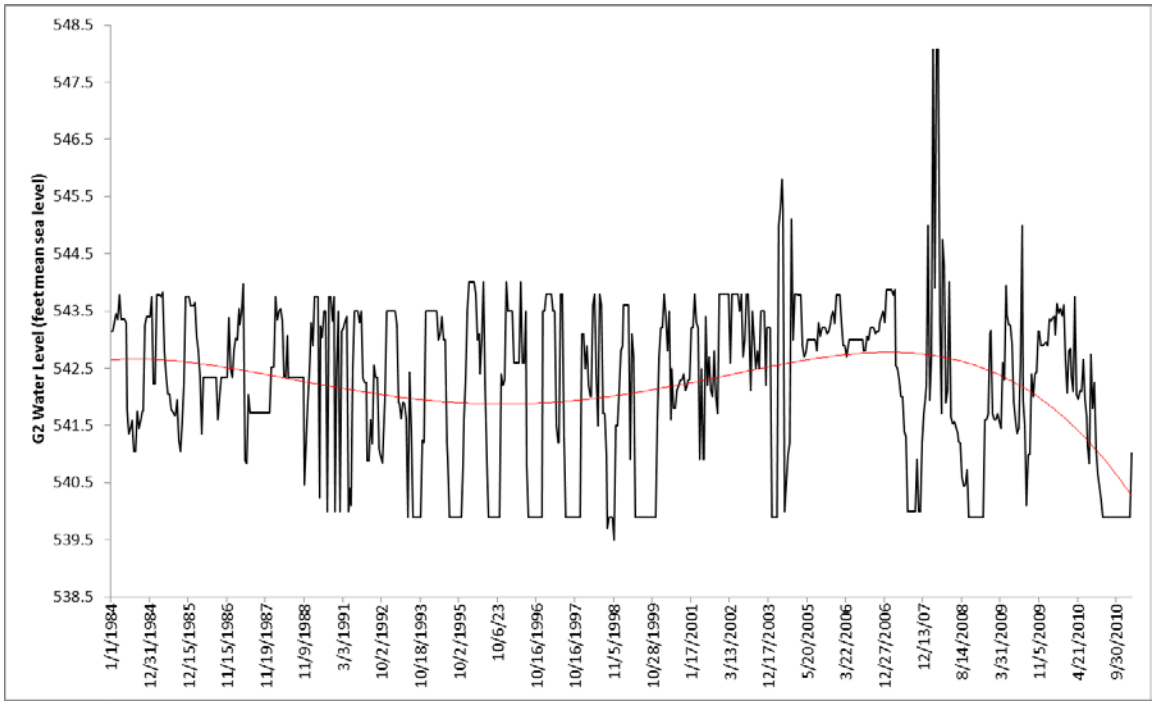


Figure 22: Twenty-six Years of Water Levels in Green Tree Unit Two



Active impoundment of the GTRs ceased in 2007 although the units still flood following significant rain events and Moss Lake still strongly influences G1. Since 2007, the GTRs have experienced natural fluctuations, responding to creek and river levels, with a more pulsing hydrology. The only exception is G2 which experienced a small period of prolonged flooding due to beaver activity that permanently plugged its culvert. That culvert and screw gate were removed in March of 2010 and replaced with an open 36" culvert which dramatically reduced the impacts of flooding.

Lakes/Reservoirs

Richart Lake serves mainly as a reservoir to provide water for flooding or irrigating the northern moist soil units. However, strategic drawdowns in the fall over the past several years have provided valuable foods for dabbling ducks. Water is removed usually from September through December and relatively low water levels (i.e. 554.0 ft. MSL) provide ample shallows and mudflats that are suitable feeding habitat for shorebirds and dabbling ducks. The eastern stretches of the unit contain an expanse of dead and downed timber and cattail marsh habitat. Several deep ditches run through the lake and provide relatively deep water habitat that is used by diving ducks and provide ample habitat for fish when water levels are dropped. Waterfowl use of the lake is strongly correlated to water levels

reductions.

Stanfield Lake currently serves mainly as a fishing lake, although, it was originally designed as a reservoir to provide water for flooding Moss Lake and the lower waterfowl units. Drawdowns of the lake have not occurred since the early 1990's. Prior to the mid-90's, based on historical water level data, it appears that the unit underwent partial drawdowns nearly every fall, in late November or early December. These discharges of water served the main purpose of flooding portions of Moss Lake. However, they also contributed to waterfowl objectives by providing shallow feeding habitat for waterbirds within the lake, often coinciding with peak migratory periods. The eastern stretch of the lake has areas of dead and downed timber and some areas of cattail marsh habitat. One small portion of the lake is occupied by American lotus. Several deep ditches and holes exist within the lake that provide ample habitat for fish when water levels are dropped.

Information gleaned from bathymetric investigations will allow for water levels to be optimized for waterbird use without jeopardizing the lakes' abilities to be used for their intended purposes as reservoirs. Besides waterfowl and shorebirds, the lakes are used extensively by river otter, wading birds, tree swallows, cormorants, bald eagle, beaver, muskrat, and also contain significant fisheries dominated by largemouth bass, crappie, bluegill, and redear sunfish.

Ponds/Oxbows/Vernal Pools/Ephemeral Wetlands

Over 70 man-made ponds exist on the Refuge and many are remnant stock ponds associated with homesteads prior to Refuge establishment. Additionally, several small wetlands were created within the first few years during Refuge development and acquisition. The ditching of Storm and Mutton Creeks, beaver activity, and the meandering nature of the Vernon Fork has left several oxbow areas across the landscape. These areas are usually strongly influenced by their respective streams and, have been found to be permanently wet or ephemeral. Vernal pools and ephemeral wetlands abound within the forested sections of the Refuge mostly receiving water from direct precipitation, runoff, or overflows from streams or the Vernon Fork.

Ditches/Creeks

Water levels within the creeks on the Refuge were not monitored prior to 2009. However, Moss Lake data can be used to give minimum elevations of Storm and Mutton Creeks. Elevational surveys were conducted in 2009 allowing benchmarks to be set; benchmarks were later validated the same year with a real time kinematic GPS. Monitoring of the creeks has led to a better understanding of the impediments within the creeks, and has directed Refuge staff to the location of beaver dams and log jams.

Beginning in 2007, beaver dams were aggressively removed throughout the ditch system. Over 130 beaver dams were removed from Storm, Mutton, and Sandy Branch Creeks from 2008 to 2010. As of 2010, beaver dams were no longer present within the portions of Storm Creek from Hwy 50 to the south dike of M6. However, several dams within the Moss Lake portion of Storm Creek continue to pose problems and are consistently removed (5 times in 2010). Mutton Creek has one beaver dam between Hwy 50 and CR400, and an extremely large log jam; these continue to impede water flow within the creek.

Rainfall in excess of half an inch caused overbank flows on each of the three ditches prior to 2008. This led to issues with flooding of forested areas adjacent to the creeks as half an inch rains occur relatively frequently during most of the year. Following reductions in the water levels within Moss Lake, which began in 2009, instant and substantial gains in absorption of runoff were observed by staff and adjacent landowners. Data from 2010 indicated that with Moss Lake at 537.84 ft. MSL (base level), approximately 3.5 to 4. 3 inches of rain could be contained without producing overbank flows during the summer and fall.

The ditches have all experienced some level of siltation; however, silt levels have not been adequately assessed. Anecdotal evidence suggests that the outflow elevation at the Moss Lake structure, which drains all three creeks, was set at an elevation that is 2 to 3 feet above the ditch system's flow line. Slow flows in combination with impediments from log jams and beaver dams have resulted in localized areas of extreme siltation throughout the ditch system. Over 90 log jams have been discovered within Storm and Mutton Creeks from Hwy 50 south to the Moss Lake structure.

Dikes and Levees

Dikes are considered to be infrastructure and not wildlife habitat, however, their maintenance and protection directly impact the Refuge's ability to maintain and manage other habitats and therefore they are included within this plan.

A total of over 9 miles and 45 acres of dikes and levees exist on Muscatatuck NWR. All are earthen construction and those on Endicott South, Richart, Stanfield, and Moss Lake are armored with rip rap. Fescue is the dominant vegetation found on dikes within the Refuge, although, many areas are covered with reed canary grass.

Significant efforts have been made to correct the hydrologic issues at Muscatatuck NWR. This has involved reducing water levels and correcting issues with culverts, structures, and cutting dikes. The southern dike on G2 was cut in early 2010 to allow excess waters

to flow out of G2 to the ditch/slough south of the unit that empties into the Vernon Fork. This has prevented G2 from impounding water, yet allows it to flood and drain with the natural fluctuations of the Muscatatuck River more closely mimicking the natural floodplain hydrology that would have historically occurred. The 2009 and 2010 water management plans indicate that cuts within the Moss lake dam/dike will be necessary to facilitate high water discharges and protect the bottomland forested areas on the Refuge.

Repair of dikes is an ongoing process. High water flows often overtop the levees of M2, M3, M4, M5, M7, M8, M9, and M10 causing substantial erosion. Muskrat burrow into many areas of dikes, causing further erosion and collapse in certain areas. Dikes on M2, M3, McDonald North, M8, and M9 are those most affected by muskrat and have many areas in need of reshaping. Work was done to reshape a portion of M8 in 2008, while M5, M6 and a portion of M9 in were reshaped in 2010.

Bottomland Hardwood Forests

Wetland forests on the Refuge can be grouped into three types including: bottomland forests, floodplain forests, and beech-maple flats. Bottomland forests, as described within the CCP, included all three of the wetland forest types outlined above and total 4,180 acres. The CCP describes that Bottomland hardwood forests are a type of cold deciduous forest that are temporarily or seasonally flooded and occur on wet soils and in floodplains. American beech and a variety of maple and oak species dominate bottomland forests and ash, sweet gum, river birch and sycamore are also present. It is important to consider each of these forest types independently due to the hydrologic influences that drive them. Historical discussions of these forested types are described previously on pages 40-44 and 46 of this plan.

The beech maple flats are truly an upland forest type, however, the presence of shallow hardpan clays within the upper horizons of the soil profiles cause shallow ponding of rainfall and runoff. This wetland forest type is natural and self-sustaining and is relatively healthy where found on the Refuge.

Floodplain forests on the Refuge are affected by flooding of the Vernon Fork of the Muscatatuck River. They are not surrounded by or influenced by constructed levees or dikes. These areas flood multiple times from natural flood pulses of the river. Flooding generally lasts between 2-3 days with a range of 1-7 days with most events. The floodplain forests are found in southern portion of the Refuge in HC4. These forests are functionally intact and relatively healthy.

The true bottomland forests on the Refuge are found within the birds silt loam soil series including the floodplain areas of Storm, Mutton, and Sandy Branch creeks, and also the

Muscatatuck Seep Spring Research Natural Area and Moss Lake. Approximately 25% of this forested type has converted to shrub/scrub, emergent marsh, or moist soil type habitat due to impacts of historic water level management, beaver activity, and road construction. Approximately 1,000 acres of bottomland forest has been negatively impacted and complete tree mortality has been realized on approximately 500 acres. It is expected that further losses will continue to be realized over the coming decades. Reduction of water levels within Moss Lake have significantly improved the situation and allowed regeneration to begin in several areas that have been impacted. Much of the remaining 75% of the bottomland forest would be put at risk if current water management direction is reversed and water levels are held deeper again.

Upland Hardwood Forests

Forests located in the upland areas are most frequently dominated by oak species. Oak forests comprise approximately 10 percent of the total area and represent intermediate successional stages. Species occurring in these forests include pin, white and red oak, hickory, sweet gum, sycamore, red maple and tulip poplar.

The remaining minor woodland types are tulip/maple, pin oak, willow/sycamore, beech/tulip, sweet gum, river birch, birch/gum, birch/maple and gum/oak. Woodland vegetation from 0 to 10 years old consists largely of river birch, sycamore, red maple, tulip poplar, sweet gum, and pin oak. Beech, white oak and tulip poplar dominate the woodland vegetation that is 35 to 100 years old. (FWS 2004)

Recreating Forests

Classification of areas as reconverting has not been uniformly applied and therefore a true estimate of acreage within this habitat type is unavailable. The Refuge has been converting farmlands into forest since its establishment, and in recent years has planted approximately 15-50 acres per year in the effort to reduce fragmentation and provide solid blocks of forested habitat. Therefore, recreating forests on the Refuge represent a wide range of forest situations from abandoned fields full of naturally seeded saplings, hardwood plantations (both bottomland and upland), natural regenerating thickets, to pole-sized forests. The diversity of these forest situations results in a diversity of needs for management of these areas.

Agricultural Land

Cooperative farming agreements provide direct economic benefits to individual farmers who supplement other income by farming acreage on the Refuge. The farmer provides labor, equipment and supplies, and is required to leave 25 percent of the crop for use by

the Refuge. In 2010, croplands accounted for 310 acres of the Refuge, a reduction from 4,100 acres in 1966. Agricultural acreage is farmed in a corn, soybean, wheat, hay rotation. Farming operations will be phased out completely within the near future and approximately 290 acres of existing farm fields will be maintained as grasslands for the benefit of nesting grassland birds, migrating sandhill cranes and the federally listed whooping crane, to benefit a wide array of migrant and resident species, and to provide wildlife viewing opportunities to the public.

Grassland

Mowing, haying, and burning were historically used as methods to manage the grasslands, and these methods may continue to be employed. Some grassland areas are still included within the crop and haying programs, however, this will likely end in the next couple of years.

Structural and compositional diversity is extremely poor within existing grasslands. Grass density is extremely high and native forbs have not competed well. Grasslands on the Refuge are primarily dominated by fescue, broom sedge, and goldenrod and this plant composition is a concern . Plant and animal diversity within the grasslands is low as is use by grassland birds. Woody encroachment is one of the primary concerns in management of the grasslands, and a return to prescribed burning and occasional mowing could alleviate this concern. The second concern is low native plant diversity, which is largely due to previous anthropogenic uses and a lack of disturbance (i.e. fire, rotational mowing, etc.) in the recent past.

Chapter 3: Resources of Concern

Introduction

The Service is entrusted by Congress to conserve and protect migratory birds and fish, federally listed threatened and endangered species, inter-jurisdictional fishes, and certain marine mammals. In addition to this Service mandate, each Refuge has one or more purposes for which it was established that guide its management goals and objectives. Further, Refuges support other elements of biological diversity including invertebrates, rare plants, unique natural communities, and ecological processes that contribute to biological diversity, integrity and environmental health at the Refuge, ecosystem, and broader scales (USFWS 1999, 2003).

Given the multitude of purposes, mandates, policies, regional, and national plans that can apply to a Refuge, there is a need to identify the resources of concern and then prioritize those resources that the Refuge is best suited to focus on in its management strategies. The following is the process that Muscatatuck NWR used to identify priority resources of concern and develop habitat goals, objectives, and strategies to benefit these resources.

The Habitat Management Plan policy (620 FW) defines

> "resources of concern" as "All plant and/or animal species, species groups, or communities specifically identified in Refuge purpose(s), System mission, or international, national, regional, State, or ecosystem conservation plans or acts. For example, waterfowl and shorebirds are a resource of concern on a Refuge whose purpose is to protect 'migrating waterfowl and shorebirds.' Federal or State threatened and endangered species on that same Refuge are also a resource of concern under terms of the respective endangered species acts."

Resources of Concern for Muscatatuck NWR

We developed a matrix of resources of concern for the Refuge (see tables 7 – 11). To determine the resources of concern that would guide the management priorities we examined a multitude of guiding documents, management plans, and other information sources. These documents, plans, or policies typically identify focal species, species groups, or habitats. These sources fall into three categories:

- Legal Mandates
- U.S. Fish and Wildlife Service Priority Species
- Biological Integrity, Diversity, and Environmental Health Policy ("Integrity Policy")

Legal Mandates

See pages 6-8 in Chapter 1 Introduction of this HMP and Appendix E of the CCP for a partial listing of legal mandates that are applicable.

U.S. Fish and Wildlife Service Priority Species

Although the Refuge purposes are the first obligation, managing for priority species is also an importance for the Refuge. Priority species are further defined as follows:

Migratory Birds

A list of all the species of migratory birds protected by the Migratory Bird Treaty Act (16 U.S.C. 703–711) and subject to the regulations on migratory birds are contained in subchapter B of title 50 CFR § 10.13 and can be accessed online by visiting http://www.fws.gov/migratorybirds/RegulationsPolicies/mbta/mbtandx.html. The Migratory Bird Management Program also maintains subsets of this list that provide priorities at the national, regional, and ecoregional (bird conservation region) scales.

The primary information resources that the Refuge used to identify potential migratory birds species of concern included:

- Bird Conservation Region (BCR) 24 documents
- Continental, Regional, and State Plans for landbirds, waterfowl, shorebirds, and marsh birds
- USFWS and Region 3 Birds of Conservation Concern Lists
- Federal Threatened and Endangered Species Lists
- Status and Trend Information from Refuge Bird Surveys
- Important Bird Area Criteria
- 2002 Region 3 Resources of Concern list

The purpose of the Refuge is to provide an inviolate sanctuary for migratory birds. U.S. Fish and Wildlife Service Region 3 priority migratory bird species on the Refuge are found in Table 7 on page 70. The complete listing of Region 3 Fish & Wildlife Resource Conservation Priorities can be viewed online at http://www.fws.gov/midwest/News/documents/priority.pdf

In addition to the R3 species, the Ohio River Valley Ecosystem (ORVE) migratory birds of management concern on the Refuge are: Yellow-billed Cuckoo, Great-crested Flycatcher, Yellow-throated Warbler, Eastern Wood Pewee, Wood Thrush, Scarlet Tanager, Hooded Warbler, Willow Flycatcher, and Sedge Wren (Mumford~~,~~ 1984; USFWS Birds of Conservation Concern~~,~~ 2002).

Threatened and Endangered Species
The Endangered Species Act (16 U.S.C. §§ 1531-1544, December 28, 1973, as amended 1976-1982, 1984 and 1988) states in Sec. 8A. (a) that:

> "*The Secretary of the Interior hereinafter in this section referred to as the 'Secretary' is designated as the Management Authority and the Scientific Authority for purposes of the Convention and the respective functions of each such Authority shall be carried out through the United States Fish and Wildlife Service."*

The Act also requires all Federal departments and agencies shall seek to conserve endangered species and threatened species and shall utilize their authorities in furtherance of the purposes of this Act.
Resources used to identify federally threatened or endangered species of relevance to Muscatatuck NWR included:

- Federal Threatened and Endangered Species List
- Recovery Plans for Federally listed species in our region

Biological Integrity, Diversity, and Environmental Health
The 1997 National Wildlife Refuge System Improvement Act states that in administering the System the Service shall *"… ensure that the biological integrity, diversity, and environmental health of the System are maintained…"* (601 FW 3; also known as the "Integrity Policy"). The USFWS (2003) defines these terms as:

Biological Diversity
The variety of life and its processes, including the variety of living organisms, the genetic differences between them, and the communities and ecosystems in which they occur.

Biological Integrity
Biotic composition, structure, and functioning at genetic, organism, and community levels comparable with historic conditions, including the natural biological processes that shape genomes, organisms, and communities.

Environmental Health
Composition, structure, and functioning of soil, water, air, and other abiotic features comparable with historic conditions, including the natural abiotic processes that shape the environment.

Where possible, management on the Refuge restores or mimics natural ecosystem processes or functions and thereby maintains biological diversity, integrity, and environmental health. Given the continually changing environmental conditions and landscape patterns of the past and present (e.g., rapid development, climate change, sea level rise), relying on natural processes is not always feasible nor always the best management strategy for conserving wildlife resources. Uncertainty about the future requires that the Refuge manage within a natural range of variability rather than emulating an arbitrary point in time. This maintains mechanisms that allow species, genetic strains, and natural communities to evolve with changing conditions, rather than necessarily trying to maintain stability.

As stated by Meretsky et al. (2006), the Integrity Policy directs Refuges to assess their importance across landscape scales and to "forge solutions to problems arising outside Refuge boundaries." Some of these regional land use problems include habitat fragmentation/lack of connectivity, high levels of contaminants, and incompatible development or recreational activities.

Resources used to assess the historical condition, site capability, current regional landscape conditions, and biological diversity and environmental health data pertinent to Muscatatuck NWR included:

- Maps and associated data on site capability
- Soils, topography, and hydrology
- History of natural disturbance patterns
- Map of current landscape condition showing conserved lands network, connectivity, land use patterns, and management/ownership trends surrounding the Refuge
- Maps of existing vegetation on the Refuge
- Regional/Global environmental trends
- Climate Change
- Air and water quality
- Indiana Natural Areas Program information on rare plants and animals and significant ecological communities
- Indiana State Comprehensive Wildlife Conservation Strategy
- Status and Trend Information from Refuge surveys and other research and staff knowledge

Summary Tables

The following tables are based on the information compiled and analyzed in this section as described previously.

Table 7: Comprehensive List of Resources of Concern for Muscatatuck NWR

Species*	Seasons on Refuge[1]	Federal T&E[2]	Indiana T&E[3]	IN Comprehensive Wildlife Conservation Strategy Priorities[4]	USFW Region 3 Resource Conservation Priorities[5]	BCR 24[6]	Partners in Flight[7]	Shorebird Plan- Upper Mississippi Valley/Great Lakes Region[8]	Waterbird Plan[9]	Waterfowl Plan[10]
Bird										
American Bittern (*Botaurus lentiginosus*)	Sp-O, F-O		E	X	X				X	
Least Bittern* (*Ixobrychus exilis)*	Sp-O, S-O, F-O		E	X	X				X	
Black-crowned Night-Heron* (*Nycticorax nycticorax)*	Sp-U, S-U, F-U		E	X					X	
Yellow-crowned Night-Heron* *(Nyctanassa violacea)*	Sp-R, S-R, F-R		E	X					X	
Great Egret *(Ardea alba)*	Sp-U, S-U, F-U		SC	X					X	
Common Loon (*Gavia immer)*	Sp-O, S-R, F-O, W-O								X	
Double Crested Cormorant (*Phalacrocorax auritus*)	Sp-C, S-O, F-C, W-R				X				X	
Snow Goose (*Chen caerulescens*)	W-R				X					X
Canada Goose – Resident* (*Branta canadensis*)	Sp-A, S-A, F-A, W-A									
Canada Goose – Migrant Populations	Sp-A, S-A, F-A, W-A				X					X

(*Branta canadensis*)										
Trumpeter Swan (*Cygnus buccinator*)	W-R		E	X	X					X
Wood Duck* (*Aix sponsa*)	Sp-A, S-A, F-A, W-C				X					X
American Black Duck (*Anas rubripes*)	Sp-C, S-R, F-C, W-U				X					X
Mallard* (*Anas platyrhynchos*)	Sp-A, S-C, F-A, W- A				X					X
Blue-winged Teal* (*Anas discors*)	Sp-C, S-U, F-C, W-O				X					X
Northern Pintail (*Anas acuta*)	Sp-U, F-U, W-R									X
Canvasback (*Aythya valisineria*)	Sp-O, F-O, W-R				X					X
Lesser Scaup (*Aythya affinis*)	Sp-C, F-C, W-U									X
Mississippi Kite *(Ictinia mississippiensis)*	Sp-R, S-R, F-R`		SC	X						
Bald Eagle* (*Haliaeetus leucocephalus*)	Sp-O, F-O, W-O	T	SC	X	X	X				
Osprey *(Pandion haliaetus)*	Sp-U, F-U		E	X						
Northern Harrier* (*Circus cyaneus*)	Sp-U, S-R, F-U, W-C		E	X						
Northern Goshawk (*Accipiter gentilis*)	Sp-U, F-U, W-U				SC					
Red-shouldered Hawk* (*Buteo lineatus*)	Sp-C, S-C, F-C, W-C		SC	X	X					
Sharp-shinned Hawk *(Accipiter striatus)*	Sp-U, S-O, F-U, W-U		SC	X						
Broad-winged Hawk *(Buteo platypterus)*	Sp-O, F-O		SC	X						
Peregrine Falcon (*Falco peregrinus anatum*)	Sp-U, F-U		E	X	X	X				
Yellow Rail (*Coturnicops noveboracensis*)	Sp-R, F-R				X				X	
King Rail* (*Rallus elegans*)	Sp-O, S-R, F-R		E	X					X	
Virginia Rail* *(Rallus limicola)*	Sp-U,S-O, F-U		E	X					X	
Common Moorhen*	Sp-O, S-O,		E	X					X	

(*Gallinula chloropus*)	F-O									
Whooping Crane – Eastern Population (*Grus americana*)	W-R	E	E	X					X	
Sandhill Crane *(Grus canadensis)*	Sp-U, S-R, F-U, W-U		SC	X					X	
Greater Yellowlegs (*Tringa flavipes*)	Sp-C, S-C, F-C		SC					X		
Solitary Sandpiper *(Tringa solitaria)*	Sp-C, S-C, F-C		SC			X		X		
Upland Sandpiper (*Bartramia longicauda*)	Sp-R, S-R, F-R		E	X				X		
Stilt Sandpiper (*Calidris himantopus*)	Sp-U, S-U, F-U							X		
Ruddy Turnstone *(Arenaria interpres)*	Sp-R, S-R, F-R		SC					X		
Short-billed Dowitcher (*Limnodromus griseus*)	Sp-U, S-O, F-O		SC					X		
American Woodcock* (*Scolopax minor*)	Sp-C, S-U, F-U, W-O				X			X		
Wilson's Phalarope (*Phalaropus tricolor*)	Sp-U, S-U, F-U		SC					X		
Common Tern - Great Lakes Population (*Sterna hirundo*)	Sp-O, F-O				SC				X	
Forster's Tern (*Sterna forsteri*)	Sp-O, F-O								X	
Interior Least Tern - Interior Population (*Sterna antillarum*)	Sp-R, F-R	E	E	X	X				X	
Black Tern (*Chlidonias niger*)	Sp-R, F-R		E	X	SC				X	
Barn Owl (*Tyto alba*)	Sp-R, S-R, F-R, W-R		E	X						
Short-eared Owl (*Asio flammeus*)	Sp-O, F-O, W-O		E	X		X				
Common Nighthawk* *(Chordeiles minor)*	Sp-U, S-A, F-U		SC	X						
Whip-poor-will* (*Caprimulgus vociferus*)	Sp-R, S-U, F-R		SC	X		X	X			
Red-headed	Sp-C, S-C,					X				

Woodpecker* (*Melanerpes erythrocephalus*)	F-C, W-C									
Loggerhead Shrike (*Lanius ludovicianus*)	Sp-R, S-R, F-R, W-R		E	X	SC	X				
Bell's Vireo* (*Vireo bellii*)	Sp-R, S-R					X				
Bewick's Wren* (*Thryomanes bewickii*)	Sp-R, S-R, F-R						X			
Marsh Wren *(Cistothorus palustris)*	Sp-U, S-R, F-U		E	X						
Sedge Wren* (*Cistothorus platensis*)	Sp-C, S-C, F-C		E	X	X	X				
Wood Thrush* (*Hylocichla mustelina*)	Sp-C, S-C, F-C				X	X				
Blue-winged Warbler* (*Vermivora pinus*)	Sp-C, S-C, F-C					X	X			
Golden-winged Warbler (*Vermivora chrysoptera*)	Sp-R, F-R		E	X	X					
Black-and-white Warbler *(Mniotilta varia)*	SP-C, F-C		SC	X						
Prairie Warbler* (*Dendroica discolor*)	Sp-C, S-C, F-U					X	X			
Cerulean Warbler (*Dendroica cerulea*)	Sp-U, S-U, F-U		E	X	SC	X	X			
Worm-eating Warbler* (*Helmitheros vermivorus*)	Sp-O, S-O, F-O		SC	X		X	X			
Louisiana Waterthrush* (*Seiurus motacilla*)	Sp-U, S-U, F-U						X			
Kentucky Warbler* (*Oporornis formosus*)	Sp-C, S-C, F-C					X				
Hooded Warbler* *(Wilsonia citrine)*	Sp-O, S-O, F-O		SC	X						
Grasshopper Sparrow* (*Ammodramus savannarum*)	Sp-O, S-O, F-O				X					
Henslow's Sparrow*	Sp-O, S-O,		E	X	SC	X	X			

(*Ammodramus henslowii*)	F-R									
Le Conte's Sparrow (*Ammodramus leconteii*)	Sp-R, F-R					X				
Dickcissel* (*Spiza americana*)	Sp-R, S-R, F-R				X		X			
Bobolink (*Dolichonyx oryzivorus*)	Sp-O, F-R				X					
Eastern Meadowlark* (*Sturnella magna*)	Sp-A, S-A, F-A, W-U				X					
Rusty Blackbird (*Euphagus carolinus*)	Sp-U, F-U, W-U					X				
Mammals										
Indiana Bat (*Myotis sodalist*)	Sp, S, F	E	E	X	X					
Evening Bat (*Nycticeius humeralis*)	Sp, S, F		E	X						
Gray Myotis *(Myotis grisescens)*	Not Confirmed	E	E	X	X					
Southeastern Myotis *(Myotis austroriparius)*	Sp, S, F		SC	X						
Little Brown Myotis *(Myotis lucifugus)*	Sp, S, F		SC	X						
Northern Myotis *(Myotis septentrionalis)*	Sp, S, F		SC	X						
Eastern Pipistrelle *(Perimyotis subflavus)*	Sp, S, F		SC	X						
Silver-haired Bat *(Lasionycteris noctivagans)*	Sp, S, F		SC	X						
Red Bat *(Lasiurus borealis)*	Sp, S, F		SC	X						
Hoary Bat *(Lasiurus cinereus)*	Sp, S, F		SC	X						
Northern River Otter (*Lutra canadensis*)	Year round		SC	X						
Least Weasel *(Mustela nivalis)*	Year round		SC	X						
Reptiles										
Copperbelly Watersnake - Southern population (*Nerodia*	Year round		E	X	X					

erythrogaster neglecta)										
Kirtland's Snake (*Clonophis kirtlandii*)	Year round		E	X						
Rough Green Snake (*Opheodrys aestivus*)	Year round		SC	X						
Eastern Box Turtle *(Terrapene carolina)*	Year round		SC							
Amphibian										
Four-toed Salamander (*Hemidactylium scutatum*)	Year round		E	X						
Fish										
Eastern Sand Darter (*Ammocrypta pellucida*)	Year round				SC					
Mussels										
Threeridge (*Amblema plicata*)	Year round				X					
Washboard (*Megalonaias nervosa*)	Year round				X					
Pimpleback (*Quadrula pustulosa pustulosa*)	Year round			X	X					
Pistolgrip (*Tritogonia verrucosa*)	Year round				X					
Little Spectaclecase (*Villosa lienosa*)	Year round		SC	X						
Asiatic Clam (*Corbicula fluminea*)	Year round				X					
Insect										
Beaverpond Baskettail (*Epitheca canis)*	Confirmed		E							
Vascular Plants										
Golden Seal (*Hydrastis canadensis*)	Confirmed		WL							
Climbing Hempweed (*Mikania scandens*)	Confirmed		E							
American Ginseng (*Panax quinquefolius*)	Confirmed		WL							
Southern Rein Orchid (*Plantanthera flava var. flava*)	Confirmed		E							

Bog Bluegrass (*Poa paludigena*)	Confirmed		WL							

* Denotes species nesting on Refuge

1. Seasons on the Refuge: Sp=Spring (March-May), S=Summer (June-July), F=Fall (August-November), W=Winter (December-February) A=Abundant, C=Common, U=Uncommon, O=Occasional, R=Rare, Blank=Resident Existence

2. Federal T&E = Federal Endangered Species List: T=Threatened, E=Endangered, C=Candidate

3. State T&E= State of Indiana Threatened and Endangered Species List: T=Threatened, E=Endangered, SC= Special Concern, WL=Watch List, CR=Candidate rare, PE=Proposed endangered, PT=Proposed threatened

4. Indiana Comprehensive Wildlife Conservation Strategy
http://www.in.gov/dnr/fishwild/files/CWS_MANUSCRIPT.pdf , X=Species of greatest conservation concern

5. US Fish & Wildlife Resource Conservation Priorities Region 3, September 1999. SC=Species of Concern X=Species of greatest conservation concern

6. US Fish & Wildlife Birds of Conservation Concern 2008 X=Species of greatest conservation concern

7. Partners in Flight Landbird Priority birds (Dettmers and Rosenberg 2003).
http://www.partnersinflight.org/bcps/pl_14sum.htm X=Species of greatest conservation concern

8. Upper Mississippi Valley/Great Lakes Regional Shorebird Conservation Plan (Szalay et al. 2000). X=Species of greatest conservation concern

9. Upper Mississippi Valley/Great Lakes Waterbird Conservation Plan March 2010 X=Species of greatest conservation concern

10. North American Waterfowl Management Plan: Upper Mississippi River/Great Lakes Region Waterfowl Implementation Plan 1998. Priorities: X=Species of greatest conservation concern

Table 8: High and Moderate Priority Habitats and Associated Focal Species

Highest Priority Habitat Types	**Associated Focal Species**
Muscatatuck Seep Spring Research Natural Area	Four-toed Salamander, Copperbelly Watersnake, Worm-eating Warbler, Bog Bluegrass, Southern Rein Orchid
Bottomlands/Floodplains/Green Tree Reservoirs	Dabbling Ducks, Wood Duck, Woodcock, Indiana bat, Copperbelly Watersnake, Four-toed Salamander
Ditches/Creeks	Dabbling Ducks, Wood Duck, Copperbelly Watersnake
Emergent Marshes	Dabbling Ducks, Diving Ducks, Shorebirds, , Least Bittern, Wood Duck, King Rail, Copperbelly Watersnake, Four-toed Salamander
Moist Soil Units	Dabbling Ducks, Diving Ducks, Shorebirds, Least Bittern, Wood Duck, King Rail, Whooping Cranes, Sandhill Cranes, Copperbelly Watersnake,

	Four-toed Salamander
Riparian Forests	Indiana Bat, Whip-poor-will, Four-toed Salamander
Moderate Priority Habitat Types	**Associated Focal Species**
Grasslands	Whooping Cranes, Sandhill Cranes, Peregrine Falcon, Short-eared owl, Henslow's Sparrow
Recreated Forests	Woodcock, Red-shouldered Hawk, Worm-eating Warbler
Reservoirs/Lakes	Diving Ducks, Shorebirds, Interior Least Tern, Wood Duck, Bald Eagle, Whooping Cranes, Sandhill Cranes, Copperbelly Watersnake
Scrub/Shrub	Short-eared Owl, Red-shouldered Hawk, Loggerhead Shrike
Upland Forest	Whip-poor-will, Red-shouldered Hawk, Cerulean Warbler
Wetland Edges	Interior Least Tern, Least Bittern, King Rail, Whooping Cranes, Sandhill Cranes, Copperbelly Watersnake, Sedge Wren

Table 9: High and Moderate Priority Focal Species and Their Associations

Highest Priority Focal Species	**Associated Species**
Mallard	Snow Goose, Canada Goose, White-fronted Goose, Black Duck, Mallard, Blue-winged Teal, Green-wing Teal, Cinnamon Teal, American Widgeon, Northern Shoveler, Northern Pintail, Redhead, Canvasback, White-faced Ibis, Glossy Ibis, Trumpeter Swan Tundra Swan, American Coot
Ring-neck Duck	Lesser Scaup, Oldsquaw, Bufflehead, Common Goldeneye, Hooded Merganser, Common Merganser, Red-breasted Merganser, Ruddy Duck, Franklin's Gull, Herring Gull, Ring-billed Gull, Bonaparte's Gull, Caspian Tern, Tree Swallow, Belted Kingfisher, Grebes, Fish Crows, Black Scoter, White-winged Scoter, Surf Scoter, Common Loon
Greater Yellowlegs	Solitary Sandpiper, Upland Sandpiper, Stilt Sandpiper, Pectoral Sandpiper, Ruddy Turnstone, Short-billed Dowitcher, Long-billed Dowitcher, Wilson's Phalarope, Common Snipe, Dunlins, Willets, Lesser Yellowlegs, Killdeer, Black-bellied Plover, Semipalmated Plover
Marsh Birds	King Rail, Sora Rail, Virginia Rail, Yellow Rail, Common Moorhen

Wood Ducks	River Otter
Whooping Crane	Great Egret , Great-blue Heron, Marshbirds
Sandhill Crane	Great-blue Heron
Indiana Bat	Evening Bat, Southern Myotis, Little Brown Myotis, Northern Myotis, Eastern Pipistrelle, Silver-haired Bat, Hoary Bat
Copperbelly Watersnake	Banded Watersnake, Kirtland's Snake, Rough Green Snake, Eastern Box Turtle
Moderate Priority Focal Species	**Associated Species**
Least Bittern	Green Heron, Black-crowned Heron, Yellow-crowned Heron, American Bittern
Bald Eagle	Osprey
Whip-poor-will	Common Nighthawk
Woodcock	Ruffed Grouse
Northern Harrier	Rough-legged Hawk, Golden Eagle
Red-shouldered Hawk	Goshawk, Sharp-shinned Hawk, Broad-winged Hawk, Barn Owl, Cooper's Hawk, Red-tailed Hawk, Least Weasel
Cerulean Warbler	Kentucky Warbler, Hooded Warbler
Loggerhead Shrike	Blue-winged Warbler, Bell's Vireo,
Worm-eating Warbler	Woodthrush, Prairie Warbler, Black-White Warbler, Bewick's Wren
Henslow's Sparrow	Grasshopper Sparrow, Dicksissel, Bobolink, Eastern Meadowlark, Red Bat
Sedge Wren	Marsh Wren
Four-toed Salamander	Unknown

Table 10: Habitats and Needs of High Priority Focal Species

Focal Species	Habitat	Special Habitat Requirements	Limiting Factors
Mallard	Bottomlands/Floodplains/Green Tree Reservoirs, Ditches/Creeks, Emergent Marshes, Moist Soil Units	Up to 10 in. depth for 75% of area, 11 in. depth or greater for 25% of area	Water level held Sept.-April through controlled flooding.
Ring Neck Duck	Reservoirs/Lakes, Moist Soil Units	Water depth more than 3 ft.	Prey abundance
Greater Yellowlegs	Reservoirs/Lakes, Emergent Marshes, Moist Soil Units	Shallow water, 8 in. depth or less, with mud flats	Undisturbed resting and feeding areas

Wood Ducks	Bottomlands/Floodplains/Green Tree Reservoirs, Ditches/Creeks, Emergent Marshes, Moist Soil Units, Reservoirs/Lakes	Wetland habitat with 50% to 75% of cover	Less than 10 in. water depth preferred for foraging
Whooping Crane	Moist Soil Units, Reservoirs/Lakes, Wetland Edges	Water depths of less than 2 ft.	Palustrine wetlands with unobstructed visibility
Sandhill Crane	Moist Soil Units, Reservoirs/Lakes, Wetland Edges	Water depths of less than 2 ft.	Palustrine wetlands with unobstructed visibility
Indiana Bat	Riparian Forests	Large trees with flaky or peeling bark, 10 in. DBH or greater	Undisturbed habitat
Copperbelly Watersnake	Acid Seep Springs, Bottomlands/Floodplains/Green Tree Reservoirs, Ditches/Creeks, Emergent Marshes, Moist Soil Units, Reservoirs/Lakes, Wetland Edges	Shallow wetlands with adjacent upland woods for winter hibernation	Undisturbed habitat

H* Research indicates that Copperbelly Watersnakes require many hundreds of hectares, of contiguous habitat in order to persist.
NR=No Restrictions, habitat sizes vary

Table 11: Habitats and Needs of Moderate Priority Focal Species

Focal Species	**Habitat**	**Special Habitat Requirements**	**Limiting Factors**
Least Bittern	Emergent Marshes, Moist Soil Units, Wetland Edges	Dense marshes and wetlands	Need dense cattails, reeds, rushes, and woody vegetation
Bald Eagle	Reservoirs/Lakes	Large bodies of open water	Tall trees, or cliffs for nesting
Peregrine Falcon	Grasslands	Cliff face over 200 ft. high for nesting	Undisturbed habitat
Whip-poor-will	Riparian Forests, Upland Forest	Deciduous or mixed forests	Even aged successional

		adjacent to large clearing	habitat, well-spaced trees, and low canopy
Woodcock	Bottomlands/Floodplains/Green Tree Reservoirs, Reconverting Forests	Early successional hardwoods, dense brushland	Well drained loam soils moisture content 15-80% with high pH and nitrogen
King Rail	Moist Soil Units, Wetland Edges	Short emergent vegetation, woody vegetation, shallow water	Deeper water for nesting, very dense vegetated areas
Red-shouldered Hawk	Bottomland Forest, Scrub/Shrub, Upland Forest	Natural openings for feeding	Mature forests along wetlands for nesting
Cerulean Warbler	Upland Forest	Large mature forested landscape	Oak, hickory, and maple most preferred
Loggerhead Shrike	Scrub/Shrub	Grasslands with interspersed trees and shrubs	Short grasslands for maximum foraging
Worm-eating Warbler	Acid Seep Springs, Reconverting Forests	Deciduous forest, damp ravines,	Dense undergrowth
Henslow's Sparrow	Grasslands	Well-developed litter, low woody stem densities	High percent of grass cover with scattered forbs
Sedge Wren	Wetland Edges	Dense sedge patches around wetlands	Little standing water, prefer damp ground
Four-toed Salamander	Acid Seep Springs, Bottomlands/Floodplains/Green Tree Reservoirs, Emergent Marshes, Riparian Forests, Moist Soil Units	Hardwood or coniferous forests with adjoining wetlands	Hummocks of grasses, sedges, or wet mosses for breeding (sphagnum moss)

NR=Species do NOT have a restrictive habitat size, habitat sizes vary greatly

Significant Ecological Communities and Rare Plants

Muscatatuck Seep Spring Research Natural Area

The Muscatatuck Seep Spring Research Natural Area (MSS-RNA) occupies a 97-acre portion of the Refuge. It is considered a rare community in the state of Indiana and is one of only seven acid seep springs documented in Indiana. The cold, acidic groundwater yields a unique assemblage of plant species. Many of the plants that occur here are restricted to these exact environmental conditions. This community is also ranked G3 (Globally Rare) in the Natural Heritage system, an international database of biological and conservation sites coordinated by the Nature Conservancy. Examples of state-listed plant species found here are: American ginseng, club spur orchid, bog bluegrass, Walter's St. Johns wort, and smooth white violet. Also found here are the state-listed endangered four-toed salamander and copperbelly watersnake. Suspected in the area, yet not verified, is the eastern crowned snake (*Tantilla coronata;* Meretsky, 2001).

Management decisions regarding habitat protection in the MSS-RNA focus on water levels and the impacts of flooding on the area. Periodic flood waters from Mutton Creek drainage, aided by the dam effect caused by maintenance roads are believed to contribute negatively to the pH and MSS-RNA habitat and related species. Currently, the most significant negative impacts to the area are believed to be from Moss Lake water level management and beaver dams within Mutton Creek. Maintenance of the forest habitat found on the ridge portion of the MSS-RNA is most likely important to the health of the area. (IDNR, 1990)

Starting in 2008, efforts began to reduce the influence of Mutton Creek on the Seep. The dike at the south end of the MSS-RNA was cut in 2009 to allow faster release of flood waters from the creek and from runoff events. Moss Lake water levels were reduced in 2009 and full drawdown occurred in 2010. The reduction in water levels combined with the removal of beaver dams from within Moss Lake and Mutton Creek allowed the area to be completely drawn down in 2010 for the first time probably since 1985.

Rare plants

In the summer of 2008 a rare plant survey/mapping project was undertaken by Volunteer botanist Daniel Boone, Wildlife Biologist Wood, and biological interns. During the course of surveying, volunteers revisited and recorded known locations of rare plants on the Refuge and searched for new ones. Invasive species were monitored in seven specific locations and their surroundings, and surveys of the Muscatatuck Seep Spring Research Natural Area revealed three species of *Poa* including *Poa paludigena* (bog bluegrass). Southern rein orchid (*Platanthera flava var. flava*) and flowering populations of *Panax*

quinquefolia (ginseng) were also located within the Seep Springs Area. The State endangered climbing hempvine (*Mikania scandens*) was found thriving with several hundred plants occuring in two distinct locations, and other plants of interest encountered during the survey were aquatic milkweed (*Asclepias perennis*), puttyroot orchid (*Aplectrum hyemale*), and nodding pogonia (*Triphora trianthophora*).

A very invasive blackberry species, Armenian blackberry (*Rubus armeniacus*), was discovered during the course of these surveys and volunteers treated several patches. White poplar and oriental bittersweet were found and their locations mapped. Several large patches of garlic mustard (*Alliaria petiolata*) were located just west of the Muscatatuck Seep Spring Research Natural Area Seep Springs Area; the garlic mustard patches were mapped, and mechanically treated by volunteers.

Orchids

Brian Lowry, a volunteer botanist, has monitored rare orchids in the Muscatatuck Seep Spring Research Natural Area and at the Endicott Marsh location for over a decade. On his most recent survey in 2008 he documented 40 club-spur orchids (*Platanthera clavellata*), many of which were in bloom, and 8 vegetative plants of southern rein orchid (*Platanthera flava var. flava*) in the seep spring. At Endicott, 21 southern rein orchids were observed with one in bloom. The southern rein orchid population at Endicott has been stable at 20-25 plants while the seep springs population has fluctuated from 5 to 50 plants over the last twelve years. The club-spur orchids have been a stable population of about 40 plants in the past several years.

Wildlife

Birds

More than 279 bird species have been reported on the Refuge and 120 of those are considered nesting species. A rich diversity of waterfowl, raptors, and songbirds are commonly observed on the Refuge. Wood Duck broods are common sightings in the spring and summer months. Waterfowl use days during the winter and spring migrations number in the hundreds of thousands. A Bald Eagle nest has been active since 2002 and winter migrants are commonly seen. Muscatatuck NWR is also known for the spring and summer migration of songbirds, especially warblers, in May. The Refuge was designated a Continentally Important Bird Area in June 1998. The designation was based on Christmas Bird Count data and the Refuge's wintering numbers of Canada Geese from the James Bay population. A complete list of bird species and a general guide to their seasonal occurrence and status on the Refuge can be found in the CCP in Appendix C.

Waterbirds

The overarching goal of Refuge water and moist soil management will be to continue provide and increase, to the extent possible, optimal feeding and resting habitat for all of the major waterbird guilds (waterfowl, wading birds, marshbirds, shorebirds). This can be accomplished through reducing water levels and increasing moist soil plant production and consequently increasing waterbird abundance and retention.

Waterfowl

Waterfowl have many specific requirements during migration and winter. Surface water in the form of rivers, lakes, oxbows, flooded forests, beaver wetlands, and managed impoundments is critical to the survival of this group of birds. The temporal and spatial distribution of these habitats must correspond with the migration chronologies of migratory species and meet the year-round needs of resident species. In addition, breeding, loafing, and feeding habitats are equally important. Waterfowl need an area where they can find adequate food resources to restore energy and fat reserves lost during migratory flights.

Bottomland hardwood forests are critical to migratory and wintering waterfowl. These forests should provide food resources in the form of mast produced primarily by red oak, white oak, and pin oak. However maple, ash, and elm are also valuable to waterfowl and resident species in late winter when other masts are scarce (Fredrickson and Reid 1988; Heitmeyer 2001). Invertebrates can be extremely abundant in these habitats, and they provide an invaluable food source to waterfowl (Wayne and Krull 1973; Taylor et. al 1990). Forested wetlands also provide thermal, loafing, and escape cover for waterfowl (1990). Bottomland hardwood areas should seasonally flood to provide adequate habitat for waterfowl.

Moist soil wetlands historically occurred where openings existed in bottomland hardwoods. Forest openings were often caused by high winds, catastrophic floods, beaver, fire, and other causes (Waterfowl Handbook 2001). Early successional moist soil wetlands are critical to many species of wildlife, especially waterfowl. For example, smartweeds, millets, and other natural food producing plants provide a wide array of components necessary to ensure that the basic nutritional needs of waterfowl are fulfilled. These plants occur in abundance where some type of disturbance such as flood events or human actions manipulate wetland soils and interrupt plant succession. Waterfowl feed on seeds, invertebrates, and herbaceous matter in these shallow flooded habitats. Moist soil wetlands also provide thermal, loafing, and escape cover.

Shrub/scrub wetlands are typified by willows, buttonbush, other woody species, and

perennial herbaceous vegetation. These habitats are often transitional between emergent and forested wetlands. Decaying leaves provide substrate for invertebrates which in turn provides food for waterfowl. Plant seeds provide another important food source for waterfowl. However, the primary value of shrub/scrub habitats to waterfowl is by providing thermal roosting cover (Waterfowl Handbook 2001). These areas are generally created by beaver, catastrophic winds, hydrological changes, or by man.

Important open water areas for waterfowl are usually provided by rivers, sloughs, brakes, and oxbow lakes. These wetlands primarily provide resting and roosting cover for waterfowl. Open water is extremely valuable during dry years (Waterfowl Handbook 2001).

The temporal and spatial distribution of these habitats must correspond with the migration chronologies of waterfowl. Use of the Refuge by migratory waterfowl is determined by several factors, including the availability of flooded habitat and food resources, limited disturbance on the Refuge, and unfavorable weather and water conditions. A variety of these habitats located in close proximity ensures each species will meet its physiological requirements at each stage of its life. Studies indicate that a mallard must have all the resources needed for survival within a 12-mile radius (Waterfowl Handbook 2001).

Shorebirds

Twenty-three species of shorebirds have been recorded at Muscatatuck NWR, with only three species nesting, and nine commonly occurring species. Shorebirds find suitable habitats on the Refuge for feeding and nesting during the spring and fall migrations. Some shorebirds can be found throughout the year in this region, but it is during migration that the greatest abundance and diversity are present. Management of Refuge impoundments for waterfowl can also greatly benefit these species.

Although data for shorebird use of the Refuge is not currently collected in a consistent manner or at regular intervals, the use of the Refuge by this group apparently occurs at moderate levels. Quantitative estimates of abundance or use days are not available; however, shorebirds are estimated at over 1,000 individuals per day during peak migration (April-May and August-Oct). The most abundant species are Killdeer, Wilson’s Snipe, and a wide variety of sandpipers. A regularly conducted survey is needed to evaluate the success of management actions with regard to this waterbird guild.

Marsh Birds

Marsh birds are secretive animals and are very difficult to survey. They generally are found within stands of dense emergent vegetation. Moss Lake, Endicott Marshes, Mini Marsh, and McDonald Marshes consistently provide habitat for this group of birds. Other impoundments also contribute to suitable habitat, however, these contributions change on a seasonal basis.

Adequate data are not available to assess the populations, trends, or effects of recent water management strategies on marsh bird populations. King rails, sora rails, Virginia rails, yellow rails, least bitterns, American bitterns, common loon, pied-billed grebe, eared grebe, western grebe, horned grebe, white-faced ibis, glossy ibis, moorhens, coots, and purple gallinules are all species that have been observed at the Refuge within the recent past (<4 years). Marsh bird surveys were conducted from 1998 to 2001. These callback surveys resulted in the detection of nine species including sora rails, Virginia rails, American coot, pied-billed grebe, black rail, moorhen, yellow rail, king rail, and green heron.

Wading Birds

Wading birds are common on the Refuge. An abundance of diverse habitats are available to wading birds throughout the year; however, these birds concentrate at managed impoundments during drawdowns where foods such as invertebrates and fish become trapped and concentrated.

Great Blue Herons are the most abundant and commonly observed species of wading bird on the Refuge. Moss Lake was home to a Great blue heron rookery for over 20 yrs., and was recorded in April 2008 to have had 47 nests of which 35 were active. Some of the nests were destroyed in late summer of 2008 following severe weather associated with remnants of Hurricane Gustav and Hurricane Ike, and the remaining nests were destroyed in 2009 following 80 mph straight-line winds. A small colony consisting of 4 nests was discovered in summer of 2010 north of M4 within Green tree unit 4 (G4). In April of 2010, 19 nests were found being constructed along Storm Creek south of CR400 just before the ditch opens up into Moss Lake; however another site visit in May revealed the nests had been abandoned.

Although data are not currently collected in a consistent manner or at regular intervals as is collected for waterfowl, wading bird use of the Refuge apparently occurs at moderate levels. Green Herons are relatively common throughout the spring and summer and have been observed nesting on the Refuge. Mini Marsh and Moss Lake are the two locations where Green Herons are most often observed. Great Egrets, Snowy Egrets, Little Blue Herons, Black-crowned and Yellow-crowned Night Herons, and Least Bitterns and American Bitterns have also been observed feeding and/or nesting at the Refuge.

American Bitterns are seen annually in M2 and Moss Lake.

Migratory Landbirds

Migratory landbirds (e.g. hawks, kites, cuckoos, and songbirds) have suffered long-term declines in continental populations due in part to the loss of bottomland hardwood forests. To help address this issue, Hunter et al. (1993a) developed the PIF species prioritization scheme which ranks birds based on parameters that indicate their vulnerability to local and global extinction. This scheme includes global abundance, global extent of breeding and non-breeding distributions, threats during breeding and non-breeding periods, population trends, and the importance of the area under consideration for conservation of the species. Under the PIF prioritization scheme, a score is assigned to each species, and a higher score indicates a greater need for management. This scheme was used to develop a priority species list for the Central Hardwoods Joint Venture (Twedt et al. 1999) in which Muscatatuck NWR is located.

It is generally accepted that many of the non-game species of concern require large blocks of habitat. However, territory size varies widely and depends on many habitat characteristics. Required tracts of habitat can vary from 5 to 1000 acres. Changes in Refuge management allowing for forest succession on the eastern Refuge cropland and nearly all Refuge grasslands will eventually result in a landscape dominated by upland and bottomland hardwood forest. Fragmentation will result only from the Refuge impoundments and small amounts of grassland retained. Edge effect will be reduced and large tracts of forests will be available for forest dwelling species.

Bald eagle

The Bald Eagle is a great example of conservation success in the U.S.; they were listed as endangered in 1967. Nesting pairs in the lower 48 states increased from only several hundred in the 1960's to nearly 10,000 today. The species was removed from federal and state endangered species list by the end of 2007, although federal regulations offer the species continued protection outside of the Endangered Species Act by the Migratory Bird Treaty Act and the Bald and Golden Eagle Protection Act.

Nest building on the Refuge by Bald Eagles began in 2000; however, no eggs were laid in spring of 2001. The nest is apparently the first bald eagle nest documented on the Refuge since its inception. Anecdotal evidence based on reports from area residents indicated that this was the first Bald Eagle nest in a long time; probably none existed in the 20th century. Habitat conditions were likely not conducive much of the 20th century because most of the Refuge's wetlands had been drained and agriculture dominated the landscape until recent decades.

Since 2000, 18 eaglets have hatched and fledged. In 2005, 2009, and 2010 the nest was destroyed by damaging winds that toppled the nest tree. The only documented nest failure occurred in 2005 following the nest's destruction and subsequent rebuilding. In 2009 and 2010, the nest blew down after fledging and nests were rebuilt in the fall or winter.

Sandhill Cranes

Sandhill Cranes use the Refuge extensively during their migration. Nearly 50,000 use days by Sandhill Cranes were documented during the winter of 2009/2010, and peak numbers of over 2600 cranes were present on March 5, 2010. Sandhill Crane use has been steadily increasing over the past several years (Figs. 23 and 24). This is likely attributable to the increase in moist soil and water management efforts with increased seed production and decreased water levels.

Figure 23: Sandhill Crane Total Use Days 2006 to 2011

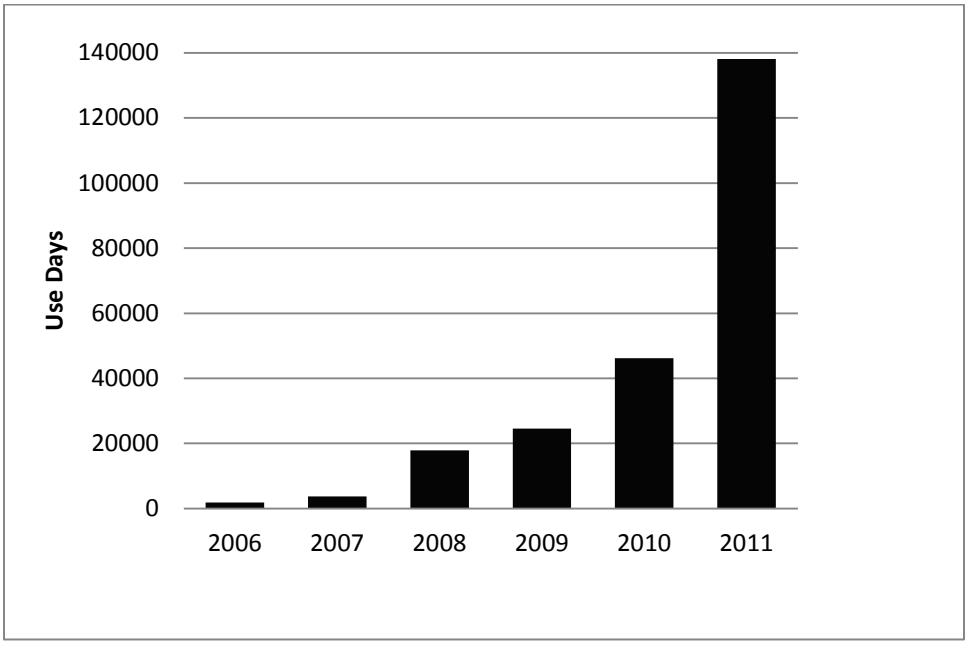
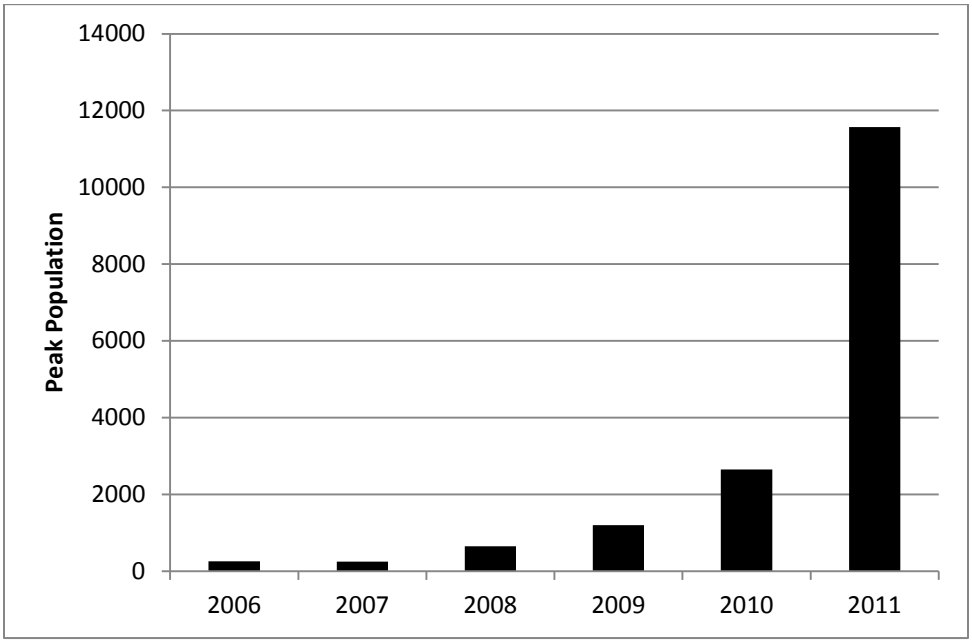


Figure 24: Sandhill Crane Peak Populations 2006 to 2011



Game Birds

Wild turkeys are abundant on the Refuge, and populations seem to be doing well. A rough estimate of between 120 and 200 birds was produced from a chance encounter visual survey in 2010. Currently this species is not monitored to provide accurate population estimates. Annually, hunters harvest between 10-15 turkeys.

Northern Bobwhite Quail have suffered severe losses in habitat on the Refuge, and this trend will continue as grasslands and shrublands revert to forest. Limited qualitative surveys in 2009 documented only two coveys on the Refuge. The Refuge allows quail hunting on the property but does not maintain records of kills or hunter effort. It is presumed that quail will not persist.

Nuisance Animals

Beaver, muskrat, mute swans, feral hogs, feral cats, and feral dogs are all considered to be nuisance animals on the Refuge. These species are discussed in detail within the approved nuisance animal plan.

Resident Wildlife

The Refuge's bottomland hardwood forests and associated habitats support high populations of endemic wildlife. Some endemic species are important game animals, such squirrels, eastern cottontail rabbits, white-tailed deer, wild turkey, and Northern Bobwhite. Other species receive less interest from the general public, such as resident songbirds, small and medium-sized mammals, reptiles, and amphibians, yet are critical to the environmental health and biodiversity of the Refuge and its ecosystems. In compliance with establishing purposes and partnership conservation plans, the Refuge utilizes sound biological principles in the assessment of populations and feasible management strategies for resident wildlife species. Management efforts for priority wildlife species and habitat conditions which were historically found at the Refuge should benefit many of these species and species' groups.

Among recorded resident species the Refuge forests, grasslands, and wetlands support 43 species of herpetofauna, 38 species of mammals, 86 species of fish, 24 species of mussels, 60 species of butterflies, and 30 species of dragonflies (species lists are available in Appendix C of the CCP). The Refuge may have both resident and migratory populations of several butterfly and dragonfly species.

Endangered, Threatened, Rare, and Species of Concern

The purpose of the Refuge is to provide an inviolate sanctuary for migratory birds. However, the Refuge does support state/federally threatened and endangered plants and animals, species of concern and a rare community (Federal Registry, 1990).

Three federally listed endangered and threatened species have been documented on the Refuge. These include Indiana Bat, Interior Least Tern, and Whooping Crane. The Copperbelly Watersnakes at Muscatatuck NWR are not included within the federally listed population.

A total of 64 state-listed endangered and special concern species have been documented on the Refuge with five more suspected to occur on the property. A listing of documented state-listed species can be viewed in Table 7 on page 70 within this plan.

Indiana Bat

3D/Environmental Services, Inc. investigated the potential distribution and habitat use of Indiana Bats at Muscatatuck NWR in 1993 and concluded that the potential existed for Indiana bat use on the Refuge based on three factors. The Refuge is within 50 miles of hibernacula known to contain large populations of Indiana bats. Habitat on the Refuge conducive to Indiana bat use includes: riparian and upland forests, well-developed river and stream corridors and channels, and an abundance of wetlands. Recommendations

included conducting mist net surveys and roost tree surveys to confirm the presence of Indiana bats on the Refuge.

Between June and August of 1995, John Whitaker of ISU conducted mist net surveys at eleven sites on the Refuge over a period of nine days. Documenting the presence of populations of Indiana bats was the primary objective of the survey effort. The survey resulted in six bat species identified from 66 captured individuals, five were Indiana Bats. One female that was assumed to be pregnant was captured on Storm Creek, T6N R6E Section 24. A post-lactating female was encountered on Mutton Creek, T5N R6E SW Section 35. Three other females were captured on Mutton Creek, T6N R6E in the extreme NE portion of Section 35. The capture of a post-lactating female and the assumed pregnant female led to speculation that at least one maternity colony existed on the Refuge at that time.

During the summer of 2007, 79 bats of 6 species were collected and released by Tim Carter of Ball State University. Twenty-eight of the 79 individuals captured were Indiana Bats. Ten of these were lactating females, 13 pregnant females, three adult males, and 2 other captures. During this study radio transmitters were placed on 18 pregnant or lactating females that were later tracked back to maternity colonies and/or roost trees. Roost locations of radio-tagged bats were determined and recorded. A total of 19 roost trees were located for the Indiana bats. Roost trees identified on Muscatatuck NWR included chestnut oak (1), maple spp. (8), and unidentified dead tree spp. (10).

Indiana bat roosts are ephemeral, frequently associated with dead or dying trees. Most roost trees may be habitable for only 2-8 years (depending on the species and condition of the roost tree) under natural conditions. Gardner et al. (1991) evaluated 39 roost trees in Illinois and found that 31% were no longer suitable the following summer, and 33% of those remaining were unavailable by the second summer. A variety of suitable roosts are needed within a colony's traditional summer range for the colony to continue to exist (Kurta et al. 1993). Bats move among roosts within a season and when a particular roost becomes unavailable from one year to the next. It is not known how many alternate roosts must be available to assure retention of a colony within a particular area.

Callahan (1993) noted: "Larger forest tracts probably increase the chances that a suitable range of roost trees will be present in the stand. Large forest components also provide an additional benefit to a philopatric species that uses an ephemeral resource (snags) for roosting." Kurta et al. (1996) noted that a relatively large area is needed to meet the roosting requirements of Indiana bats, and young, highly fragmented forests, typical in the Midwestern United States, cannot meet these requirements.

Whooping Cranes

Between 2001 and 2007, the Refuge was a stopover site for the Whooping Crane Eastern Partnership (WCEP) ultra-light-led Whooping Crane migration in the fall. On February 26, 2008 a Whooping Crane was seen in the shop field with Sandhill Cranes. This was the first time a Whooping Crane was verified as landing on the Refuge on the migration north unaided by ultra-light. Nine Whooping Cranes spent 24 days at the Refuge from December 11, 2009 to January 3, 2010. Eight Whooping Cranes arrived and stayed at Muscatatuck feeding and resting in the southern waterfowl units, mostly at M9 from March 1-March 11, 2010. It is expected that use of the Refuge by Whooping Cranes will increase over time as long as the population continues to increase.

Interior Least Tern

The Interior Least Tern is listed as a rare species in the spring and fall within the Refuge Bird Checklist and also within the CCP species lists. However, after extensive searches of historic bird data, unusual sightings reports, the Indiana Natural Heritage Database records, Brock's CD of Indiana Birds (2006), asking within the birding community, and speaking with the State Ornithologist, no documented records of the species at the Refuge could be produced. Anecdotal evidence from one Refuge staff member is the only source for the occurrence of this species. Although it is possible for the species to appear at the Refuge, Interior Least Terns would not be expected on a regular basis. This is a bird of sand and gravel bars along major rivers such as the Ohio and Wabash in Indiana and some artificial sites, i.e. power plants, adjacent to those rivers (Castrale 2011). The species' federal/state status alone warrants its status as a high priority species at the Refuge; however, considering its preferred habitat, management decisions will likely never affect the species.

Copperbelly Watersnake

As of November 1996, under the provisions of the Copperbelly Watersnake Conservation Agreement and Strategy, scientific investigation began to better understand the life history patterns of the copperbelly watersnake (*Nerodia erythrogaster neglecta*) in the southern part of its range. The five-year long project allowed quantitative research to be conducted on the status and health of populations in western Kentucky and adjacent southeastern Illinois and southwestern Indiana (USFWS, Muscatatuck NWR unpublished report 2001). The Copperbelly Watersnake population at Muscatatuck NWR is not protected under any Federal Endangered Species legislation but is given consideration under the Copperbelly Watersnake Conservation Agreement and Strategy.

The staff and volunteers of Refuge have been instrumental in data collection on aspects of Copperbelly Watersnake ecology relating to behavior, movements, and habitat use.

The Refuge provides ideal habitat for the species and an opportunity to study its movements and behavior in an unfragmented landscape (Minton 2001). The Refuge has been a stronghold for the federal and state endangered species, allowing for intimate study (Kingsbury 1997). While many in the scientific community (Conant et al. 1991) have commented on the ecology of the species, few have detailed aspects of its life history; telemetry work at the Refuge has proven valuable in uncovering its ecological requirements.

Observational and tracking/locating data collected in the 1990's revealed the snake's dependence on both the palustrine emergent habitat, as well as the floodplain forest provided by the Refuge. Habitat preference appeared to correlate most closely with weather (high and low temperatures) and the availability of southern leopard frogs (*Rana sphenocephala*), its dominant prey.

In 2008, the Refuge entered into a cooperative research project with Purdue University and received a Challenge Cost Share grant for $20,000 to conduct telemetry research, visual surveys, and hibernation site monitoring at the Refuge. The telemetry data were collected for the purpose of determining habitat use, seasonal changes in use, impacts of management, and impacts of roads on the species. The research may allow for the estimation of abundance and/or density of copperbelly watersnakes at Muscatatuck NWR and also capture enough habitat related data to create a habitat selection model that can be used to predict occurrence or to make recommendations for restoring sites for copperbelly watersnakes. Temperature probes and data loggers were installed at hibernation burrows to try to determine if emergence was correlated with ground temperature inversions in the spring and to determine if snakes chose hibernation sites that were thermally stable and warmer than random sites. The final report and analyses have not been received but will be considered in habitat management decisions.

A long-term Copperbelly Watersnake monitoring project occurred from 2005 to 2009. The purpose of this study was to estimate population size, compare population statistics to prior studies, and analyze population viability of the species through a mark-recapture/release study. Snakes were captured and permanently marked with Passive Integrated Transponder (PIT) tags to enable future identification. Other data such as sex, age, body mass, length, and location were also recorded to provide life-history data on future recaptures.

Invasive Species

According to 2006 Refuge Annual Performance Planning (RAPP) data, two million acres of Fish and Wildlife Service-managed lands were infested with invasive species (USFWS, 2007). While a comprehensive inventory of plant species has not been completed for the Refuge, a full listing of invasive species found thus far on the Refuge can be viewed in Table 12.

Table 12: Invasive Species Documented at Muscatatuck NWR

Family	Scientific Name	Common Name	Distribution
Plants			
Apiaceae	*Daucus carota L.*	Queen Anne's lace/wild carrot	Limited
Asteraceae	*Cirsium arvense*	Canada Thistle	Moderate
Berberidaceae	*Berberis thunbergii*	Japanese Barberry	Unknown
Brassicaceae	*Alliaria petiolata*	Garlic Mustard	Wide
Caprifoliaceae	*Lonicera japonica*	Japanese Honeysuckle	Wide
Caprifoliaceae	*Lonicera maackii*	Amur Honeysuckle	Wide
Caprifoliaceae	*Lonicera tatarica*	Tatarian Honeysuckle	Moderate
Celastraceae	*Celastrus orbiculatus*	Oriental Bittersweet	Unknown
Celastraceae	*Euonymus alata*	Winged Burning Bush	Unknown
Celastraceae	*Euonymus fortunei*	Winter Creeper	Unknown
Convolvulaceae	*Convolvulus arvensis L.*	Field bindweed	Unknown
Dioscoreaceae	*Dioscorea opposita*	Chinese Yam	Isolated
Elaeagnaceae	*Eleaegnus umbellata*	Autumn Olive	Wide
Fabaceae	*Albizia julibrussin Durazz.*	Mimosa	Isolated
Fabaceae	*Coronilla varia*	Crown Vetch	Limited
Fabaceae	*Melitotus* spp.	Sweet Clovers	Wide
Fabaceae	*Pueraria montana*	Kudzu	Isolated
Fabaceae	*Sericea lespedeza*	Sericea Lespedeza	Moderate
Haloragaceae	*Myriophyllum spicatum*	Eurasian Waterbilfoil	Limited
Littorinidae	*Vinca minor* and *vinca major*	Periwinkle	Isolated
Lythraceae	*Lythrum salicaria*	Purple Loosestrife	Isolated
Myrsinaceae	*Lysimachia nummularia*	Moneywort/creeping jenny	Wide

Oleaceae	*Ligustrum sinense*	Chinese Privet	Moderate
Oleaceae	*Ligustrum* spp.	Other Privets	Limited
Poaceae	*Lolium arundinaceum*	Tall Fescue	Wide
Poaceae	*Microstegium vimineum*	Japanese Stiltgrass	Wide
Poaceae	*Phalaris arundinacea*	Reed Canary Grass	Limited
Poaceae	*Sorghum halepense*	Johnson Grass	Moderate
Polygonaceae	*Polygonum cuspidatum*	Japanese Knotweed	Isolated
Polygonaceae	*Rheum rhabarbarum*	Rhubarb	Unknown
Potamogetonaceae	*Potamogeton crispus*	Curly leaf pondweed	Limited
Rosaceae	*Rosa multiflora*	Multiflora Rose	Wide
Rosaceae	*Rubus armeniacus*	Armenian/Himalayan Blackberry	Wide
Salicaceae	*Populus alba*	White Poplar	Isolated
Salicaceae	*Salix alba*	White Willow	Isolated
Scorphulariaceae	*Verbascum thapsus*	Common mullein	Limited
Simaroubaceae	*Ailanthus altissima*	Tree of Heaven	Moderate
Taxaceae	*Taxus cuspidata*	Japanese Yew	Isolated
Animals			
Anatidae	*Cygnus olor*	Mute swans	Isolated
Canidae	*Canis lupus*	Feral dogs	Limited
Coccinellidae	*Harmonia axyridis*	Asian ladybugs	Wide
Corbiculidae	*Corbicula fluminea*	Asian clam	Wide
Cyprinidae	*Cyprinus carpio*	Common carp	Unknown
Felidae	*Felis catus*	Feral cats	Moderate
Icteridae	*Molothrus ater*	Brown-headed cowbirds	Wide
Lymantriidae	*Lymantria dispar*	Gypsy moths	Unknown
Muridae	*Mus musculus*	House mouse	Unknown
Muridae	*Rattus norvegicus*	Norway rat	Unknown
Passeridae	*Passer domesticus*	House sparrows	Wide
Pieridae	*Pieris rapae*	Cabbage white	Unknown
Poeciliidae	*Gambusia affinis*	Mosquitofish	Wide
Scolytidae	*Xylosandrus crassiusculus*	Asian ambrosia beetle	Unknown
Sturnidae	*Sturnus vulgaris*	European starling	Wide

Table 13: Invasive Watch List-Species Found Near Refuge

Family	Scientific Name	Common Name
Plants		
Amaranthaceae	*Chenopodium murale L.*	Nettleleaf goosefoot
Apiaceae	*Aegopodium podagraria L*	Bishop's goutweed
Apiaceae	*Conium maculatum L.*	Poison hemlock
Apiaceae	*Heracleum mantegazzianum*	Giant hogweed
Apocynaceae	*Vincetoxicum rossicum*	Pale swallow-wort
Araliaceae	*Hedera helix*	English Ivy
Asparagaceae	*Convallaria majalis L.*	European lily of the valley
Asteraceae	*Arctium minus Bernh.*	Common burdock
Asteraceae	*Carduus nutans L.*	Musk thistle
Asteraceae	*Cichorium intybus L.*	Chicory
Boraginaceae	*Buglossoides arvensis (L.) I.M. Johnston*	Corn gromwell
Brassicaceae	*Brassica rapa L.*	Birdsrape mustard
Brassicaceae	*Hesperis matronalis*	Dame's rocket
Butomaceae	*Butomus umbellatus*	Flowering rush
Caprifoliaceae	*Lonicera morrowi*	Morrow's honeysuckle
Caryophyllaceae	*Cerastium fontanum Baumg.*	Common mouse-ear chickweed
Caryophyllaceae	*Cerastium fontanum ssp. vulgare*	Big chickweed
Caryophyllaceae	*Dianthus armeria L.*	Deptford pink
Commelinaceae	Commelina communis L.	Asiatic dayflower
Fabaceae	*Kummerowia stipulacea*	Korean lespedeza
Hydrocharitaceae	*Egeria densa*	Brazilian elodea
Hydrocharitaceae	*Hydrocharis morsus-ranae*	European frog-bit
Lamiaceae	*Ajuga reptans L.*	Carpet bugle
Lamiaceae	*Pilea nummularifolia*	Creeping Charlie
Malvaceae	*Alcea rosea L.*	Hollyhock
Poaceae	*Bromus racemosus L.*	Bald brome
Poaceae	*Bromus tectorum*	Cheatgrass
Poaceae	*Dactylis glomerata L.*	Orchardgrass
Poaceae	*Taeniatherum nevki*	Medusahead
Salvinaceae	*Salvinia molesta*	Giant salvinia
Solanaceae	*Datura stramonium L.*	Jimsonweed
Animals		

Cerabycidae	*Anoplophora glabripennis*	Asian Longhorned beetle
Gobiidae	*Neogobius melanostomus*	Round Goby
Percidae	*Gymnocephalus cernuus*	Eurasian Ruffe
Suidae	*Sus scrofa*	Feral hogs

In 2001, 60% of forested acres on the Refuge were found to be affected by multiflora rose. Shrub-scrub and grassland areas were affected 33% and less than 30%, respectively. Autumn olive occurred more often in shrub-scrub areas with some 33% affected. Grassland areas were less than 30% affected and less than 20% of forested areas were affected. Garlic mustard occurred in forested habitat on the Refuge, but was found only in low densities. Canada thistle was found to occur on an estimated 10% of Refuge grassland acreage. Survey results indicate that multiflora rose is the invasive of greatest management concern on the Refuge. Autumn olive is also a species of some management concern having a relatively high density. Fortunately, garlic mustard was not found to be a serious Refuge concern. Canada thistle is also not a source of serious concern according to survey results.

In 2003, multiflora rose continued to be the invasive of greatest management concern with its highest density occurring in forested habitats. Also an infestation of garlic mustard was mapped on the south side of Stanfield Lake. In 2004, spraying and mowing was conducted for Johnson grass and Canada thistle control. Purple loosestrife scouting took place and a few plants were found and sprayed near US HWY 50 by Quarters 40. Also, a small infestation of Japanese knotweed was found on CR 1225 E. and was sprayed. Japanese stilt grass was also spotted on the Refuge in 2004.

In 2005, Refuge staff personnel were able to map Japanese stilt grass which occupied approximately 100 acres of the Refuge. An estimated 1/3 of the area affected area was treated. Some other invasive species found on the Refuge in 2005 include kudzu, oriental bittersweet and Japanese knotweed. Less than an acre of kudzu was reported and treated along CR 900. The small infestation of Japanese knotweed on CR 1225 E that was reported in 2004 was treated again in 2005, and a small patch of oriental bittersweet found along chestnut trail was also treated.

In 2006, interns took the first step in eliminating the Refuge's small Tree-of-Heaven population by girdling and chemically treating the stand of trees near Turkey Trail. Refuge staff also mapped and treated approximately a 120 acre area of Japanese stilt grass which was said to be the entire affected area. Other species that were mapped and treated in 2006 include kudzu, garlic mustard, and purple loosestrife. Less than an acre of kudzu along CR 900 was treated again in 2006 along with a patch of garlic mustard that was located near the west entrance of the Refuge. Purple loosestrife was also found on

private land near Sandy Branch, west of US Hwy 31, and treatments were made there as well.

In 2007, the area affected by kudzu along CR 900 was treated again for the third consecutive year. The purple loosestrife that was found on private property, near Sandy Branch, was treated again, along with the Japanese knotweed found along CR 1225 E. Garlic mustard was hand-pulled from numerous target sites and the tree-of-heaven along Turkey Trail was treated once again. Also, most of the known infestations of Japanese stilt grass were mapped and initially treated; however, a second round of Japanese stilt grass growth occurred resulting in less than expected control for many of those infestations.

In 2008, the Japanese knotweed found along CR 1225 E. along with a small patch found on E CR 500, were treated. The purple loosestrife found on private property near Sandy Branch, the kudzu found along CR 900, and the tree-of-heaven found along turkey trail were all treated once again. Also, garlic mustard was hand-pulled along E CR 400 to keep an infestation from occurring in the acid Seep spring. Mapping of the Japanese stilt grass continued in 2008 with a few more areas located and chemically treated. The addition of ATV mounted 60 gallon sprayer increased the amount of Japanese stilt grass that was able to be treated to an estimated 210 acres and reduced the amount of effort necessary to treat the infestations. A contractor sprayed a 30-acre field south of Richart that was infested with stilt grass. In 2008, autumn olive was manually treated near the Visitor's Center throughout the summer. Approximately five acres were cut-stump-treated with salt applications around the cambium layer in order to prevent resprouting. Also in 2008, a new exotic species was discovered on the Refuge by Daniel Boone during a rare plant survey; the species is Armenian blackberry. Only a few plants were chemically treated in 2008 and the rest mapped. White poplar was also found along the southern road leading to Lake Linda.

Led by WB Wood, Muscatatuck NWR joined a multi-refuge Invasive Species Occupancy Study in 2009. The study was developed largely by Perry Williams, Wildlife Biologist at Big Oaks NWR. The Refuges involved in 2009 were Big Oaks, Mingo, and Muscatatuck. The study was designed to collect data on 100 random sites per year at each Refuge and involved sampling vegetative and physical characteristics of each site. Data recorded included invasives present, species diversity, tree species diversity, tree diameter at breast height, slope, aspect, cover type, among others. Data derived from this study will be used for RAPP reports and to assist in the decision making processes with regard to invasive species control efforts. The insights gained from the study will also aid in preparation of an integrated pest management plan, serve as a means of early detection rapid response, and be incorporated into a GIS based model that should allow the Refuge to make predictability models that may lead to the discovery of currently unknown infestations.

Areas of permanent water, streams, and managed wetlands were not included in the survey.

Results from the study indicate that 74% of all terrestrial sites on the Refuge are invaded. Although thorough analyses have not yet been completed, it seems as though species diversity is highly correlated with invasions; the higher the diversity of native species the less likely the site was invaded. Nearly 28% of the Refuge's terrestrial sites were invaded by three or more invasives. The dominant invasive species encountered (and the percentage of sites invaded by them) were multiflora rose (~49%), autumn olive (~26%), Japanese honeysuckle (~23%), Armenian/Himalayan blackberry (~19%), moneywort/creeping jenny (~9%), bush/Amur honeysuckle (~8%), Japanese stiltgrass (~6%), garlic mustard (~5%), and common mullein, oriental bittersweet, thistle, crown vetch, Sericea lespedeza, and reed canary grass (all of which were ~ <5%). Approximately 60% of survey sites were infested immediately adjacent to the sample plots.

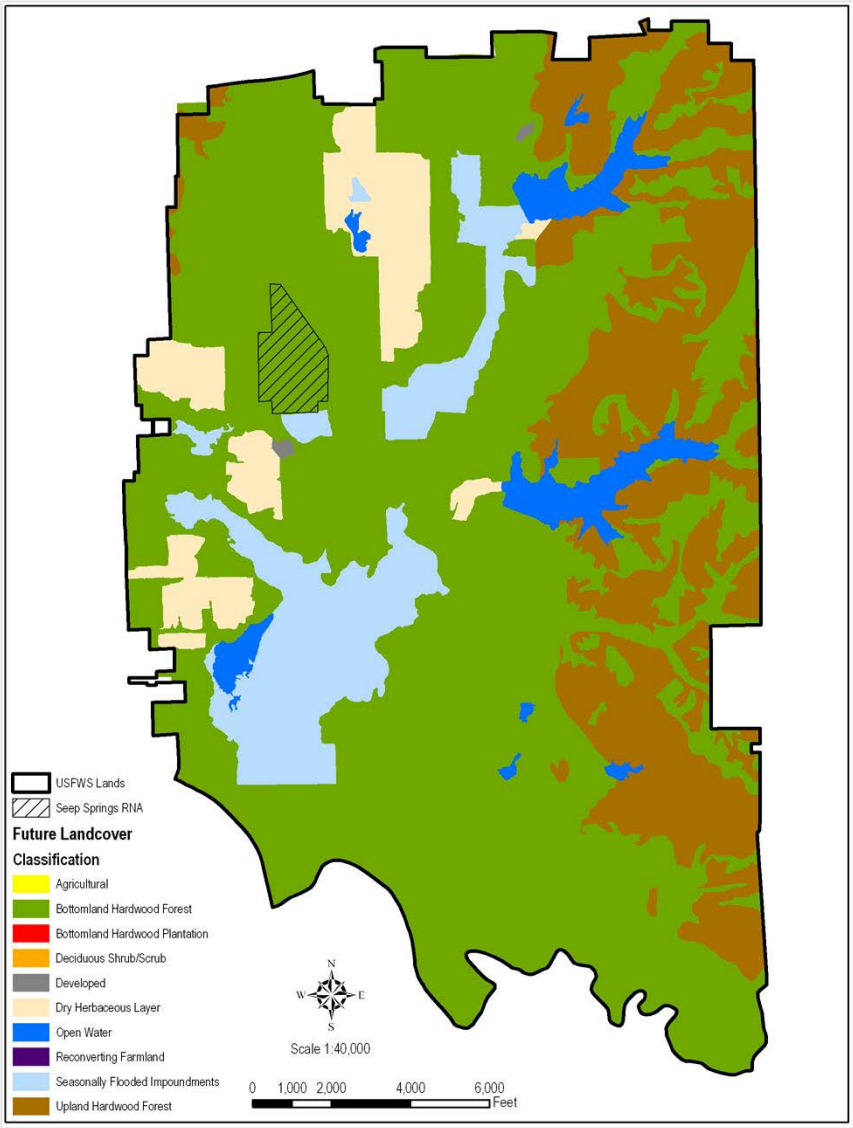
In 2010, the Muscatatuck NWR continued the invasive species occupancy study; it revealed a more complete picture of the status of invasive plants on the Refuge. Data were pooled with 2009 data. From this we estimated that 57% of the Refuge is covered in multiflora rose, 33% is covered in autumn olive, 32% is covered in Japanese honeysuckle, 8% is covered in moneywort, and 17% is covered in Himalayan blackberry. In 2010, interns treated the kudzu located along CR 900, the Japanese knotweed located on CR 500, and the purple loosestrife located on private property west of the Refuge. Other invasive plants that were treated in 2010 include: Chinese yam located at the Stanfield boat ramp road, tree-of-heaven located along old barn road, reed canary grass located on some levees and in some moist soil units, Canada thistle located on private property near CR 1225, Johnson grass located on some levees, and autumn olive located along many roadsides and in reconverting fields.

Autumn olive, garlic mustard, reed canary grass, multiflora rose, crown vetch and many other species dominate certain portions of the landscape. Japanese stiltgrass, multiflora rose, tree-of-heaven, autumn olive and kudzu threaten the diversity and health of the bottomland and upland hardwoods. Other species, such as reed canary grass, attempt to out-compete native vegetation along riparian corridors, in moist soil units and in other wetland types. Many of the invasive species encountered have the capability over time of producing solid monocultures that shade out native vegetation and reduce overall plant diversity and, consequently, overall animal diversity (Pimentel, 2005).

Chapter 4: Habitat Goal, Objectives, Strategies, and Prescriptions

The goal for the habitat management program at Muscatatuck National Wildlife Refuge is to provide a spatial and temporal distribution of habitats to meet breeding, feeding and resting needs for species using the Refuge with an emphasis on the priority species, as well as restore, protect, and manage an expanse of upland and bottomland deciduous forest similar to that historically present to provide habitat for resident and regional conservation priority species. To achieve that goal, the habitat should consist of a complex of wetland types with varying water depths, diverse plant communities and an abundance of aquatic invertebrates for foraging, resting and nesting birds and provide solid contiguous blocks of upland and hardwood forests with adequate structural and compositional diversity.

Figure 25: Future Landcover, Muscatatuck NWR



Goal: Maintain a dynamic mosaic of vegetation that includes an expanse of upland and floodplain deciduous forest similar to that historically present along with lakes, marshes, and moist soil units.

A table of prioritization for objectives and strategies that outlines timeframes and desired order of actions can be found in Appendix B that will be used in developing annual habitat management work plans.

Objective 1.1: Upland Hardwood Forest

Over the long-term (100-200 years), on areas dominated by upland flats and moist slopes, achieve an approximately 1,520-acre mosaic of upland hardwood stands of different age and structural classes dominated by poplar, oak, hickory, white ash, black cherry, maple, and beech. Within 15 years, restore approximately 310 additional acres of reverting farmland to upland hardwood and maintain the existing approximately 1,210 acres of upland forest with a mix of age classes present. The farming program will be terminated in 2013. Determination of how this will be accomplished will be outlined in a Forest Management Plan to be completed within five years of the completion of this HMP. Restoration of the entire 310 acres will likely be dependent on partnering and utilization of programs such as GoZero; if such partnering is not possible the refuge will restore small portions of this acreage (i.e. 30 acres) every year for each of the 10 consecutive years following FMP completion. It may be determined that natural succession and regeneration is the most viable option. Also within 15 years, enhance 150 acres of upland forest by removing invasive species and employing various improvement techniques to ensure proper understory development, regeneration, and age class and species compositions. This will be conducted in small increments of approximately 15 acres per year if funding and staff levels allow.

Rationale: Land use practices, invasive plant introduction, and modifications to the hydrology of the landscape over the past century have drastically altered the vegetative communities on the Refuge and led to increased fragmentation of the habitat. Studies have shown that forest fragmentation reduces nesting success of migratory birds because of increased nest predation and parasitism. Area sensitive forest bird species generally require large, contiguous blocks of forested habitat and are also negatively affected when fragmentation results in smaller contiguous acreages (Robinson et al. 1995).

Historically, the Refuge was a part of an expansive, contiguous hardwood forest that covered most of the central and southern part of Indiana (Jackson 1997). Of the identified upland soils within the Refuge boundary, approximately 1,210 acres are currently forested. An additional 310 acres (approximately) of potential upland forest have been identified that are currently farmed. We anticipate allowing natural regeneration of upland hardwoods and supplement tree diversity with plantings of species that were historically present. Certain species such as oak and hickory species may not regenerate on their own and thus supplemental plantings of these hard mast species may be necessary to progress more quickly toward the climax community desired. These processes will help reduce forest fragmentation and provide habitat for migratory birds,

Wood Ducks and the Indiana bat.

The Refuge has carried out reforestation activities in recent years to reduce fragmentation of forested habitats by retiring former agricultural fields and pastures. The intent is to manage native forest land for structural and plant species diversity and ensure healthy soil and water. Closed canopy forests often result in poor regeneration of shade intolerant species, especially oak species, and often result in poor understory development. However, natural openings caused by death or wind throw of one or more trees create open habitats that are quickly colonized by herbaceous plants, shrubs, and tree seedlings. These temporary openings are desirable because they prevent even-aged stand development, provide diversity within the otherwise forested matrix, and are important habitat for wildlife (Collins and Battaglia 2002). To replicate these natural openings, artificial openings of one acre or less in size may be created as part of forest management.

Invasive species such as autumn olive, Japanese honeysuckle, bush honeysuckle, multiflora rose, Japanese stiltgrass, and garlic mustard have invaded a large percentage of the Refuge's forested habitats. These species outcompete and shade-out native vegetation, resulting in the development of monotypic stands of non-native vegetation. This reduces vegetative diversity, inhibits regeneration, and threatens rare and endangered plant populations (Pimentel et al. 2005). This objective represents the Refuge's intent to more actively manage and restore upland forest habitat to benefit forest-dependent wildlife, such as certain species of migratory waterfowl, neotropical migratory birds, and mammals (e.g. Indiana bat, southern flying squirrel). Large contiguous blocks of native upland forests are expected to provide breeding and nesting habitat for the Wood Thrush, Chestnut-sided Warbler, Yellow-billed Cuckoo, Pileated Woodpecker, and Cerulean Warbler, as well as habitat for the Indiana Bat, waterfowl and other migratory birds, and upland game species. A forest management plan will make prescriptions for implementing most of the strategies below.

Strategies and Prescriptions:

1. Within 15 years of this HMP, Convert approximately 310 acres of former cropland to upland hardwood forest within FMU2 at a rate of 30 acres per year on average in years 5-10. This may include site preparation, planting a cover crop, planting tree seedlings, and weed control treatments. Some areas may be allowed to naturally revert to forested habitat through natural succession.
    a. Utilize Foresters from Region 4 to conduct a forest inventory and make recommendations for prescriptions on all acres of former cropland within each Forest Management Unit within three years of the completion of this plan.
    b. Use forest inventory data and prescriptions/recommendations from foresters to create a step-down Forest Management Plan within five years of the completion of this HMP. The forest management plan will make prescriptions for implementing the objectives and strategies listed here.
    c. Potentially, partner with programs such as GoZero to plant or use supplemental planting to achieve the desired results outlined in the Forest Management Plan.
    d. Use tree plantings of white and red oaks, black cherry, persimmon, black

walnut and a variety of other native trees, including fast growing, light seeded species such as: cottonwood, sycamore, maple, and ash to supplement naturally regenerating forest stands.

e. The Refuge will create or oversee the creation of site specific planting plans as a further step down from the Forest Management Plan.

f. The Refuge will consider soil types, elevational gradients, moisture gradients, and native trees species in planting plans for all acres of former cropland. We anticipate in many former crop fields that species such as beech and maple will be restored through natural regeneration; however, direct seeding of trees may prove beneficial and may be utilized as part of the plantings. Plantings of only hard mast species are discouraged.

g. Planting plans will be written in cooperation with FWS Foresters.

2. Removal of invasive plant species within upland forested habitats through integrated pest management (IPM) strategies outlined in an approved IPM plan to be completed within seven years of the completion of this HMP.

a. Complete a refuge wide invasive species inventory and create distribution maps from that inventory within two years of this HMP's completion.

b. Utilize data and maps from the inventory to inform the IPM plan and in cooperation with Regional and Zone biologists employ decision support tools such as those being developed through the Eastern Broadleaf Biological Network Forest Invasives Adaptive Management Project to guide the IPM planning process (to be completed within seven years of the completion of this HMP).

c. Acquire the necessary tools, equipment, and personnel to effectively battle priority invasive species.

d. High priority habitats on the Refuge should include the Muscatatuck Seep Spring Research Natural Area, moist soil units, marshes, weed-free areas determined from the inventory project, vector areas, and areas of high public use.

3. Decrease undesirable trees through selective cutting to promote establishment and growth of more desirable native hardwoods. Silviculture treatments may be conducted under contract by commercial timber harvesting firms.

a. Determine what trees are undesirable from FWS forester recommendations, inventory, and planning within five years of this plan.

b. Obtain recommended silviculture treatments from FWS foresters and incorporate within the Forest Management Plan.

c. Include prescriptions for this strategy within the forest management plan that is to be created within five years of the completion of this HMP.

4. Use timber stand improvement to achieve the desired conditions outlined in an approved forest management plan on a minimum of 150 acres of upland forest on approximately 15 acres of upland forest per year in years five through fifteen following the completion of this plan.

a. Management may include thinning dense stands, deadening cull trees, and selective harvest on a small scale to improve habitat diversity and opening of canopy to stimulate plant growth, regeneration and recruitment on forest floor.

b. As prescribed in an approved Forest Management Plan, apply appropriate silvicultural treatments to manage forest health, species composition, and age structure. Treatments may include non-commercial forest stand improvement treatments (girdling, cutting, and/or applying herbicide to individual stems), and commercial timber cutting (thinning, improvement cuttings, and regeneration cuttings).
c. Thin young stands of trees (similar to pre-commercial thinning) using appropriate methods to reduce competition for resources and allow residual trees to develop into healthy mature stands using stand, stem density, and DBH guidelines established in an approved Forest Management Plan.

5. Artificially replicate the small openings in the forest (1 acre or less) that would have occurred naturally to provide the natural diversity of habitat that should be present within the forest matrix and to mimic a natural disturbance regime. Complete a minimum of 10% of the total desired openings within the life of this plan.
a. Prescriptions will be outlined within an approved Forest Management Plan.
b. Management plans will include details as to the number of openings per stand, per year, and will also include instructions pertaining to the rotation and/or maintenance of these openings.
c. Plans will consider and incorporate invasive species management to prevent the release and spread of invasive species by the action.
6. Fill the existing (vacant) tractor operator position and add a biological science technician to assist with reforestation efforts, eradication of non-native tree species, and timber stand improvement efforts within six years of this plan.

Objective 1.2: Bottomland Hardwood Forest

Over the long-term (100-200 years) achieve approximately 4,790 acres in large blocks (greater than 500 acres) of mature bottomland forest (12-30 inch average dbh) with a canopy cover of 60-80 percent consisting of mixed sycamore, oak, beech, green ash, sweet gum and maple. Within 15 years of the completion of this plan, in addition to maintaining the approximately 4,135 acres of bottomland hardwoods, 650 additional acres will come from:

- Reconverting farmland (approximately 500acres).
- Current farmland (approximately 15 acres).
- Water management units 8, 9 and 10.
- Inundated portions of the Muscatatuck Seep Spring Research Natural Area and Mutton Creek (approximately 135 acres). (The Rustle Unit is considered separately in Objective 1.7.)

Within 15 years, restore natural hydrology in the area of the current green tree reservoirs, moist soil units 8, 9, 10, and Moss Lake green tree area to allow flooding and ebbing with the natural changes in the river. Immediately stop maintaining Mallard and Display Ponds and allow them to revert to bottomland hardwood forest. Within 10 years of this HMP's completion, actively promote reversion of the current lower moist soil units, with the exception of M7, back to bottomland hardwood forests with an oak component. This should occur with a minimum of one moist soil unit removed from moist soil

management every three years from the completion of this HMP. Sheet flow through these areas will be restored to allow more natural movement of runoff and dead timber areas within green tree reservoirs will be restored to live stands through the natural regeneration of oaks, if possible, and through seeding or planting, if necessary.

Rationale: Historically the Refuge was a part of the expansive, contiguous hardwood forest that covered most of the central and southern part of Indiana (Jackson 1997). The Muscatatuck Flats and lowlands area is in the Bluegrass Natural Region of southeast Indiana. The bottomland is characterized by relatively level plain poorly drained flats. The Muscatatuck River floodplain is one of the most extensive areas of bottomland hardwood forest remaining in the Midwest. The floodplain forest along the Muscatatuck River is characterized by sweet gum, swamp white oak, and shellbark hickory (Sieracki et al. 2002). Increasing, the bottomland hardwood areas at Muscatatuck NWR along the Muscatatuck River and smaller streams will provide important breeding habitat for Wood Duck, Acadian Flycatcher, and Cerulean Warbler as well as summer habitat for the federally-listed endangered Indiana Bat and habitat for the state-listed endangered copperbelly watersnake (Sallabanks et al. 2000; Kingsbury 1997). Land use practices, development of roads, beaver dams, and modifications to the hydrology of the Refuge have impeded drainage and caused seasonal flooding to persist for longer than had occurred historically. The prolonged flooding helped shift composition of bottomland hardwood forests towards tree species with greater water tolerances and largely eliminated regeneration, resulting in single-aged mature stands. In some areas, semi-permanent flooding resulted in complete tree mortality and shifts in habitat type from forested wetland to open water or marsh (Kozlowski 2002). Planned modifications to the drainage system will allow for water management that more closely resembles historical conditions and the restoration of species associated with those conditions. This objective represents the Refuge's intent to more actively manage bottomland forest habitat to benefit forest-dependent wildlife, especially certain species of migratory waterfowl, neotropical migratory birds, resident cavity nesting species, and mammals (e.g. Indiana bat, southern flying squirrel). The Refuge's intent is to actively manage the return of the forested landscape to conditions that allow passive hydrological management that resembles the historic hydrological regime to benefit and protect the wide array of plant and animal species that flourish in such environments. One measure of the biological integrity of bottomland hardwood forests is whether the timing and frequency of events such as flooding correspond to historical conditions.

Strategies for Green Tree Reservoirs (G1, G2, and Moss Lake acres):

1. Within six years of the completion of this HMP develop and implement a restoration plan for restoring Moss Lake GTR from its current condition to a bottomland forest similar to that present prior to the construction of the Moss Lake dam.
    a. Complete topographic mapping of the Moss Lake Complex within 3-5 years of the completion of this HMP. This can be either through LIDAR, manual data point collection, or other viable means.
    b. Using GIS technologies create time series flood maps to be used to model the effects of impounding water at each stoplog interval within the main outflow structure.

c. Use the topographic maps and time series flood maps to determine maximum flood elevations for the unit and make recommendations for further dam lowering actions to protect the newly forming forest.
d. Work with partners and experts in the field of bottomland restoration to develop the restoration plan.
e. Investigate options such as aerial seeding for bottomland restoration of the Moss Lake Green Tree areas as conditions prohibit normal seeding and/or planting methods.

2. Immediately discontinue prescription flooding of the Green Tree Reservoirs (GTR), with an exception to low level impoundment within Moss Lake, and allow them to fluctuate naturally from the creeks and river influences and from precipitation and resulting runoff. The units will no longer be purposely flooded via management intervention.

a. Within five years of the completion of this plan, remove sections of dikes and all water control structures to allow free flow of water into and out of the units and prevent long duration impoundment of the forests. This will include:

- removing the south, east, and west dikes surrounding G2
- replacing the stoplog water control structure leading from G1 to G2 with a larger diameter culvert, i.e. 30 inches or greater to remove impoundment capabilities of G1 and increase discharge capabilities of the unit
-removing the section of the Moss Lake dam between Moss Lake and G1 and essentially restore the stretch of Myer's Branch that runs through G1. This will allow waters from either direction, Moss Lake to the Vernon Fork or from the Vernon Fork to Moss Lake to passively discharge and will prevent unnatural impoundment within the forested areas of Moss Lake GTR, G1, and G2.

b. Monitor the GTRs for regeneration on an annual basis during the growing season as outlined in an approved inventory and monitoring plan.
c. Prevent long duration and deep level impoundment of Moss Lake as outlined in the following strategies:

-Actively pursue draining excess water prior to the growing season (beginning in February and completed by March 1st) to encourage regeneration and avoid killing trees.
-The stoplogs within the structure at Moss Lake will not be set higher than 540.0 ft. MSL at any time, no higher than 539.32 between February 1 and March 1, and no higher than 538.82 March 1 to November 15th, to protect the forested systems that are struggling to survive along the borders of the unit.
- It may be determined from bathymetry/forestry investigations that the maximum elevation for stoplogs should be 539.5 or 539.0, and thus the maximum elevation may be further reduced.
-Consult with regional hydrologists to verify length, but cut a 300ft section of Moss Lake dam on the west side of the water control structure; use an elevation of 540.00 for the flowline.

3. Modifications will be made on the Moss Lake water control structure and the dam by 2027 to increase the discharge capabilities of the structure and/or the dam itself; this is the highest priority within the HMP.

a. Screw gates, slide gates, or other comparable designs should be installed in the remaining four bays within the structure to:

- increase discharge during or following rain events by opening the screw gates
-reduce the buildup of sediment within the impoundment
-allow for discharge at the flowline as opposed to discharging over the stoplogs
-increase safety for staff by removing the need to enter the water or remove logs during high flow situations

b. Moss Lake GTR areas will no longer serve as a green tree reservoir, but will function as a floodplain forest whose hydrology will attempt to mimic what the natural influence of the Muscatatuck River would be without dikes and structures while still retaining impoundment capabilities on 175 to 200 acres of emergent marsh and moist soil habitat as originally planned in the refuge Master Plan and the 1978 EA for the benefit of all waterbird species that utilize the refuge and various other wetland dependent species.

4. Acquire the tools and or machinery necessary (i.e. explosives or amphibious excavator) to access and remove the beaver dams and other impediments to water flows on the creeks, at the various water control structures, and in other areas where drainage is impeded.

a. Work with regional heavy equipment coordinators, refuge supervisors, and upper level management to get the tools necessary.

b. Ensure that one staff member receives training and certification in the use of explosives within 2 years of the completion of this HMP for the purpose of removing dams and log jams.

6. Within 10 years of the completion of this plan remove portions of cross dikes at G2, M10, and M9 to allow unrestricted flow and influence from the Vernon Fork on those areas.

a. Prescriptions for G2 are outlined above.

b. Make cuts in the south and east dikes of M10, the south, east, and west dikes of M9 using bulldozers or excavators at strategic locations which will generally be the areas of lowest elevations including old stream beds and slough areas.

7. Specific annual prescriptions and direction for management of individual units will be outlined in annual water management plans (WMP) to be completed by February of each year and will follow guidance established within the 2008, 2009, 2010, and 2011 annual water management plans and this HMP.

Strategies for Bottomland Hardwoods (includes Green Tree Reservoirs):

8. Allow natural regeneration of trees to occur when possible and augment natural processes with planting seeds or seedlings when necessary.

a. Manage timber to promote regeneration of mast and cavity producing tree species; this includes ensuring a mixture of hard and soft mast species are present to allow a diversity of food sources for resident and migratory species.

9. Conduct forest surveys or inventories as time and budgets allow monitoring changes in health, composition, and structure of bottomland forests (at least once every ten years or as outlined in an approved inventory and monitoring plan).
10. Develop and implement a forest management plan for all forests within 5 years of HMP completion as a step down from this habitat management plan. The forest management plan will make prescriptions for implementing all strategies within this objective.
11. Conduct forest management activities such as thinning dense stands or midstory and selective harvest on a small scale to allow for habitat diversity and opening of canopy to stimulate plant growth, regeneration and recruitment on forest floor (based on recommendations from FWS foresters and the forest management plan).
12. Conduct a study within 10 years of the completion of this plan to learn more about the hydrology and geomorphology of the Refuge.

a. This study can be conducted in house if staff has adequate expertise, or coordination with the regional hydrologist, USGS, IDEM Water Resources, IDNR Water Division, or contracted with experts in the field of Hydrogeomorphology (HGM) such as Dr. Mickey E. Heitmeyer.

b. Acquire detailed topographic information of bottomland areas and the entire refuge to inform the HGM study.

c. Use results of the HGM study and associated recommendations to amend, if necessary, the objectives, strategies, and prescriptions in this HMP and prepare for the 2024 CCP.

13. Timber stand improvement to include thinning dense stands, selective harvest on a small scale and deadening cull trees that are competing with more valuable wildlife trees to allow for habitat diversity and opening of canopy to stimulate plant growth, regeneration and recruitment on forest floor.

a. As outlined in an approved Forest Management Plan, apply appropriate silviculture treatments to manage forest health, species composition, and age structure.

b. Treatments may include non-commercial forest stand improvement treatments (girdling, cutting, and/or applying herbicide to individual stems), and commercial timber cutting (thinning, improvement cuttings, and regeneration cuttings).

c. Thin young stands of trees (pre-commercial) using appropriate methods to reduce competition for resources and allow residual trees to develop into healthy, advanced stands.

14. Restore hydrology and micro/macrotopography based on current knowledge, and if/when available, future recommendations from hydrogeomorphological investigations.

a. Attempt to replicate historic conditions that included hydrologic features such as depressions, oxbows, and swale topography, also, to replicate the permanent, semi-permanent and seasonally flooded wetlands that were historically present in the Muscatatuck River Basin.

b. Provide vernal pools where feasible by excavating shallow depressions.

-This focused on areas of bottomland restoration where equipment access is not restrictive.

-Areas to be considered for this activity primarily include M8, M9, and M10.

15. Reduce fragmentation by immediately allowing the East and West River trails to

revert back to forest.

a. Monitor areas for colonization of priority invasive species

b. Remove invasives as outlined in an approved Integrated Pest Management Plan.

16. Specific annual prescriptions and direction for water management of individual units will be outlined in annual water management plans (WMP) to be completed by February of each year and will follow guidance established within the 2008, 2009, 2010, and 2011 annual water management plans and this HMP.

Objective 1.3: Grassland

Maintain approximately 470 acres of open grassland to benefit wildlife viewing and to provide habitat for Sandhill and Whooping Cranes, as well as provide limited nesting, quality resting, and high quality forage habitat for migratory bird species. These areas should be capable of providing high-quality feeding habitat for listed species (e.g., Henslow's Sparrow), waterbirds (e.g. Blue-winged teal) and other migratory birds (e.g. , Bobolink, Dickcissel, Loggerhead Shrike, Grasshopper Sparrow and Sandhill Crane), and contribute to the native biological diversity of the Refuge. In addition to 80 acres of existing grassland areas, approximately 310 acres of currently agricultural land and approximately 85 acres of formerly cropped but now reconverting lands will be managed for grassland habitat within six years of the completion of this plan.

Rationale: Pre-European settlement vegetation within the current boundaries of the Refuge was dominated by deciduous forest with little to no open grasslands occurring except small openings where natural events (i.e. wind throws, tornadoes, or beaver) created gaps in the forest (Jackson 1997). Small temporary and permanent forest openings are part of the historic vegetative condition of the Refuge. Furthermore, the diversity of birds present at the Refuge can be attributed to the diverse habitat types and many wildlife enthusiasts, observers, and bird watchers are drawn to the Refuge because of the diversity of species and habitats. The diversity provides Refuge visitors with quality wildlife-dependent recreation opportunities. Even though historically larger grasslands were not prominent on the Refuge, benefits to grassland bird species may still be derived from the retention and/or expansion of grassland habitat in strategic locations. Populations of many grassland bird species are declining, in part because of loss of habitat (Herkert 1994). These grasslands can serve as habitat for Grasshopper Sparrow, Henslow's Sparrow, Eastern Meadowlark and Sandhill Crane. They will also provide habitat for Kirtland's snake (Conant and Collins 1991) and confer obvious benefits to a wide array of resident species and migratory bird species.

Strategies and Prescriptions:

1. Develop a grassland management plan within five years of HMP completion.
2. Protect, restore, or enhance the blocks of grassland habitat.

a. Ensure they are comprised of short, medium, and tall height, and variable density patches containing diverse structure (e.g., bare soil, stiff-stemmed forbs, and sparse woody vegetation) with a 75 percent grass and 25 percent forbs mix

b. Ensure the presence of a minimum of six grass species and a minimum of 30 herb species and utilize adaptive management strategies for promoting native

grassland plant diversity such as those developed through Region 3 adaptive management projects.

c. The Refuge will focus on creating blocks of grassland habitat that are structurally open and free of major linear woody edges. In most cases, woody cover will represent less than 5 percent of the grasslands habitat.

d. Maintain Refuge grasslands through periodic burning and/or mowing with some grasslands (115-235 acres ~ 25-50 percent of the total grassland landscape) remaining free from burning or mowing, between 3 and 6 years to provide habitat for Henslow's Sparrow, Northern Bobwhite Quail, Field Sparrow, and other species that prefer a well-developed duff layer and the presence of some shrubs. GMU1 would likely be the best fit for longer interval burning and mowing as its overall acreage is greater, giving more promise of benefit for the aforementioned species.

e. Some thicket areas and isolated trees will be allowed to persist along grassland edges to provide breeding habitat for Loggerhead Shrike, Bell's Vireo, Yellow breasted Chat, and other species in some/all of the grassland areas and to promote the desired feathered edge effect.

3. Place grassland openings along the perimeter of the Refuge and along the wildlife auto tour route to minimize fragmentation, promote habitat diversity, and promote wildlife observation.

4. Periodically inventory grasslands (i.e. every 5 years) to determine plant species composition and stem density and to detect invasive species. Complete the first inventory within 4 years of this plan's completion and use to guide the Grassland Management Plan.

a. Follow guidelines described within an approved inventory and monitoring plan

b. Follow guidelines described within an approved integrated pest management plan

5. Under the guidance of an integrated pest management plan, work toward removing and preventing the establishment of non-native invasive species within Refuge grasslands with special emphasis placed on autumn olive, multiflora rose, and Johnson grass.

6. Promote soft or feathered edges, which are considered to be more beneficial to wildlife than hard edges, on all grasslands within 10 years of the completion of this HMP. Soft or feathered edges are areas where habitat transitions from forest to old field type habitat to grassland as opposed to grassland that abuts directly with mature forest.

a. These soft edges can be created by not mowing within a specified distance from the forest edge (i.e. 20ft to 50 ft. band)

b. Allow small shrubs and trees to dominate the edge for several years and then brush hogging or forestry mowing (Fecon) the edge every 3-8 years depending on species composition and growth rates to maintain that early successional shrub type edge.

-Shrubs should not be allowed to exceed two inches in diameter to allow ease of removal by heavy equipment.

-Species composition is not important; the strategy is to provide structure for edge species.

7. Grasslands require adequate fertility; many of the grasslands were previously farmed and soil nutrient levels may not have been restored to optimum or natural conditions.

a. Soil tests should be conducted on all grassland areas within 4 years of HMP completion and then at least once every ten years thereafter.
b. Lime and fertilizer should be applied based on soil test results to improve growing conditions.

8. Remove major linear edges (i.e. fencerows, etc.) within the interior of Grassland units 1, 2, and 4 within 15 years of the completion of this HMP.
a. Use chainsaws, Fecon forestry mower, hydroaxe equipment to clear these areas and reduce fragmentation of the grasslands.
b. Where appropriate and as outlined in an approved grassland management plan, use fire to remove these interior linear edges.
c. Remove any fencing and old dumpsites from these areas.

9. Conduct management experiments utilizing adaptive management strategies to promote native vegetation and reduce fescue density within grasslands to increase structural and compositional diversity.
a. This may include strategically timed strip or patch disking to determine best practices to enhance grassland areas.
b. It may also include seeding of native vegetation especially within the current agricultural fields as they are converted to grasslands.
c. The areas associated with these adaptive management experiments should have pre and post-treatment monitoring completed to determine the response of native and invasive plant species.

Objective 1.4: Moist Soil Units and Emergent Marsh Units

Annually maintain moist soil units 1-7, the small western portion of M8, McDonald South, and Sue Pond under moist soil management to provide annual food crops and resting habitat for migratory waterbirds, Wood Duck habitat, and mudflats for shorebirds. A minimum of 75% of moist soil units will be maintained on an annual basis to produce beneficial moist soil plants and a minimum of 10% of the moist soil and marsh habitat will be managed to provide habitat for shorebirds (which may include small acreages of suitable habitat within primarily flooded moist soil and marsh units). A minimum of 70% of moist soil unit acreage will be flooded at optimum water levels during peak waterfowl migratory periods (November – March). Also, maintain an additional 238-634 acres (depending on Moss Lake water levels) of emergent marsh in McDonald North and Endicott Marshes, Minimarsh, and Moss Lake to provide feeding, resting, and nesting habitat for all waterbirds including secretive marsh birds, waterfowl, wading birds, and shorebirds. Average annual target use day levels for all managed wetlands combined are as follows: waterfowl (ducks, geese, swans) ~500,000 use days; shorebirds ~ 200,000 use days; wading birds (egrets, herons, etc.) ~ 40,000; cranes (sandhill and whooping) ~ 40,000. (The Restle Unit is considered separately in Objective 1.7.)

Rationale: Moist soil management is a widespread practice for producing a diverse mixture of native herbaceous plant foods and invertebrates. It partially mimics seasonal flooding that has long occurred in the Muscatatuck NWR lowlands, but moist soil units – areas impounded by dikes, and structures that permit precise control of water levels – allow managers to produce conditions favorable to growth of native plants such as millets and sedges (Haukos and Smith 1993). Seeds produced by these plants provide balanced

nutrition for migrating waterfowl, and also provide food and habitat for other migratory birds and wildlife. The diverse mixture of native plants also creates conditions that produce abundant invertebrates, a high protein wildlife food source. Emergent marshes are some of the most productive natural systems in the world (Waide et al. 1999). The productivity, however, is derived from the dynamic nature of hydrological events and the resulting vegetative responses (Haukos and Smith 1993). Cyclical management of marsh units, including periodic full and partial drawdowns need to be incorporated into the water management regime. Changes in these systems could drastically increase use of the units and the Refuge by waterbirds, increase amphibian and macro invertebrate production, and increase the overall plant diversity of the marshes and the Refuge.

Strategies for Moist Soil Units:

1. Disturb an average of one-third of the moist soil unit acreage annually to set back succession.
    a. Rotate the units such that they are disked or mowed on average every third year.
        - Five years should be the maximum amount of time between disking.
        - Mowing can be used in years 3 and 4 in highly productive units, if the unit needs it, to knock back pest plants (i.e. cocklebur) and woody species (i.e. buttonbush) and extend the life of the unit between diskings.
    b. In wet years portions of certain units (M2, M4, M5, M6, M7) may have to be partially disked one year and the remainder disked the following year if conditions allow.
    c. Disturbances should be conducted as early in the growing season as possible to allow adequate time for moist soil plant production in the same year (May, June, and July).
        -Sometimes early disturbance is not feasible and later disturbances will only help to set back succession. Benefits in terms of more robust plant growth of desirable species will be observed in the following year.
        -Delayed disking, i.e. August and September, can confer benefits to shorebirds by providing mudflat habitat upon reflooding late in the season following the action.
        -Irrigation of a given unit following disturbances will serve to facilitate and promote growth of beneficial moist soil plants when soil moisture levels are low due to high temperatures and lack of rainfall. Irrigation is possible on M1, M2, M3, and M4 from discharges from Richart Lake; it is also possible in some years from Moss Lake to M7, via pumping from Mutton Creek into M6, pumping from Storm Creek into M5 and McDonald North, and from Judy Pond into Sue Pond.
2. Moist soil units will be maintained in early successional native plant communities for the production of annual seed crops.
    a. Not more than 25% of a given unit will be managed to persist in perennial vegetation.
    b. Willows, cottonwoods, and other tree species should not be allowed to colonize moist soil units; treatment actions will be triggered when levels reach 10% or at a minimum every five years.

c. Annual species such as wild millets, native sedges, chufa, rice cutgrass, and ammania among other beneficial species, should dominate approximately 75% of the remainder of the units. This will provide an estimated 250,000 waterfowl use days (referred to in the literature as Duck Use Days or Duck Energy Days) annually from moist soil use; this assumes an average production of 500 lbs of seed per acre. Also, this constitutes half of the expected total waterfowl use of the refuge.

d. Continue documentation and experimentation with the timing, rate, and frequency of drawdowns and resultant vegetative responses to gain more knowledge of each unit's potential and report this information in the water management plan; potentially use annual habitat work plan databases to generate multiple year reports and track responses.

e. Avoid long duration shallow flooding throughout the spring and summer as this tends to result in promulgation of dense stands of primrose (Ludwigia spp.) which confer little to no benefit to most waterbirds.

f. Avoid fast drawdowns (less than 3 to 4 weeks in duration) after July 1st as this tends to yield few beneficial moist soil plants and can lead to severe problems with cocklebur.

d. Avoid prescription approaches for individual units and promote variable management with drawdown timing and rates differing among years within a given unit to prevent pest plants from dominating. Repetitive management actions can be extremely harmful to overall productivity.

-Utilize graphs such as those depicted in Figure 26 to analyze management of previous 3 to 5 years and to ensure variability and recommend future management

-Use water level, vegetation, and wildlife response data as previously described in conjuction with multi-year analyses to determine management direction on an annual basis. On the fly monitoring and adjustments should be made based primarily on vegetation responses and weather conditions.

-Basic guidelines for moist soil management, examples of applied decision processes, and a foundation for future annual water management plans can be found within Muscatatuck NWR Annual Water Management Plans, years 2008-2012, housed at the Refuge Office.

-An approved inventory and monitoring plan will outline data collection protocols for the collection of water level, waterfowl poplation estimates, and vegetation data sets.

-General guidelines for moist soil management can be obtained online through several publications; however, it must be noted that management of impoundments must rely heavily on local information collection at each individual unit to provide for adequate decision making. A listing of recommended publications can be found below.Some aspects of the guidance obtained from online publications will not be pertinent at Muscatatuck, e.g. some publications speak of reduced viability of early season drawdowns; this is not the case at Muscatatuck NWR on some of the units.

Suggested readings for moist soil management general guidelines:

http://www.fws.gov/columbiawildlife/MoistSoilReport.pdf
http://el.erdc.usace.army.mil/elpubs/pdf/trel99-11.pdf
http://msucares.com/pubs/publications/p1864.pdf
http://www.ms.nrcs.usda.gov/technical/NRCS%20Wetland%20Mgt%20for%20Waterfowl.pdf
http://digitalcommons.unl.edu/icwdmwfm/ (Waterfowl Management Handbook)

3. Prevent public access on moist soil and emergent marsh dikes and levees, beginning one year after the completion of this plan, during peak migratory seasons to decrease disturbance and increase waterbird use of those areas

a. Intall public use signs consistent with policy.

b. Close the dikes and levees to hiking, bird watching, etc., from October 1 to 30 April.

4. Maintain most moist soil units (at least 75%) dry throughout much of the growing season (April through September) to produce food for migratory birds except where shallow irrigation will aid in beneficial moist soil plant production, or when managing a unit for a late summer/fall drawdown to benefit fall migrant shorebirds, or to deter pest or invasive plant species.

a. Drawdowns should be dynamic with interannual and interseasonal variations in the hydrology present within each unit. Ensure that water management regimes between and within years incorporates variation in depth, duration, and in the timing of drawdown and reflooding. The seasonal and annual shifts in hydrologic condition set the stage for vegetation development within the various impoundments.

b. Graphs such as those depicted in Figure 26 should be created annually as part of the water management plan and used to plan drawdowns for the upcoming seasons. This graph was used to plan 2011 water management actions. This ensures variability in drawdown timing among years and helps to answer questions about why certain species, especially pest species, dominate a particular unit. The same types of graphs can be used to plan longer term water management actions and compared in successive years to see if goals were achieved. A general guideline for the use of these graphs follows.

-Review the previous years' vegetation data

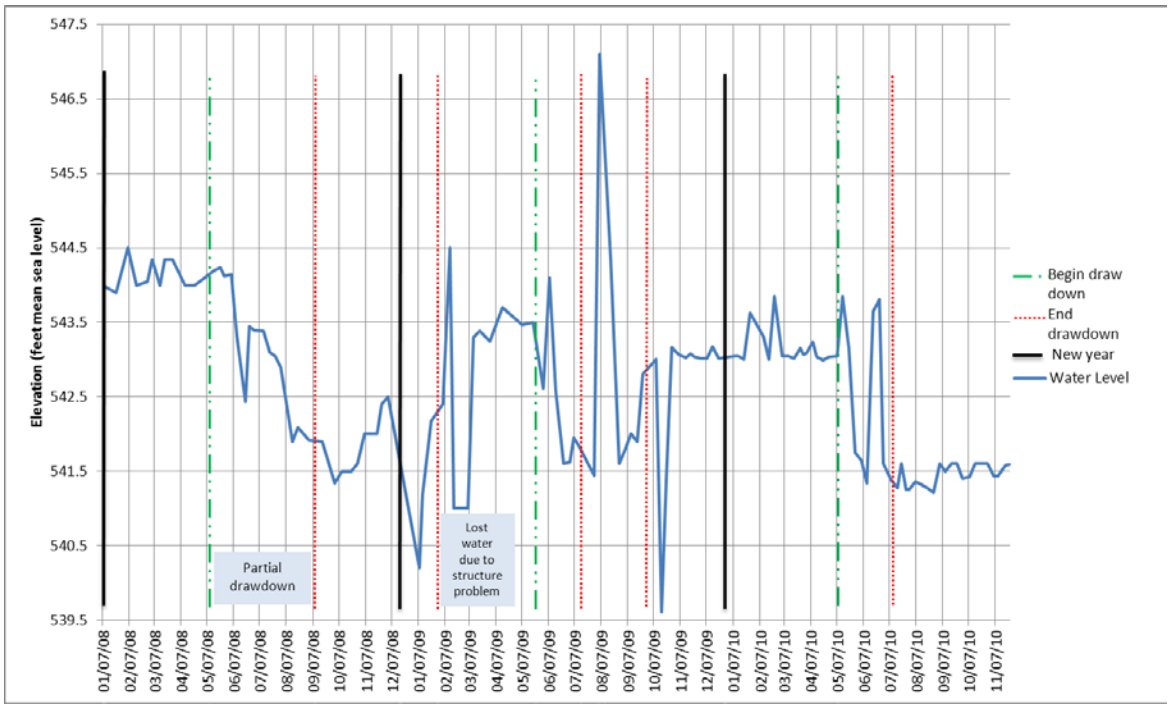
-Review the previous years' drawdown timing

-Plan future years' timings such that they do not replicate the same hydrologic regime; i.e. if in year A a fast early drawdown occurs, in year B propose a mid-season slow drawdown, in year C propose a late season drawdown (ensuring only a slow drawdown to maintain soil moisture at sufficient levels for moist soil seed germination and survival). Modify the recommendations to benefit beneficial moist soil plants and/or discourage benefits to undesireable moist soil plants.

-Utilize definitions for early, mid, and late season drawdowns and

beneficial versus undesireable moist soil plants as defined by Fredrickson and Reid (1988).
- Observe the previous years' flood up schedules and timing
-If in year A flood up occurred in September, propose a flood up beginning in November in year B, and a flood up in October in year C.
-The proposed plans should be flexible enough to accommodate redirection if conditions warrant change in the plans, e.g. if cocklebur is found to be problematic in year B and flood up is schedule for November, it may be necessary to flood up in August or September to control the nuisance plant population. If rainfall is not sufficient and no beneficial moist soil plants are being produced and the unit is dominated by woody plants or non-beneficial perennials above the threshold level of 25% of the unit, it may be best to shift direction and conduct a disturbance action such as a mowing followed by disking and then flood the unit shallowly and slowly draw down the unit again to provide mudflat habitat for shorebirds. The list of possible scenarios and viable management alternatives is quite large and highly dependent on other variables such as rainfall, water availability, soil moisture, temperature, time remaining in the growing season, equipment availability, staff availability, etc.
-It is important to reiterate here that management of impoundments is an art; one must rely on some level of past experience, either personal or those that were documented in previous plans, in combination with instinct and a prophetic approach to management which will largely rely on understanding probabilities of weather patterns including temperature, rainfall, etc. based on historical records and cyclical trends, and incorporate predictions of plant response.

Figure 26: Three years of water level manipulations in moist soil unit six: 2008-2010.



5. Maintain dikes and water control structures (WCS) in good working order
    a. Dikes and WCS should be mowed frequently to keep them free of trees and shrubs
    b. Repetitive mowing improves visibility while operating equipment and deters muskrat and beaver from burrowing thus preventing excessive damage (i.e. honeycombing) and disruption of water management capability.
    c. Repetitive mowing (~6x per year) reduces the viability and survivorship and recruitment of reed canary grass (RCG).
    d. Mowings should begin in March but no later than the first of April to discourage grassland nesting birds and to prevent RCG from going to seed in May.
6. Provide additional fall-flooded, shallow-water habitat for shorebirds when feasible.
    a. Use the bathymetric maps and time series flood maps to optimize the spatial extent of optimum feeding conditions (i.e. 0 to 10 cm of water) for shorebirds
    b. Shorebird habitat should be rotated among the following units, McDonald Marsh North, M6, M5, M3, and portions of Richart, Stanfield, and Moss Lakes, as these are the best suited for shorebird management. Rotation should be planned such that management of each unit remains dynamic among years and repetitive management actions are avoided.
7. Begin draining some moist soil units or portions of those units in March/April when feasible to expose mudflats by mid-April to benefit migrating shorebirds that can feed on invertebrates.
    a. 10% of the total moist soil acreage should be managed annually to produce suitable shorebird habitat

b. Water depths in that 10% should be between 0 to 10 cm in depth.

c. Use the bathymetric maps and time series flood maps contained within the Bathymetric models of Muscatatuck NWR Units (housed in the biology office library or electronic versions available within the GIS folders and files on the Refuge's sharedrive) to optimize the spatial extent of optimum feeding conditions (i.e. 0 to 10 cm of water) for shorebirds.

8. Manage water levels within moist soil units to provide maximum spatial extent of optimum depths for dabbling ducks (0 to 10 inches), shorebirds (0 to 4 inches), and wading birds (0-12 inches), timed to coincide with peak migrations.

a. Use the bathymetric maps and time series flood maps to optimize the spatial extent of optimum feeding conditions (i.e. 0 to 10 cm of water) for waterbirds (waterfowl, wading birds, shorebirds, and marshbirds) and outline these conditions in annual water management plans.

b. Use historical waterbird data from Refuge records (i.e. from the past 20 years) to determine peak migration timeframes for focal species and important taxa.

9. Remove trees (with the exception of cypress trees in units M3 and M5), stumps, fallen logs, and other woody debris from Units M1-M6 via bulldozer or other means, yet ensure that topsoil is retained within 10 years of this plan's approval. This will facilitate proper management of these units especially during maintenance/disturbance operations and will help to prevent the establishment of willows and other undesirable woody vegetation within the units.

a. Complete M1 and M4 in the year of this plan's completion

b. Within two years of this plan's approval, complete M5 and M6, however, leave buttonbush in M6.

10. Remove debris piles from rehabilitation work within two years of the rehabilitation to allow disturbance throughout the units via disking or mowing and to prevent establishment and continued issues with the proliferation of willows within the units. If necessary utilize prescribed fire to eliminate current and/or future debris piles.

11. The refuge will continue to produce annual water management plans that will direct the specific management prescriptions for each unit.

a. Water level monitoring will be conducted on a weekly basis and data should be input into the currently used excel database, or if possible switch to the SWIM database as soon as possible.

b. Weekly waterfowl counts will continue and should be expanded to include other waterbird guilds including shorebirds, and wading birds

c. Conduct annual vegetation monitoring to gather data necessary, including windshield type surveys, seed production estimates, and vegetation distribution mapping to make management decisions and to evaluate and document management actions and corresponding responses. Moist soil plant production should be surveyed and estimated prior to the end of the growing season, between September and October, for all managed units

d. Analyses of waterfowl, water level, and moist soil plant response data sets should be included in annual water management plans to continue to build knowledge of wildlife responses to management actions and water level management. Current methods for analysis rely on summary information and comparisons of a series of charts, graphs, and tables to determine anecdotally, the

level of success of management actions. This approach leads to more of a subjective analysis than a quantitative and qualitative analyses. A more structured, quantitative, qualitative, and unified approach of consolidating and interpreting the three data sets needs to be developed and should be completed within five years of this plan's creation. Development of new approaches to analysis will include the following tasks:

-The Refuge will seek input from Migratory Bird Office, Zone, Regional, and National Biologists, as well as from academic researchers, USGS, and other agency biologists

-Consult with other refuges to determine their methods

-Conduct a thorough literature review of existing methods

-Develop in cooperation with partners a model for data set analysis, interpretation, and the process for utilizing such information to adequately inform the planning process.

12. Control exotic and invasive plant and animal species as outlined in an approved integrated pest management plan.

13. Monitor, map, and control invasive species that occur on dikes and levees, most importantly reed canary grass to prevent spread to managed units.

a. Follow guidance established in approved integrated pest management and habitat and species inventory and monitoring plans.

14. Conduct regular mowing of the dikes and levees (at least six per growing season from April to November) to discourage use by muskrat and beaver, reduce the presence and density of reed canary grass, prevent establishment of woody vegetation and trees, and to allow increased visibility of eroded areas, muskrat burrows, sinkholes, logs, debris and other hazards that may be present. This ensures management capabilities of the managed units are not compromised

15.Maintain water within the borrow pits of moist soil units for the benefit of a wide array of wetland dependent wildlife species but specifically for wading birds, i.e. herons and egrets.

a. Consult the time series flood maps to determine drawdown elevations that would allow borrow pits to remain full.

b. Removal of water from borrow pits in M2, M6, and McDonald Marshes will be necessary in years when these units have planned disturbance projects because no access across the borrows are currently available.

- To alleviate this problem, large diameter culverts (24 inch or greater can be installed and crossings created to be completed within 10 years of this plan's completion.

-A second option is available which entails using either larger rubber or wooden wetland access mats. Even more promising are new types of floating mats for heavy equipment access in marsh habitats.

16. As funding and staffing levels permit, repair damaged/eroded areas of dikes and levees and when possible reshape levees to at least a 5:1 slope to deter burrowing of aquatic mammals and to prevent damages and soil loss from mass wasting and other erosive forces to ensure management capabilities of the units.

a. When possible avoid using rip rap and/or netting materials to prevent erosion

- these solutions are problematic for a variety of reasons, i.e. turtles cannot

aestivate in areas of rip rap and snake mortality is often an issue with erosion control netting.

b. Bulldozers or excavators can be used to reshape dikes, followed by a cutaway disk and then finish disk.

c. Repair of dikes should be conducted as early in the growing season as feasible such that areas can be reseeded and the vegetation can become well established prior to fall/winter dormancy.

d. Reed canary grass should be controlled with herbicides prior to moving dirt to reduce the probability of reestablishment following reshaping. Glyphosate applications in March, April, and May seem to be quite effective at Muscatatuck NWR.

17. Remove the southern M9 and M10 dikes, and their cross dikes to allow M9 and M10 to naturally flood from the Vernon Fork.

a. Allow natural regeneration of these areas to occur restoring these areas to bottomland/floodplain forests.

b. Supplement natural regeneration with plantings or seeding of desirable species as outlined within approved forest management and planting plans.

18. Remove the small levee between M4 and G4 to prevent unnatural and prolonged flooding of G4 and restoring the ephemeral stream that meanders through the area by 2012.

19. Through education and outreach efforts effectively communicate to the public the philosophy and reasoning for wetland management and dike closures during migratory periods especially targeting the wildlife observation, photography, and hunting user groups.

a. Provide information in news releases in the local area

b. Provide information via public presentations to be held at the visitor's center auditorium in 2012, 2013, and then every two years after.

c. Educate staff and volunteers on the impacts of disturbance to waterfowl so they can adequately address questions or concerns they receive from the public.

d. Create and provide fact sheets describing wetland management to staff and volunteers and provide public copies at the visitor's center.

20. Specific annual prescriptions and direction for management of individual units will be outlined in annual water management plans (WMP) to be completed by February of each year and will follow guidance established within the 2008, 2009, 2010, and 2011 annual water management plans and this HMP.

Strategies for Emergent Marsh Units:

21. Ensure proper water levels to promote the development of diverse complex vegetative structure within the units and to provide water depths suitable for waterbird use.

a. Prevent prolonged, deep, flooding of Marsh units (i.e. water depths greater than two feet.

b. Utilize bathymetric maps and time series flood models to optimize the spatial extent of optimum water levels for intended waterbird guilds [optimum depths for dabbling ducks (0 to 10 inches), shorebirds (0 to 4 inches), and wading birds (0 to 12 inches)].

22. Increase the distribution and interspersion of emergent vegetation.

a. Ensure that water management regimes between and within years incorporates variation in depth, duration, and in the timing of drawdown and reflooding. The seasonal and annual shifts in hydrologic condition set the stage for vegetation development within the various impoundments.
b. Conduct periodic drawdowns (at least once every 3-5 years) to consolidate sediment, increase plant germination, and reduce fish populations.
c. Conduct periodic disturbance of emergent marshes through drawdown and techniques such as mowing, disking, and burning to retain the early successional qualities of the marshes and prevent colonization and proliferation of willows, cottonwoods, buttonbush and other woody species with the exception of Moss Lake unless specified in the Moss Lake restoration plan.

- Threshold levels for woody species removal is 20% coverage of the unit
- Threshold sizes for woody species is 2 inch diameter (any larger and brushhog use becomes difficult and bull dozers become necessary)
- Perrenial vegetation is not seen as problematic within marsh units as it is in moist soil units unless stands become dominant (>50% of the unit) or if monotypic stands develop.
- Monotypic stand development should be discouraged; threshold levels for treatment of monotypic stands would begin at abundances or distributions on 50% of the the unit

23. Control exotic and invasive plant and animal species.
a) Threshold levels will be determined and outlined within an approved integrated pest management plan
b) Recommendations will be made by consulting with a decision support tool, such as that being utilized and developed as part of the Region 3, Eastern Broadleaf Biological Network, Forest Invasives Adaptive Management process.
24. Conduct biennial or triennial marsh monitoring using established rapid assessment protocols for wetlands including vegetative, amphibian, and macro invertebrate indices of biotic integrity and secretive marsh bird surveys.
25. Specific annual prescriptions and direction for water management of individual units will be outlined in annual water management plans (WMP) to be completed by February of each year and will follow guidance established within the 2008, 2009, 2010, and 2011 annual water management plans and this HMP.

Objective 1.5: Ponds/Oxbows/Vernal Pools/Ephemeral Wetlands

(This is a new objective, not included within the CCP)
Passively manage, when feasible, all ponds, oxbows, vernal pools, and ephemeral wetlands to provide habitat for resident and migratory species. Within 10 years of this plans completion, inventory and identify constructed wetlands that require monitoring and management intervention to protect the hydrology of adjacent forested areas. Within the same timeframe, identify and deconstruct, where feasible, constructed ponds that can be reverted back to ephemeral streams.

Rationale: Over 70 constructed ponds and small wetlands exist at Muscatatuck NWR; countless oxbows, vernal pools, and ephemeral wetlands are present. Plants, plant litter, and invertebrate populations within seasonal wetlands are the basis of the food chain and

are largely affected by the length of the hydroperiod. These plants and invertebrates confer benefits to a wide array of both resident and migratory wetland dependent species. Many of these wetlands exist within the forest matrix, providing breeding, feeding, and rearing habitat for amphibians, reptiles, migratory birds, and Wood Ducks. Ephemeral wetlands are extremely important to forest amphibians as the areas tend to prohibit fish populations from developing which allows for increased amphibian productivity which in turn benefits other predator species including reptiles such as the Copperbelly Watersnake and migratory birds such as herons.

Many of the constructed wetlands were created by damming ephemeral woodland streams and have overflow pipes and some have emergency spillways. Beaver activity at the outflow areas has caused issues in the past with flooding of forested areas adjacent to the wetlands and by increasing depths and hydroperiods within the wetlands themselves. Increased depths increase a wetlands capacity to maintain a fishery component. Monitoring for and removing obstructions is the main course of action to protect adjacent forests, discourage fish production, and encourage the productivity of plants and animals within these habitats, especially amphibian populations and their predators.

Strategies:

1. Within 10 years of the completion of this HMP, as outlined in an approved inventory and monitoring plan, inventory and identify constructed wetlands that must be monitored for proper hydrology and identify those that can be restored back to ephemeral streams and where feasible conduct such restorations as outlined in an approved restoration plan..
    a. Utilize historic maps and aerial photos to create a master list of constructed wetlands on the refuge.
    b. Visit each constructed wetland within the next ten years to determine the need for water level monitoring.
        -Wetlands with overflow pipes, water control structures, or emergency spillways should be monitored as outlined within an approved habitat and species inventory and monitoring plan.
        -Wetlands storing equal to or greater than 50 acre/feet of water and have dams greater than or equal to 6 foot in height (measured from the lowest point of the toe of the dam to the crest) should be monitored.
        -Wetlands that are impacting adjacent or upstream forested areas should be monitored.
2. Conduct regular inspections (minimum is an annual inspection) of the outflows of any wetlands identified for monitoring, removing obstructions to flow as necessary.
3. Determine which ponds have levees that can be breached to reduce water levels, fish populations, and maintenance costs or to restore ephemeral and/or permanent streams.
4. Breech levees as funding and staffing levels permit with a target of completing all identified wetlands within 15 years of this plan’s completion.
    a. If outflow pipes exist, place breaches in those locations
    b. If no outflow pipes exist, place breaches in the following locations:
        -obvious overbank discharge areas
        -lowest elevations surrounding the pond if no obvious outflow
        -emergency spillways if present

5. Allow passive management where feasible.
6. Remove nuisance aquatic animals as necessary to promote proper drainage of wetlands that require monitoring and management.
    a. Follow measures outlined in the approved nuisance animal plan
    b. If trapping becomes an option in the future, guide activities to priority locations
7. Ensure proper hydrology of all wetlands by preventing long duration, deep flooding of the creeks and Moss Lake.
    a. Strategies are outlined in Objectives 1.2, 1.4, 1.6, and 1.7.
8. Specific annual prescriptions and direction for water management of individual units will be outlined in annual water management plans (WMP) to be completed by February of each year and will follow guidance established within the 2008, 2009, 2010, and 2011 annual water management plans and this HMP.

Objective 1.6: Lakes/Reservoirs

(This is a new objective, not included within the CCP)
Manage to provide habitat for migratory birds, with a special emphasis on migratory waterbirds, on the Refuge's three lakes/reservoirs: Moss Lake, Richart Lake, and Stanfield Lake. Targets of 100,000 waterfowl use days in Moss Lake, 75,000 use days in Richart Lake, and 10,000 use days in Stanfield Lake. Focal species within Richart and Moss Lake consist primarily of dabbling ducks (all species), shorebirds (all species), wading birds (all species), and sandhill cranes. Stanfield Lake will be managed primarily to provide deep water habitat to diving ducks and as a reservoir to provide water for management of Moss Lake.

Rationale: Richart and Stanfield Lakes were designed as reservoirs to provide water to gravity feed moist soil units, marshes, green tree reservoirs, and Moss Lake. Discharges from Richart Lake can be used to fill M1, M2, M3, and M4 or can be released into Storm Creek to raise the levels of M5, M4, and Moss Lake. Discharges from Stanfield Lake flow into Moss Lake; water from Moss Lake can be diverted to fill M7, M8, M9, and portions of M10 borrow ditch. Water should generally be released from these two reservoirs in the late summer and fall to provide habitat for migrating waterbirds. Water is sometimes used in the summer for irrigation of the units.

Drawdowns of Richart conducted in 2008, 2009, and 2010 resulted in wildlife responses that indicate the lake can provide substantial amounts of waterbird habitat for a wide array of species when water levels are lowered. Water is removed from Richart between September and November and used to fill moist soil units M1, M2, M3, and M4, and to provide large expanses of shallow water feeding habitat suitable for shorebirds, dabbling ducks, and other fall migrant waterbirds. Waterfowl use strongly corresponds to the reductions in water levels. Approximately 28,700 total waterfowl use days were recorded for Richart in 2009 of which approximately 65% occurred from September through December when water levels were at their lowest (~554 MSL). The majority of waterfowl use is expected to occur between November and March; water levels should be managed lower during that time period to benefit migrant dabbling and diving ducks, as well as other focal species such as Tundra Swans and Sandhill Cranes. Complete drawdown will not be attempted on this lake in order to protect the fisheries component

within the lake and to maintain adequate water supplies for future irrigation and/or flooding of downstream moist soil units.

Moss Lake water levels directly influence water levels throughout the watershed and can cause flooding of the forests throughout the Birds silt loam soil series. These areas have experienced the most dramatic changes in habitat type on the Refuge with over 1,000 acres affected. The impacts are recognized as community shifts from bottomland forest to scrub/shrub and emergent marsh habitat types. Areas most affected are those that occur within the 537.8 to 542 feet MSL elevational range. These areas are likely to be extremely important to Indiana bats, neotropical migrants, and a whole host of other forest and forested wetland dependent species. Waterfowl use within Moss Lake can be extremely high when water levels are low enough to facilitate feeding (

Strategies:

1. Within two years of completion of this plan, conduct bathymetric investigations of Richart and Stanfield lakes. When funding and a method become available, but preferably within four years from this plans completion, conduct bathymetric investigation of Moss Lake.
    a. This work will be consistent with the Moss lake restoration plan that is developed under Objective 1.2 of this HMP.
    b. Analyze the data from bathymetry studies to:
        - determine the volume of water within each lake
        -maximize the spatial extent of optimum habitat conditions for 49 species of waterbirds (10 inch depths or less) during peak migrations
        -determine minimum water levels necessary for flooding moist soil units for waterbirds (volume investigations) while maximizing beneficial waterbird habitat within the lakes themselves.
        -develop time series flood models within ArcGIS
3. Manage water at lower levels such that irrigation or filling of the moist soil units is possible, yet provide suitable habitat for dabbling ducks (0 to 10 inches), shorebirds (0 to 4 inches), wading birds (0-12 inches), and other waterbirds.
4. Manage water within the lakes to provide dynamic temporal (interannual and interseasonal) conditions, encourage vegetative development within Richart and Stanfield, and increase overall productivity.
    a. Expansion of American Lotus within Richart Lake should be encouraged; the plant is native, provides excellent escape cover for wood duck broods and molting adults, the seeds are utilized by some waterfowl and other wildlife, and it provides habitats for an abundance of invertebrates that are consumed by a wide variety of waterbirds, amphibians and reptiles. This will mitigate for losses in available habitat in Moss Lake, and from movement away from managing moist soil units as brood marshes.
        - natural expansion and propagation can be achieved through lowering water levels in the fall, (August-November) on an annual basis.
        - propagation can be enhanced by collecting and scattering seeds after water levels are lowered, focusing on scattering in shallow areas above silty soils. However this is not considered to be a high priority and will

only occur if time and staffing allow on small areas (100 sq. ft) annually.

b. Utilize multi-year evaluation and planning processes in the annual water management plans (such as the 3-year graphs shown in Objective 1.4, Strategy 4, prescription b) to plan dynamic water level management actions.

5. Reduce water levels in the late summer and fall to benefit migrant waterbirds and enhance American Lotus

a. Elevations should be dropped at a minimum of one foot to 554.5 feet msl but more appropriately to levels below 544.0 feet msl to 543.0 msl. These recommendations are based on observational experiences from 2008-2011. Further refinement of these recommendations can be made following the analyses of bathymetric data and related products.

b. Water should be used, when possible, to reflood or partially reflood MS1, MS2, MS3, and MS4 as opposed to sending discharge waters down Storm Creek into Moss Lake.

6. Prevent impoundment of water higher than 540.0 MSL in Moss Lake during the growing season (February through November) as described within Objective 1.2 of this HMP.

7. Reflood Moss Lake only after senescence of seedlings and saplings which generally occurs later than senescence of mature trees and will rarely, if ever, occur prior to November 15th.

8. Prior to the end of the dormant period (generally in February) and definitely prior to bud break and leaf out ensure the drawdown of excess waters above the 540.0 MSL mark within Moss Lake to protect forests that may be initiating root respiration in late winter

a. It is advised to pull all stoplogs prior to this period as the structure will not discharge at a fast enough rate to keep up with inflows from runoff).

b. Stoplogs should not be set higher than 539.0 after February 1st.

c. All stoplogs should be removed by March 1st.

9. Ensure proper correspondence and outreach among staff, partners, and the general public to explain the rationale and reasoning for changing water regimes within the lakes/reservoirs.

a. The purpose of the reservoirs is to help meet migratory bird management objectives, as outlined within the rationale, and to serve as reservoirs for meeting those objectives within other management units as outlined within those wetland management objectives and strategies.

b. Management of the lakes for fisheries purposes are not necessarily in opposition with migratory bird management objectives, although providing normal means for public access is in many cases, i.e. the boat ramp access is limited when water levels are lowered below the 559.0 feet MSL elevation.

- Very little public complaints were received in 2010 when levels dropped below 558.0 feet MSL.

-Fishermen that launched boats from the bank during that period were quite successful as conditions had concentrated fish to a greater extent

10. Specific annual prescriptions and direction for water management of individual lake units will be outlined in annual water management plans (WMP) to be completed by February of each year and will follow guidance established within the 2008, 2009, 2010, and 2011 annual water management plans and this HMP.

Objective 1.7: Ditches/Creeks

(This is a new objective, not included within the CCP)
Manage the Refuge's ditches and creeks in a sustainable fashion such that the bottomland and/or riparian forests adjacent to the creeks are not impacted, degraded, or destroyed by flooding and such that management of other adjacent habitats is not impacted and restore flow, where feasible, to natural streams or portions of streams.

Rationale: The ditches serve several purposes at Muscatatuck NWR; in order of importance these are to facilitate drainage of the Mutton, Storm, and Sandy Branch Watersheds (including Refuge property and that of adjacent landowners), to provide a direct water source for filling certain wetlands, including McDonald North and South, M1 through M6, and Moss Lake. The ditches provide stream habitat for a variety of wetland dependent species including the Indiana bat, the wood duck, and the Copperbelly Watersnake.

Historic flows have been severely altered by roads and ditches causing disruption in natural drainage patterns. Several issues preclude the Refuge's ability to restore streams in many instances and well intentioned restorations have the potential to increase forest degradation and loss. Stream restoration may be feasible along portions of Storm and Mutton creeks and smaller tributaries where and when adequate discharge capabilities exist to allow those streams to function naturally. Restorations of streams or portions of streams must be conducted either following or in concert with modifying the major impediments to flow (CR500, CR400, and Moss lake dam) so that unnatural impoundment of forested areas does not continue or increase.

Water flows are routinely disrupted within the ditch system at Muscatatuck by beaver dams and log jams. It is quite common, if left unchecked, for water to stage approximately 6 to 8 feet deep from Moss Lake north to Hwy 50 in a single season. This causes water to stage higher than the drainage tiles on adjacent lands north of Hwy 50 and can cause negative impacts to Refuge relations with the landowners. The higher water levels reduce the Refuge's capacity to absorb runoff and any excess precipitation above infiltration capacities of the soil contribute to flooding of the forests adjacent to the creeks and increases flood retention times within the forested systems ultimately contributing to tree mortality and overall community shifts from forest to emergent marsh or scrub/shrub habitats.

Beaver dams and log jams within the creeks/ditches directly impact other habitats on the Refuge. Drainage of M5, M6, and the Muscatatuck Seep Spring Research Natural Area is impossible when water levels within Storm and Mutton Creeks are above 539.08 for M5, 541.6 for M6, and approximately 541.0 MSL for the Seep. The ditches also directly influence water levels within the former G3 unit, G4, Mini Marsh, and forested sections within the birds silt loam series (Fig. 7; the large expanse of blue on the map is the birds silt loam soils).

Strategies:

1. Monitor water levels, as part of the weekly water level monitoring, within the ditch system at strategic locations including Moss Lake, the bridges at CR400 and CR500.
    a. By 2013, survey and establish bench marks that will allow for water level monitoring at the Hwy 50 bridges on Mutton and Storm Creek Ditches and at the Hwy 31 Bridge on Sandy branch creek.
2. Monitor creeks/ditches on a weekly basis, for beaver dams and log jams that stage water and impede flow. In many instances weekly water level data can be used to compare elevations at Moss lake water control structures, the bridges on CR400 and CR500, and eventually the Hwy 50 bridges.
3. Remove impediments from creeks and ditches on a regular basis, but most importantly during the growing season (February through November) to protect bottomland forests and adjacent habitats.
    a. Beaver dams within the portions of Storm Creek in the middle of the Moss Lake Complex must be removed several times in the spring and summer to facilitate drainage of M5 and sometimes M4.
4. Remove nuisance aquatic animals as necessary to reduce the frequency of dam construction and subsequent need for dam removal.
    a. Follow guidance outlined within the approved nuisance animal plan
    b. If trapping becomes an option in the future, guide activities to the ditches as priority locations; especially the remote areas of the ditches within the Moss Lake complex.
5. Obtain the necessary means to more efficiently remove obstructions within the ditch system. This may include explosives training and acquisition, acquisition of an amphibious excavator or backhoe, and/or amphibious ATV.
6. Ensure adequate resources are available to deal with water level monitoring and beaver dam removal by recruiting, training, and managing interns, volunteers, and entry levels staff such as STEPs and SCEPs and training permanent staff and making this a priority in the event that biological staff are unavailable.
7. Where possible and as funding and staff resources are available, continue to investigate and restore natural hydrology of streams on the Refuge.
    a. Use, when completed, the HGM study/recommendations to develop a stream restoration plan within 12 years of the approval of this HMP.
    b. Begin stream restorations within 15 years of the completion of this HMP.
8. Within 10 years of this plan increase discharge capacities of HC1 and HC2 to restore sheetflow, protect forested habitats within the hydrologic cells, and, if feasible, to restore flow to historic meanders of Storm and Mutton Creeks.
    a. Install additional large diameter culverts, create box culverts, or create low water crossings at strategic locations along CR400 and CR500
    b. Use topographic, aerial, and/or bathymetry data to determine the placements of these locations.
    c. Use inflow calculations from a completed runoff and volume staging model or from inflow data acquired through data collection efforts such as those outlined in the cooperative USGS Science Support grant proposals from 2010 or 2011.
        -Adequate accuracy runoff/inflow estimations can be obtained using the NRCS runoff equation and remotely sensed data to determine the values

of each variable used in that equation for all lands within the 67 sq. mi. watersheds of Mutton, Storm, and Sandy Branch Creeks.
-Sizing of culverts or low water crossings should be determined from volume calculations based on the aforementioned research unless funding becomes available prior to the research at which time regional hydrologists will be consulted and action taken.

d. When the bridges on CR400 and CR500 are replaced (within the next 8-10 years), increase overall spans of each bridge to allow for at least doubling the discharge capacity.
-each bridge is severely undersized to accommodate the large volume of water entering the refuge from the 67 sq. mi. watersheds to the north.

9. Specific annual prescriptions and direction for water management of individual streams will be outlined in annual water management plans (WMP) to be completed by February of each year and will follow guidance established within the 2008, 2009, 2010, and 2011 annual water management plans and this HMP.

Objective 1.8: Current Agricultural Land

(This is a new objective, not included within the CCP)
Remove all remaining Refuge acres from the farming program and return them to a natural plant community within three years of plan approval. All 230 acres will be converted to grassland within that timeframe and depending on budget and staffing constraints may occur in one year or the process may be spread out over that time period.

Rationale: Historically, the Refuge existed primarily in a forested state; however, much of the land was cleared and farmed, hayed, or grazed. Since Refuge establishment, nearly 4,000 acres have been converted from agricultural land to more native habitat types.

Cooperative farming agreements generally require the cooperator to leave 20% of the crop in the field and that portion of the crops was considered important to both resident and migratory wildlife, particularly waterfowl, Sandhill Cranes and Whooping Cranes. However, on-Refuge investigations from 2008-2009 have shown little to no use of the crops. Nearly the entire unharvested crop in 2008 (>93%) still remained untouched in the field by late spring of 2009 (6 months following harvest). These observations reveal that grain crops are likely not as important as once thought and the Refuge is providing adequate natural food sources for its resident and migratory wildlife. The Refuge is surrounded by a sea of agriculture and waste grain within those acreages adjacent to Refuge lands is sometimes utilized by Sandhill Cranes and other wildlife. It is now believed that agricultural production on Refuge land is not necessary.

Strategies:
1. Eliminate farming of the remaining 215 acres of cropland by 2013. The 54 acres of hayed land should be enhanced to provide diverse native grassland habitat.

a. Stop annual haying of any grasslands and use haying only as a management tool as defined within an approved grassland management plan or for the benefit of cranes within all of Grassland Unit 2 and the southeastern field in Grassland Unit 3.

b. Hayings for cranes should be conducted near the end of the growing season (September 15- November 30) to provide suitable habitat for those species.

2. Utilizing monitoring and adaptive management, ensure that native plants recolonize the abandoned fields.

a. Follow guidance within applicable management plans including the grassland and forest management plans, integrated pest management plan, inventory and monitoring plan, and any restoration or planting plans.

b. Where possible utilize programs such as Go-zero or other comparable organizations to facilitate planting and forest restorations at little to no cost to the Refuge.

3. Utilize partners for restoration of agricultural lands to forest or grassland.

4. All current agricultural lands fall within the boundaries of other habitat management units and should be managed according to the habitat objectives and strategies outlined in this plan for those habitat types.

Objective 1.9: Former Cropland/Old Fields

(This is a new objective, not included within the CCP)

Over the life of this plan, ensure that the 640 acres of reconverting forest and old field communities consist of a diversity of native plant species that will provide the adequate structural and compositional needs of resident and migratory species. Monitoring of a protion of these habitats (approximately 50-75 acres) should be conducted each year from years 5-15 after this plan's completion to determine the need for management action and treatment will occur as outlined in an approved Inventory and Monitoring Plan and Forest Management Plan.

Rationale: Over 800 acres of former cropland exist at Muscatatuck NWR which is a significant portion, constituting a little over 10%, of total Refuge acreage. Many of these acres were simply abandoned, some were planted with oaks and other mast producing seedlings, and others have been continuously hayed. Some instances of abandonment have resulted in solid monotypic stand development of autumn olive and/or multiflora rose. Others have transitioned nicely and consist of diverse plant assemblages. Based on anecdotal and observational data, areas that have developed diverse native vegetation get far more use by wildlife and provide a benefit to a wide array of species.

Strategies:

1. Inventory and control invasive and non-native species within a portion of the former cropland, approximately 50-75 acres per year in years 5-14 after this HMP is completed.
2. Within 15 years of the plan's approval, consolidate information from annual inventory of successional acreage to determine species composition and stem densities.
3. Based on inventory, prescribe long term timber stand improvement actions to achieve desired stem density and composition.

Objective 1.10: Hydrologic Cells

Modify infrastructure and water management to restore hydrology within hydrologic cells to create more natural flooding regimes, to increase discharge capacities, increase sheet flow capabilities, to decrease the duration of flooding events preventing unnatural and prolonged flooding within forested sections of the units, reduce flood impacts to adjacent lands, and to stave off the loss of bottomland hardwood forests on the Refuge. The Refuge will attempt to modify a minimum of one structure, dike, road, bridge, or other impediment to flow or restore one ephemeral stream annually as outlined within annual water management plans.

Rationale: Refuge hydrology is substantially altered from historic or natural conditions largely due to the straightening and dredging of creeks, road, bridge, dike, and levee construction, and impoundment of water at unnatural levels. CR400, CR500, and the Moss Lake dam are the three most serious impediments to flow and contribute substantially to long duration flooding of the bottomland forested areas within the Birds silt loam soils on the Refuge.

Water "stacks up" at the Moss Lake dam, at CR500, and at CR400 with waters staging highest between CR400 and CR500. Water levels north of CR400 tend to be two feet higher than south of CR400 following heavy rainfall events. Discharges from the Moss Lake water control structure are often too low to handle inflows; this is especially true during the rainy season when rain events occur on a weekly basis or more often. During those times discharges cannot keep pace with inflows and long duration impoundment of forested areas occur contributing to tree mortality and community shifts.

Beaver dams within the hydrologic cells decrease flow rates, increase the duration of flood events, increase base flow levels, and contribute to forest losses. Beaver are a native species and a part of the natural system; they create suitable habitat for many wetland dependent species. However, one beaver dam in a strategically correct location can impact several hundred acres of trees. Only 4,180 acres of bottomland forest exist on the Refuge; over 1,000 acres have already been killed or severely impacted from lack of beaver dam removal coupled with water levels that were managed too high in Moss Lake.

Strategies:

1. Develop a hydrologic model, in cooperation with Regional hydrologists, at the watershed level that allows for inflow calculations of rainfall and runoff events.
2. Use the hydrologic model, topographic information, and other data to determine and make recommendations for creating the cut within the Moss Lake dam, if not already completed, that will allow faster discharge of waters throughout HC1, HC2, and HC3 during high flow conditions. Maximum elevation for the cut should not be higher than 543.0 MSL and the minimum elevation should not be less than 540.0. This ensures retention capabilities for gravity feeding water to M7 and flooding of the emergent marsh portions of Moss Lake.
3. Following Moss Lake dam modifications, monitor hydrology within the Hydrologic cells to determine effects of such modifications.

4. When modifications to CR400 and CR500 bridges are necessary expand the width of bridges on those roads to allow increased discharges from HC1 and HC2.
5. Within the life of this plan, install additional large diameter culverts, create box culverts, or create low water crossings at strategic locations along CR400 and CR500 to increase discharge capacities of HC1 and HC2 and, if feasible, to restore flow to historic meanders of Storm and Mutton Creeks.
6. Conduct weekly water level monitoring and analyze the collected data to discern where beaver dams exist within the ditch system.
7. Conduct regular monitoring, at least monthly although this is preferred on a weekly basis, throughout the hydrologic cells searching for beaver dams from February-November.
8. Routinely remove beaver dams directly before and throughout the growing season (February through November).
9. Where possible and as funding and staff resources are available, continue to investigate and restore natural hydrology within the hydrologic cells.
10. Specific annual prescriptions and direction for water management of hydrologic cells or portions of hydrologic cells will be outlined in annual water management plans (WMP) to be completed by February of each year and will follow guidance established within the 2008, 2009, 2010, and 2011 annual water management plans and this HMP.

Objective 1.11: Invasive Plant Species (CCP objective 1.5)

Inventory all Refuge lands for invasive plant species within 5 years of plan approval. Identify, monitor, control, and eliminate exotic and invasive species found on the Refuge and rapidly respond to new invasive species based at the maximum sustainable rate based on staff and budgetary contstraints. The number of acres will likely fluctuate based on those constraints but a minimum effort of 50 acres of treatment should be conducted on an annual basis or as outlined in an approved integrated pest management plan.

Rationale: Invasive species are detrimental to native plant and animal populations. Invasive species are considered to be one of the greatest threats to the National Wildlife Refuge System. Autumn olive, garlic mustard, reed canary grass, Canada thistle, crown vetch and many other species dominate certain portions of the Refuge landscape. Japanese stiltgrass, multiflora rose, Japanese honeysuckle, tree-of-heaven, and kudzu threaten the diversity and health of the bottomland and upland hardwoods while other species, such as reed canary grass and purple loosestrife, compete with native vegetation along riparian corridors, in moist soil units, and in other wetland types. Many of the invasive species encountered have the capability over time of producing solid monocultures, shading out native vegetation and reducing overall plant diversity and consequently overall animal diversity (Blossey 2004). Many of the same natural disturbances, such as drought, flood and wildfire, which maintain productivity of natural systems, also provide opportunities for invasive species to multiply and spread. Human activities and disturbances on the landscape also create conditions conducive to the spread of invasive species. It is very important that the Refuge staff is able to inventory and monitor the spread of invasive species and take actions to minimize the distribution of a species or control its abundance on the landscape. Though it is unlikely that invasives will be completely eradicated from the landscape, targeted chemical,

mechanical, manual, and biological controls or prescribed fire can reduce their impact on native species. Success will be based on reducing the spread and size of infestations, complete eradication, or stabilization of infestations. The Refuge will employ a strategy of early detection, rapid assessment, and rapid response (ED/RA/RR). ED/RA/RR amplifies the probability that invasions will be managed effectively while populations are confined to a small area and eradication is feasible. Populations, once well established, are rarely completely eradicated; mitigation of their negative impacts is a reasonable expectation (Blossey 2004). Furthermore, overall costs of ED/RA/RR are inevitably much lower than costs associated with long-term reduction and control of well-established populations.

Strategies:

1. Within 3 years of the completion of this HMP, develop an integrated pest management (IPM) plan.
2. Inventory and map the distribution of invasive species.
3. Using IPM strategies identify treatment protocols for all known invasive plants inhabiting the Refuge and for the plants most likely to invade in the near future.
4. Prioritize species and locations for treatment. Use a diverse array of control tools and techniques individually or in combination, including but not limited to mowing, biological controls, herbicides, prescribed fire, and revegetation.
5. Evaluate all ground-disturbing management actions for their potential to facilitate the spread of invasive plants. Establish and implement a survey design that monitors invasive species and allows comparison of different management regimes.
6. Develop an annual monitoring and mapping strategy for invasive species.
7. Implement early detection, rapid assessment, and rapid response strategies for 'new' invaders.
8. Increase training for staff members on invasive species identification.
9. Increase public awareness of the invasive species issues facing the Refuge and encourage public involvement through workshops, presentations, work days, special events, and other stewardship opportunities.
10. Cooperate with state and federal agencies, non-government organizations, and neighboring landowners to strategize, inventory, monitor, and treat invasive species on a larger landscape level scale.
11. Fill the existing (vacant) full-time tractor operator position to assist with invasive species eradication. Also, add one wildlife biologist to oversee and manage field efforts and add two full-time biological science technicians to help with controlling invasives, forestry, and grassland management.
12. Develop and enhance relationships with adjacent landowners, universities, colleges, schools, and other organizations such as the Boy Scouts, Girl Scouts, Wildlife Society, Audubon Society etc. and encourage participation in the fight against invasive species on the Refuge.

Objective 1.12: Muscatatuck Seep Spring Research Natural Area (CCP objective 1.6)

Within the life of this HMP, restore the hydrology and begin restoring the vegetative community of the Muscatatuck Seep Spring Research Natural Area to a condition that

approximates an undisturbed Seep springs site as defined by future communications and consultation with experts such as the State Botanist and the Indiana Natural Heritage Program.

Rationale: The Muscatatuck Seep Spring Research Natural Area is one of only seven acid Seep springs documented in Indiana. The cold, acidic groundwater yields a unique assemblage of plant species, and many of the plants that occur here are restricted to these exact environmental conditions. These conditions are extremely uncommon in the landscape, especially in southern Indiana. This community is also ranked as Globally Rare in the Natural Heritage system, a ranking system developed by The Nature Conservancy. State-listed plant species found here include: American ginseng, club spur orchid, southern tubercled orchid, bog bluegrass, Walter's St. Johns wort, and smooth white violet. The state-listed endangered four-toed salamander and the state listed endangered copperbelly watersnake are also found in the Muscatatuck Seep Spring Research Natural Area. Refuge staff and partners have recognized that the condition of the vegetative community is in poor condition, needs immediate attention, and that changes to several current management practices are required. The following issues have been identified as problems that have caused poor drainage conditions to exist, the persistence of high water levels, and the degradation of the Muscatatuck Seep Spring Research Natural Area's vegetative community over the past several decades:

- County road 400 S, immediately to the south of the Seep Springs, was raised in the early 1980s and a drainage culvert under this road was removed.
- Beaver populations and activity have increased in the area and contributed to consistently higher water levels in Mutton Creek and throughout the Refuge
- Log jams have accumulated in the Mutton Creek system, contributing to poor drainage. Jams are difficult to remove because of limited access for equipment
- Moss Lake had been maintained at a level of 541msl - a level where water begins to have an impact on the Muscatatuck Seep Spring Research Natural Area and increases the time required for drainage during periods of heavy inflow and flooding.

All of these factors and others have contributed to higher water levels and altered the flow regimes in the area. The changed conditions in the area have led to an observable change in the vegetation, severe tree mortality, and a shift in the habitat type from a seasonally flooded forested wetland to a permanently flooded marsh. In order to preserve and restore the special characteristics of the Muscatatuck Seep Spring Research Natural Area, it is necessary to better understand the current and historical conditions at the site and then formulate approaches to returning the site to a less disturbed condition. The key to maintaining the health of the Muscatatuck Seep Spring Research Natural Area community is to understand how water flows into and out of the site, and the nature of the historical hydrologic regime that led to the development of the seep. Some immediate steps are needed to improve the drainage of the area and reduce long-term retention of water on the community. The site is also threatened by a number of invasive species including garlic mustard, moneywort, reed canary grass, and Japanese stiltgrass. Control of these invasive species will need to be addressed. All of these issues will have to be addressed to facilitate the recovery of the Research Natural Area. Even with implementation of the proposed strategies, continued degradation and tree mortality at the

site is likely for a period of several years to a decade as the full impacts of extended flooding are realized. Funding is a limiting factor in the rate of response to these problems, as several issues that must be addressed will require additional maintenance dollars.

Strategies:

1. Reduce the impact of Moss Lake and Mutton Creek on the Muscatatuck Seep Spring Research Natural Area during the growing season, February-November by reducing water levels and increasing discharge rates of the Moss Lake water control structure (WCS) during high flow periods and to allow the Refuge the ability to mimic a natural short duration pulsing flood regime.
2. Construct access routes for equipment and personnel along Storm Creek between County 500 North and Moss Lake, within three years of the completion of this plan, to facilitate access for beaver dam, log jam, and sediment removal, to allow for population control of nuisance species, and to allow for consistent monitoring.
3. Control the beaver population on the Refuge and reduce the number of creek obstructions.
4. Restore the full drainage capability of Moist Soil Unit 6 (M6) within two years of this plan's completion, through removal of silt from channels and borrow ditches.
5. Remove the berm and beaver dams that restrict discharge flows into and along the primary drain for the Muscatatuck Seep Spring Research Natural Area into Mutton Creek; this is the southeastern drainage ditch north of County Road 400 North, and southeast of the seep. This should be completed within two years of this plan's completion.
6. Install a backflow preventer on the M6 outflow culvert to reduce flooding and maintain a lower water table.
7. Install water level gauges to allow water level monitoring of the RNA; monitor these water levels as part of the weekly water level monitoring effort.
8. Form a working group of qualified professionals and stakeholders to collaboratively assist in the implementation of these strategies and to make recommendations on water levels, management practices, and modification of existing and/or construction of new water control structures, drainage, and moist soil unit infrastructure (particularly M6 and its outlet structure) needed to provide the best possible conditions for the flora and fauna of the Muscatatuck Seep Spring Research Natural Area.
9. Conduct an investigation to determine historic water regimes and to determine realistic recommendations for restoring the hydrology and, in particular, to reduce the influence of Mutton Creek on the Muscatatuck Seep Spring Research Natural Area during the growing season, February-November.
10. Determine best management practices for restoring the forested habitat that has been degraded, ensuring proper species composition and preventing establishment or release of invasive species into the Muscatatuck Seep Spring Research Natural Area.
11. Inventory, monitor, map, and control invasive species in and near the Muscatatuck Seep Spring Research Natural Area.
12. Develop a monitoring plan/protocol to monitor the overall health of the Muscatatuck Seep Spring Research Natural Area and to watch for changes in plant communities, sedimentation, and hydrology.

13. Determine if the Muscatatuck Seep Spring Research Natural Area should be protected from all public entry and, if so, sign the area and develop and make available informational material to educate the public.

Objective 1.13: Restle Unit (CCP objective 1.7)

Maintain 48 acres of bottomland forest and manage a 30-acre moist soil unit to support water bird feeding, resting, and breeding with a goal of providing 20,000 waterfowl use days, 8,000 shorebird use days, and 500 wading bird use days on average annually.

Rationale: The Refuge must "perpetually manage the real estate as a wetland habitat for native wildlife and plant enhancement and protection." To best fulfill its commitment, the Refuge will manage the constructed unit on the Restle Unit as a moist soil unit because this follows the establishing direction for the Refuge. The Refuge purpose "…for use as an inviolate sanctuary, or for any other management purpose, for migratory birds" derives from the Migratory Bird Conservation Act. The forest will be maintained, but not managed. The donation document for the Restle Unit states: "No timbering, burning, hunting, trapping, or fishing shall be permitted, except that plant harvesting or controlled burning for the protection of the wetland or research into the protection of wetlands are permitted." The donation document also states: "Wildlife harvesting within the levee constructed by the Fish and Wildlife Service in 1990 is also permitted for the protection of the wetland within the levee. The permitted activities specified in this paragraph are to be conducted only by personnel of the grantee or their designees for that specific purpose."

Strategies:

1. Develop a water management plan within 2 years of plan approval to guide management of the impoundment.
2. Maintain dike and water control structure in good working order as funds and staffing allow.
3. Use mechanical, chemical and biological controls to check the spread of invasive plant species.
4. Communicate with other state and federal resource agencies, as well as non-governmental organizations, to stay current on emerging threats and effective management and control techniques related to invasive species.
5. Control aquatic nuisance animals, to protect the integrity of the levee, as allowed by State nuisance animal control permits.
6. Within five years of the completion of the HMP, develop a management partnership with an academic institution (e.g. Indiana University- Bloomington) or other partner or agency (e.g. Bloomington Parks and Recreation or Sycamore Land Trust) to handle the day to day management tasks, water level management and monitoring, beaver dam removal, and waterfowl and vegetation surveying and monitoring, etc.. Muscatatuck NWR staff will create annual planning documents to guide the partner's activities.

Objective 1.14: Conservation Easements (CCP objective 1.8)

Meet Service monitoring guidelines for FSA over next 15 years.

Rationale: The Refuge is responsible for managing FSA easements (formerly Farmers Home Administration easements, or FmHA) within a 30- county Wildlife Management District. These easements were placed on the properties when landowners defaulted on their Farmers Home Administration loans. Properties were then resold to the original landowner or to another individual at a discounted price due to the easement. FSA easements are an agreement between the FSA and the FWS, authorizing the Service to protect important natural resource interests on easement properties such as wetlands, floodplains, riparian corridors, and endangered species habitat. Ownership of the easement land is retained by private individuals, but with certain restrictions on altering important natural resources on the easement lands. Service employees are granted access for management, maintenance, monitoring,
and enforcement purposes. There is no public access to these easement properties unless explicitly stated in the individual easement document.

Strategies:
1. Bi-annually inspect each FSA easement and follow-up with landowner contact.
2. Send letters to new landowners informing them of existing easements on their property, along with the associated regulations
3. Follow protocols within the Service's easement manual to handle all potential violations.

Objective 1.15: Landscape Conservation (CCP objective 1.9)

In collaboration with internal and external partners, identify priority areas and begin implementing strategies for watershed improvement and regional land conservation.

Rationale: The scale at which environmental problems, and their solutions, are addressed has begun to evolve from traditionally site-specific or locality-based approaches to a broader, more regional approach. It is not possible for a National Wildlife Refuge to work only within Refuge boundaries and expect to meet its ideals for the long-term conservation and protection of wildlife, habitats, and ecological services. The trend toward this landscape-level perspective has been catalyzed by new environmental research, expanded computing and technological capabilities, changing communication forums, and an increased understanding of landscape-level environmental issues and constraints. In addition, a number of initiatives within the Fish and Wildlife Service have resulted in the agency beginning to shift its emphasis toward a broader and more integrated approach to conservation, including the adoption of Strategic Habitat Conservation (SHC) and increased focus on global climate change. As a part of the conservation landscape, Refuge lands and Service personnel will play an active role in efforts directed at understanding and mitigating these new environmental challenges. Furthermore, it is only by working with partners, both public and private, that threats such as habitat loss, fragmentation and degradation, water quality and quantity concerns, interrupted or altered natural processes, global climate change, biotechnology, declines in native biodiversity, growing numbers of invasive species, and other such issues can be addressed.

Strategies:

1. Gather and review existing literature and data relevant to landscape and watershed conservation in the region (Indiana and the Midwest) with regard to waterfowl, waterbird, sandhill and whooping cranes, neotropical migrant passerines, grassland birds, copperbelly watersnakes, and bottomland hardwood systems.
2. Meet with partners and stakeholders to discuss the range of issues and interests in landscape conservation and watershed planning.
3. Involve the public in Service planning related to landscape conservation and watershed planning.
4. Coordinate across Service divisions to leverage expertise, programs, and services for landscape conservation and watershed planning initiatives.
5. Conduct a science-based landscape assessment that incorporates the interests of partner agencies, organizations, stakeholders, and the public in its analyses.
6. Identify target areas for conservation efforts, including land acquisition, conservation easements, work on private lands, and other tools available for land conservation and watershed improvement.
7. Share results with partners and stakeholders.
8. Work with partners, stakeholders, and willing private landowners to protect, enhance, or restore conservation targets identified by the analysis.
9. Seek additional funding for landscape conservation and watershed improvement efforts.
10. Participate in local discussions, meetings, and projects related to landscape-level issues.
11. Raise local awareness of the Service's role in landscape conservation and watershed improvement.
12. Work with partners and stakeholders to increase the collective awareness of landscape and watershed conservation issues, opportunities, and benefits through environmental education, outreach, and technical assistance.
13. Encourage local communities to use the science- based assessments in their planning.

Objective 1.16: Federally Listed Threatened and Endangered Species

(Objective 2.2 in the CCP)
Monitor and protect federally listed species and their habitats.

Rationale: Whooping Cranes, Indiana bats, and Interior Least Terns use the Refuge. Interior Least Terns and Whooping Cranes use the Refuge during migration. Indiana bats are resident species. The Refuge population of copperbelly watersnakes is not included in the federal listing, which addresses populations north of Indianapolis. However, ongoing research indicates that the Muscatatuck NWR population may be important because it is thriving while many populations are declining and may be attributable to various habitat components. A population of bog bluegrass is located in the Muscatatuck Seep Spring Research Natural Area. This plant is apparently flourishing in that area.

Strategies:
1. Maintain close coordination with the Ecological Services office on any habitat alteration that may affect Indiana bat habitat.
2. Facilitate continued research and monitoring of Indiana bats on the Refuge.

3. Facilitate continued research and monitoring of copperbelly watersnakes on the Refuge.
4. Facilitate inventory, mapping, monitoring, and research as necessary on the federally-listed Indiana bat, Whooping Crane, and any future listings or candidate species that occur during the life of this plan following guidance within an approved habitat and species inventory and monitoring plan.
5. Consider federally-listed species when making management decisions and actions.
6. Protect, as necessary, areas and habitats known to benefit or support federally-listed species.

Objective 1.17: State T&E Species and Species of Concern

(Objective 2.3 in the CCP)
Consider known populations of state-listed species in management actions.

Rationale: Species on the state endangered list can be found in Table 9 on page 77 (a complete listing of State T&E species can be found online at http://www.in.gov/dnr/naturepreserve/4725.htm).

Several other plant species are included on a state watch list. Those species are: American ginseng, bog bluegrass, Walter's St. John's wort, smooth white violet, and club spur orchid. The Refuge is within the range of several other state listed species. Surveys need to be conducted to document the presence of these species on Refuge lands. A monitoring plan will be developed and surveys will be conducted to confirm species presence. State-listed threatened and endangered species will be considered in management actions on the Refuge.

Strategies:
1. Facilitate inventory, mapping, monitoring, and research as necessary of state-listed or candidate species that are found at the Refuge within the life of this plan following guidance outlined within an approved habitat and species inventory and monitoring plan.
2. Protect, as necessary, areas and habitats known to benefit or support state-listed species.
3. Consider state-listed species when making management decisions and actions.

Management strategy constraints

Active management of the Refuge's water resources, removal of the Refuge's acreage from the cooperative farming program, natural succession, reestablishment of the prescribed fire program, and possible tree planting should allow for the development of the Refuge's habitat vision. Implementation of this plan will be constrained by budgets and lack of personnel. A lack of expertise in relation to implementation of some strategies may be constraining, however, it is expected that the Refuge will work with USFWS staff from the Regional Office, Ecological Services Field Offices, Fisheries Offices, the Division of Migratory Birds, other National Wildlife Refuges, and other Federal agencies such as USGS, Forest Service, etc. and partners, including but not limited to: universities, extension offices, non-governmental organizations, State

agencies, and others. The wildlife sciences fields are rapidly evolving and continuously adapting to meet the increasingly complex demands of the resources and user groups. Lack of scientific information, social and political pressures, and a myriad of other factors could potentially constrain management.

Impacts to the resources of concern associated with the implementation of the proposed habitat management strategies

Reduction of forest fragmentation through natural succession and tree planting in the former cropland areas should result in positive benefits for neotropical migrants, forest interior birds, and other migratory birds. Positive effects should be garnered for a whole host of resident species as well from most faunal assemblages. However, negative impacts to grassland dependent and edge type species will surely ensue in the long term. Short term positive impacts may be realized for early successional species, however, these benefits will fade as habitats reach later seral stages. The land-use change may result in temporary increases in the spread of invasive species and a reduction in wildlife observation/photographic opportunities for the public (Regional Office, 2002).

Management of the Refuge's water resources will help fulfill the Refuge mission and purpose of meeting the needs of breeding and migratory waterfowl, other wetland dependent species, Service species of concern, and state listed species.

Management strategy selection

Annual water management plans will be developed in agreement with this plan to prescribe management schedules and techniques necessary for moist soil plant production, structural maintenance and repair. Water levels will be monitored on a weekly basis to assess attainment of management objectives in terms of vegetative production, wildlife use and maintenance needs. Historic Refuge data has demonstrated the need for continual assessment of water level management for optimum results due to weather patterns, flooding, and repair and rehabilitation requirements.

Planting plans and forest management plans will be developed in agreement with this plan to guide management of forested habitats. Forest restoration of reverting cropland will primarily be accomplished through natural succession; most of the fields are small in size and surrounded by excellent seed sources for deciduous trees. In some instances, mixed hardwood tree plantings will be added to the program depending upon site needs, feasibility, funding, and staff availability.

Cropland reduction will be accomplished through non-renewal of existing cooperative contracts. Existing logic in this decision is based on need to reduce forest fragmentation

for the benefit of migratory birds and the lack of impact caused by a reduction in supplemental food sources for migratory waterfowl.

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Appendix A. Common and Scientific Names of Species in this HMP

Animals		
Common Name	**Scientific Name (Genus Species)**	**Family**
Bald eagle	*Haliaeetus leucocephalus*	Accipitridae
Broad-winged Hawk	*Buteo platypterus*	Accipitridae
Cooper's Hawk	*Accipiter cooperii*	Accipitridae
Golden Eagle	*Aquila chrysaetos*	Accipitridae
Mississippi Kite	*Ictinia mississippiensis*	Accipitridae
Northern Goshawk	*Accipiter gentilis*	Accipitridae
Northern Harrier	*Circus cyaneus*	Accipitridae
Osprey	*Pandion haliaetus*	Accipitridae
Red-shouldered Hawk	*Buteo lineatus*	Accipitridae
Red-tailed Hawk	*Buteo jamaicensis*	Accipitridae
Rough-legged Hawk	*Buteo lagopus*	Accipitridae
Sharp-shinned Hawk	*Accipiter striatus*	Accipitridae
Belted Kingfisher	*Ceryle alcyon*	Alcedinidae
American Black Duck	*Anas rubripes*	Anatidae
American Wigeon	*Anas americana*	Anatidae
Black Scoter	*Melanitta nigra*	Anatidae
Blue-winged teal	*Anas discors*	Anatidae
Bufflehead	*Bucephala albeola*	Anatidae
Canada geese	*Branta canadensis*	Anatidae
Canvasback	*Aythya valisineria*	Anatidae
Cinnamon Teal	*Anas cyanoptera*	Anatidae
Common Goldeneye	*Bucephala clangula*	Anatidae
Common Merganser	*Mergus merganser*	Anatidae
Hooded merganser	*Lophodytes cucullatus*	Anatidae
Lesser Scaup	*Aythya affinis*	Anatidae
Mallard	*Anas platyrhynchos*	Anatidae
Animals cont.		

Common Name	Scientific Name (Genus Species)	Family
Northern Pintail	*Anas acuta*	Anatidae
Northern Shoveler	*Anas clypeata*	Anatidae
Oldsquaw (Long-tailed Duck)	*Clangula hyemalis*	Anatidae
Redhead	*Aythya americana*	Anatidae
Ring-necked Duck	*Aythya collaris*	Anatidae
Ruddy Duck	*Oxyura jamaicensis*	Anatidae
Snow goose	*Chen caerulescens*	Anatidae
Surf Scoter	*Melanitta perspicillata*	Anatidae
Trumpeter Swan	*Cygnus buccinator*	Anatidae
Tundra Swan	*Cygnus columbianus*	Anatidae
White-fronted Goose	*Anser albifrons*	Anatidae
White-winged Scoter	*Melanitta fusca*	Anatidae
Wood duck	*Aix sponsa*	Anatidae
Mute Swans	*Cygnus olor*	Anatidae
American bittern	*Botaurus lentiginosus*	Ardeidae
Black crowned night herons	*Nycticorax nycticorax*	Ardeidae
Great Blue Herons	*Ardea herodias*	Ardeidae
Great Egrets	*Ardea alba*	Ardeidae
Green Heron	*Butorides virescens*	Ardeidae
Least bittern	*Ixobrychus exilis*	Ardeidae
Little blue herons	*Egretta caerulea*	Ardeidae
Snowy egrets	*Egretta thula*	Ardeidae
Yellow crowned night herons	*Nyticorax violacea*	Ardeidae
Gray fox	*Urocyon cinereoargenteus*	Canidae
Feral dogs	*Canis lupus*	Canidae
Common Nighthawk	*Chordeiles minor*	Caprimulgidae
Animals cont.		

Common Name	Scientific Name (Genus Species)	Family
Whip-poor-will	*Caprimulgus vociferus*	Caprimulgidae
Dickcissel	*Spiza americana*	Cardinalidae
Beaver	*Castor canadensis*	Castoridae
Bluegill	*Lepomis macrochirus*	Centrarchidae
Crappie	*Pomoxis spp.*	Centrarchidae
Largemouth bass	*Micropterus salmoides*	Centrarchidae
Redear sunfish	*Lepmois microlophus*	Centrarchidae
Asian Longhorned beetle	*Anoplophora glabripennis*	Cerabycidae
White tailed deer	*Odocoileus virginianus*	Cervidae
Black-bellied Plover	*Pluvialis squatarola*	charadriidae
Killdeer	*Charadrius vociferus*	Charadriidae
Semipalmated Plover	*Charadrius semipalmatus*	Charadriidae
Asian Ladybug	*Harmonia axyridis*	Coccinellidae
Copperbelly watersnake	*Nerodia erythrogaster neglecta*	Colubridae
Kirtland's snake	*Clonophis kirtlandii*	Colubridae
Rough Green Snake	*Opheodrys aestivus*	Colubridae
Southeastern crowned snake	*Tantilla coronata*	Colubridae
Asian Clam	*Corbicula fluminea*	Corbiculidae
Beaverpond Baskettail	*Epitheca canis*	Corduliidae
Fish Crow	*Corvus ossifragus*	Corvidae
Muskrat	*Ondatra zibethicus*	Cricetidae
White-footed mouse	*Peromyscus leuopus*	Cricetidae
Yellow-billed Cuckoo	*Coccyzus americanus*	Cuculidae

Animals cont.

Common Name	Scientific Name (Genus Species)	Family
Yellow-billed cuckoo	*Coccyzus americanus*	Cuculidae
Bigeye chub	*Hybopsis amblops*	Cyprinidae
Common Carp	*Cyprinus carpio*	Cyprinidae
Field Sparrow	*Spizella pusilla*	Emberizidae
Grasshopper Sparrow	*Ammodramus savannarum*	Emberizidae
Henslow's Sparrow	*Ammordramus henslowii*	Emberizidae
Le Conte's Sparrow	*Ammodramus leconteii*	Emberizidae
Eastern Box Turtle	*Terrapene carolina*	Emydidae
porcupine	*Erethizon dorsatum*	Erethizontidae
Peregrine Falcon	*Falco peregrinus anatum*	Falconidae
Bobcat	*Lynx rufus*	Felidae
Feral cats	*Felis catus*	Felidae
Northern studfish	*Fundulus catenatus*	fundulidae
Common loon	*Gavia immer*	Gaviidae
Round Goby	*Neogobius melanostomus*	Gobiidae
Sandhill Crane	*Grus canadensis*	Gruidae
Whooping Crane	*Grus americana*	Gruidae
Tree Swallow	*Tachycineta bicolor*	Hirundinidae
Bobolink	*Dolichonyx oryzivorus*	Icteridae
Eastern meadowlark	*Sturnella magna*	Icteridae
Rusty Blackbird	*Euphagus carolinus*	Icteridae
Brown-headed Cowbird	*Molothrus ater*	Icteridae
Loggerhead shrike	*Lanius ludovicianus*	Laniidae
Black Tern	*Chlidonias niger*	Laridae
Bonaparte's Gull	*Larus philadelphia*	Laridae
Caspian Tern	*Sterna caspia*	Laridae
Animals cont.		
Common Name	**Scientific Name**	**Family**

	(Genus Species)	
Common Tern	*Sterna hirundo*	Laridae
Forster's Tern	*Sterna forsteri*	Laridae
Franklin's Gull	*Larus pipixcan*	Laridae
Herring Gull	*Larus argentatus*	Laridae
Interior least tern	*Sterna antillarum*	Laridae
Ring-billed Gull	*Larus delawarensis*	Laridae
Eastern cottontail rabbits	*Sylvilagus floridanus*	Leporidae
Gypsy Moths	*Lymantria dispar*	Lymantriidae
Wild turkeys	*Meleagris gallopavo*	Meleagrididae
House Mouse	*Mus musculus*	Muridae
Norway Rat	*Rattus norvegicus*	Muridae
Least Weasel	*Mustela nivalis*	Mustelidae
Northern River Otter	*Lutra canadensis*	Mustelidae
River otter	*Lontra canadensis*	Mustelidae
Northern bobwhite quail	*Colinus virginianus*	Odontophoridae
Black-and-white Warbler	*Mniotilta varia*	Parulidae
Blue-winged Warbler	*Vermivora pinus*	Parulidae
Cerulean Warbler	*Dendroica cerulea*	Parulidae
Chestnut-sided Warbler	*Dendroica pensylvanica*	Parulidae
Golden-winged Warbler	*Vermivora chrysoptera*	Parulidae
Hooded warbler	*Wilsonia citrina*	Parulidae
Kentucky Warbler	*Oporornis formosus*	Parulidae
Louisiana Waterthrush	*Seiurus motacilla*	Parulidae
Prairie Warbler	*Dendroica discolor*	Parulidae
Worm-eating Warbler	*Helmitheros vermivorus*	Parulidae
Animals cont.		

Common Name	**Scientific Name (Genus Species)**	**Family**
Yellow breasted chat	*Icteria virens*	Parulidae
Yellow-throated warbler	*Dendroica dominica*	Parulidae
Eastern sand darter	*Ammocrypta pellucida*	Percidae
Double Crested Cormorant	*Phalacrocorax auritus*	Phalacrocoracidae
Ruffed Grouse	*Bonasa umbellus*	Phasianidae
Pileated Woodpecker	*Dryocopus pileatus*	Picidae
Red-headed Woodpecker	*Melanerpes erythrocephalus*	Picidae
Cabbage White	*Pieris rapae*	Pieridae
Four-toed Salamander	*Hemidactylium scutatum*	Plethodontidae
Eared Grebe	*Podiceps nigricollis*	Podicipedidae
Horned Grebe	*Podiceps auritus*	Podicipedidae
Pied-billed grebe	*Podilymbus podiceps*	Podicipedidae
Western grebe	*Aechmophorus occidentalis*	Podicipedidae
Mosiquitofish	*Gambusia affinis*	Poeciliidae
Raccoon	*Procyon lotor*	Procyonidae
Barn Owl	*Tyto alba*	Psittachidae
American Coot	*Fulica americana*	Rallidae
Common Moorhen	*Gallinula chloropus*	Rallidae
King rail	*Rallus elegans*	Rallidae
Purple gallinules	*Porphyrula martinica*	Rallidae
Sora	*Porzana carolina*	Rallidae
Virginia rail	*Rallus limicola*	Rallidae
Yellow rail	*Coturnicops noveboracensis*	Rallidae
Eastern chipmunk	*Tamias striatus*	Sciuridae
Animals cont.		

Common Name	**Scientific Name (Genus Species)**	**Family**
Gray squirrel	*Sciurus carolinensis*	Sciuridae
Southern Flying Squirrel	*Glaucomys volans*	Sciuridae
American Woodcock	*Scolopax minor*	Scolopacidae
Common Snipe	*Gallinago gallinago*	Scolopacidae
Dunlin	*Calidris alpina*	Scolopacidae
Greater Yellowlegs	*Tringa melanoleuca*	Scolopacidae
Lesser Yellowlegs	*Tringa flavipes*	Scolopacidae
Long-billed Dowitcher	*Limnodromus scolopaceus*	Scolopacidae
Ruddy Turnstone	*Arenaria interpres*	Scolopacidae
Short-billed Dowitcher	*Limnodromus griseus*	Scolopacidae
Solitary Sandpiper	*Tringa solitaria*	Scolopacidae
Stilt Sandpiper	*Calidris himantopus*	Scolopacidae
Upland Sandpiper	*Bartramia longicauda*	Scolopacidae
Willet	*Catoptrophorus semipalmatus*	Scolopacidae
Wilson’s snipe	*Gallinago delicata*	Scolopacidae
Wilson's Phalarope	*Phalaropus tricolor*	Scolopacidae
Asian Ambrosia Beetle	*Xylosandrus crassiusculus*	Scolytidae
Short-eared Owl	*Asio flammeus*	Strigidae
European Starling	*Sturnus vulgaris*	Sturnidae
Feral hogs	*Sus scrofa*	Suidae
Scarlet tanager	*Piranga olivacea*	Thraupidae
White faced Ibis	*Plegadis chihi*	Threskiomithidae
Glossy ibis	*Plegadis falcinellus*	Threskiornithidae
Bewick's Wren	*Thryomanes bewickii*	Troglodytidae
Marsh Wren	*Cistothorus palustris*	Troglodytidae
Sedge wren	*Cistothorus platensis*	Troglodytidae
Animals cont.		

Common Name	Scientific Name (Genus Species)	Family
Eastern wood pewee	*Contopus virens*	Tryannidae
Wood Thrush	*Hylocichla mustelina*	Turdidae
Acadian Flycatcher	*Empidonax virescens*	Tyrannidae
Great-crested flycatcher	*Myiarchus crinitus*	Tyrannidae
Willow flycatcher	*Empidonax traillii*	Tyrannidae
Little Spectaclecase	*Villosa lienosa*	Unionidae
Pimpleback	*Quadrula pustulosa*	Unionidae
Pistolgrip	*Tritogonia verrucosa*	Unionidae
Threeridge	*Amblema plicata*	Unionidae
Washboard	*Megalonaias nervosa*	Unionidae
Black bear	*Ursus americanus*	Ursidae
Eastern Pipistrelle	*Perimyotis subflavus*	Vespertilionidae
Evening bat	*Nycticeius humeralis*	Vespertilionidae
Gray Myotis	*Myotis grisescens*	Vespertilionidae
Indiana bat	*Myotis sodalist*	Vespertilionidae
Little Brown Myotis	*Myotis lucifugus*	Vespertilionidae
Northern Myotis	*Myotis septentrionalis*	Vespertilionidae
Red Bat	*Lasiurus cinereus*	Vespertilionidae
Silver -haired Bat	*Lasionycteris noctivagans*	Vespertilionidae
Southeastern Myotis	*Myotis autroriparius*	Vespertilionidae
Hoary Bat	*Lasiurus cinereus*	Vespertilionidae
Bell's vireo	*Vireo bellii*	Vireonidae
Plants		
Common Name	**Scientific Name (Genus Species)**	**Family**
Red maple	*Acer rubrum*	Aceraceae
Silver maple	*Acer saccharinum*	Aceraceae
Sugar maple	*Acer saccharum*	Aceraceae
Plants cont.		
Common Name	**Scientific Name**	**Family**

	(Genus Species)	
Duck potato	*Sagittaria latifolia*	Alismataceae
Nettleleaf Goosefoot	*Chenopodium murale L.*	Amaranthaceae
Pawpaw	*Asimina triloba*	Annonaceae
Queen's Anne's Lace/Wild Carrot	*Caucus carota L.*	Apiaceae
Bishop's Goutweed	*Aegopodium podagraria L.*	Apiaceae
Giant Hogweed	*Heracleum mantegazzianum*	Apiaceae
Poison Hemlock	*Conium maculatum L.*	Apiaceae
Pale Swallow-wort	*Vincetoxicum rossicum*	Apocynaceae
American ginseng	*Panax quinquefolius*	Araliaceae
English Ivy	*Hedera helix*	Araliaceae
Aquatic milkweed	*Asclepias perennis*	Asclepiadaceae
European Lily of the Valley	*Convallaria majalis L.*	Asparagaceae
Climbing hempvine (hempweed)	*Mikania scandens*	Asteraceae
Cocklebur	*Xanthium strumarium*	Asteraceae
Goldenrod	*Solidago sp.*	Asteraceae
Canada Thistle	*Cirsium arvense*	Asteraceae
Chicory	*Chichorium intybus L.*	Asteraceae
Common Burdock	*Arctium minus Bernh.*	Asteraceae
Musk Thistle	*Carsuus nutans L.*	Asteraceae
Japanese Barberry	*Berberis thunbergii*	Berberidaceae
Blue beech (American hornbeam)	*Carpinus carolinana*	Betulaceae
Plants cont.		
Common Name	**Scientific Name**	**Family**

	(Genus Species)	
European alder	*Alnus glutinosa*	Betulaceae
River birch	*Betula nigra*	Betulaceae
Corn Gromwell	*Buglossoides arvensis (L.) I.M. Johnston*	Boraginaceae
Birdsrape Mustard	*Brassica rapa L.*	Brassicaceae
Dame's Rocket	*Hesperis matronalis*	Brassicaceae
Garlic mustard	*Alliaria petiolata*	Brassicaceae
Flowering Rush	*Butomus umbellatus*	Butomaceae
Bush/Amur honeysuckle	*Lonicera mackii*	Caprifoliaceae
Amur Honeysuckle	*Lonicera maackii*	Caprifoliaceae
Japanese honeysuckle	*Lonicera japonica*	Caprifoliaceae
Morrow's Honeysuckle	*Lonicera morrowi*	Caprifoliaceae
Tatarian Honeysuckle	*Lonicera tatarica*	Caprifoliaceae
Big Chickweed	*Cerastium fontanum ssp. Vulgare*	Caryophyllaceae
Common Mouse-ear Chickweed	*Cerastium fontanum Baumg.*	Caryophyllaceae
Deptford pink	*Dianthus armeria L.*	Caryophyllaceae
Oriental Bittersweet	*Celastrus orbiculatus*	Celastraceae
Winged-burning Bush	*Euonymus alata*	Celastraceae
Winter Creeper	*Euonymus fortunei*	Celastraceae
Walter’s St. Johns wort	*Triadenum walteri*	Clusiaceae
Asiatic dayflower	*Commelina communis L.*	Commelinaceae
Plants cont.		

Common Name	**Scientific Name (Genus Species)**	**Family**
Field Bindweed	*Convoluvulus arvensis L.*	Convolvulaceae
Black gum	*Nyssa sylvatica*	Cornaceae
Flowering dogwood	*Cornus florida*	Cornaceae
Bald cypress	*Taxodium distichum*	Cupressaceae
Eastern red cedar	*Juniperus virginiana*	Cupressaceae
Cattail	*Carex typhina*	Cyperaceae
Chufa	*Cyperus esculentus*	Cyperaceae
Pennsylvania sedge	*Carex pensylvanica*	Cyperaceae
Chinese Yam	*Dioscorea opposita*	Dioscoreaceae
Common persimmon	*Diospyros virginiana*	Ebenaceae
Autumn olive	*Elaeagnus umbellata*	Elaeagnaceae
Black locust	*Robinia pseudoacacia*	Fabaceae
Redbud	*Cercis canadensis*	Fabaceae
Soybean	*Glycine max*	Fabaceae
Crownvetch	*Coronilla varia*	Fabaceae
Korean Lespedeza	*Kummerowia stipulacea*	Fabaceae
Kudzu	*Pueraria montana*	Fabaceae
Mimosa	*Albizia julibrussin Durazz.*	Fabaceae
Sericea lespedeza	*Lespedeza cuneata*	Fabaceae
Sweet Clover	*Melitotus* spp.	Fabaceae
American chestnut	*Castanea dentata*	Fagaceae
Black oak	*Quercus velutina*	Fagaceae
Bur oak	*Quercus macrocarpa*	Fagaceae
Chestnut oak	*Quercus prinus*	Fagaceae
Plants cont.		

Common Name	**Scientific Name (Genus Species)**	**Family**
Chinquapin (chinkapin) oak	*Quercus muehlenbergii*	Fagaceae
Pin oak	*Quercus palustris*	Fagaceae
Red oak	*Quercus rubra*	Fagaceae
Swamp white oak	*Quercus bicolor*	Fagaceae
White oak	*Quercus alba*	Fagaceae
Eurasian Waterbilfoil	*Myriophyllum spicatum*	Haloragaceae
Sweet gum	*Liquidambar styraciflua*	Hamamelidaceae
Yellow buckeye	*Aesculus flava*	Hippocastanaceae
Brazilian elodea	*Egeria densa*	Hydrocharitaceae
European frog-bit	*Hydrocharis morsus-ranae*	Hydrocharitaceae
Black walnut	*Juglans nigra*	Juglandaceae
Mockernut hickory	*Carya alba*	Juglandaceae
Pignut hickory	*Carya glabra*	Juglandaceae
Shagbark hickory	*Carya ovate*	Juglandaceae
Carpet bugle	*Ajuga reptans L.*	Lamiaceae
Creeping Charlie	*Pilea nummularifolia*	Lamiaceae
Sassafras	*Sassafras albidum*	Lauraceae
Spicebush	*Lindera benzoin*	Lauraceae
Periwinkle	*Vinca minor (major)*	Littorinidae
Purple loosestrife	*Lythrum salicaria*	Lythraceae
Tulip (yellow) poplar	*Liriodendron tulipfera*	Magnoliaceae
Hollyhock	*Alcea rosea L.*	Malvaceae
American lotus	*Nelumbo lutea*	Nelumbonaceae
Water lilies	*Nymphaea sp.*	Nymphaeaceae
Yellow cow lily	*Nuphar lutea*	Nymphaecaceae
White ash	*Fraxinus americana*	Oleaceae
Chinese Privet	*Liqustrum sinense*	Oleaceae
Plants cont.		
Common Name	**Scientific Name**	**Family**

	(Genus Species)	
Other Privets	*Ligustrum* spp.	Oleaceae
Primrose	*Oenothera biennis*	Onagraceae
Club-spur orchids	*Platanthera clavellata*	Orchidaceae
Nodding pogonia	*Triphora trianthophora*	Orchidaceae
Puttyroot orchid	*Aplectrum hyemale*	Orchidaceae
Southern rein orchid	*Platanthera flava*	Orchidaceae
Southern tubercled orchid	*Platanthera flava*	Orchidaceae
House Sparrow	*Passer domensticus*	Passeridae
Eurasian Ruffe	*Gymnocephalus cernuus*	Percidae
Red pine	*Pinus resinosa*	Pinaceae
Virginia pine	*Pinus virginiana*	Pinaceae
White pine	*Pinus strobus*	Pinaceae
Sycamore	*Platanus occidentalis*	Platanaceae
Big bluestem	*Andropogon gerardii*	Poaceae
Bog bluegrass	*Poa paludigena*	Poaceae
Broomsedge	*Andropogon virginicus*	Poaceae
Canada wildrye	*Elymus canadensis*	Poaceae
Corn	*Zea mays*	Poaceae
Indian grass	*Sorghastrum nutans*	Poaceae
Kentucky blue grass	*Poa pratensis*	Poaceae
Little bluestem	*Schizachyrium scoparium*	Poaceae
Needle grass	*Nassella spp.*	Poaceae
Prairie dropseed	*Sporobolus heterolepis*	Poaceae
Rice Cutgrass	*Leersia oryzoides* (L.) Sw.	Poaceae
Plants cont.		
Common Name	**Scientific Name**	**Family**

	(Genus Species)	
Switch grass	*Panicum virgatum*	Poaceae
Western wheat grass	*Pascopyrum smithii*	Poaceae
Wheat	*Triticum spp.*	Poaceae
Bald Brome	*Bromus racemosus L.*	Poaceae
Cheatgrass	*Bromus tectorum*	Poaceae
Japanese Stilt Grass	*Microstegium vimineum*	Poaceae
Johnsongrass	*Sorghum halepense*	Poaceae
Medusahead	*Taeniatherum nevki*	Poaceae
Orchardgrass	*Dactylis glomerata L.*	Poaceae
Reed canary grass	*Phalaris arundinacea*	Poaceae
Tall Fescue	*Lolium arundinaceum*	Poaceae
Japanese Knotweed	*Polygonum cuspidatum*	Polygonaceae
Rhubarb	*Rheum rhabarbarum*	Polygonaceae
Curly Leaf Pondweed	*Potamogeton crispus*	Potamogetonaceae
Moneywort/creeping jenny	*Lysimachia nummularia*	Primulaceae
Golden Seal	*Hydrastis canadensis*	Ranunculaceae
Black cherry	*Prunus serotina*	Rosaceae
Armenian blackberry	*Rubus armeniacus*	Rosaceae
Multiflora rose	*Rosa multiflora*	Rosaceae
Buttonbush	*Cephalanthus occidentalis*	Rubiaceae
Cottonwood	*Populus deltoids*	Salicaceae
White poplar	*Populus alba*	Salicaceae
Willow	*Salix L.*	Salicaceae
Plants cont.		

Common Name	**Scientific Name (Genus Species)**	**Family**
White Willow	*Salix alba*	Salicaceae
Giant Salvinia	*Salvinia molesta*	Salvinaceae
Common mullein	*Verbascum thapsus*	Scrophulariaceae
Tree-of-Heaven	*Ailanthus alitissima*	Simaroubaceae
Greenbrier	*Smilax* L.	Smilacaceae
Jimsonweed	*Datura stramonium L.*	Solanaceae
Japanese Yew	*Taxus cuspidata*	Taxaceae
Leatherwood	*Dirca palustris*	thymelaeaceae
Basswood	*Tilia americana*	Tiliaceae
White basswood	*Tilia heterophylla*	Tiliaceae
American elm	*Ulmus americana*	Ulmaceae
Cork (Rock) elm	*Ulmus thomasii*	Ulmaceae
Hackberry	*Celtis occidentalis*	Ulmaceae
Slippery elm	*Ulmus rubra*	Ulmaceae
Smooth white violet	*Viola macloskeyi*	Violaceae

Appendix B.

Table of Prioritization and Timeline of Major Planning and Habitat Management Projects

Objective	Strategy	Project	Timeframe	Priority (1-x)	Year and Annual Work Items
1.1	1.	Convert 310 acres of former ag. lands to upland hardwood forest in Forest Management Unit 2	By 2027		See strategies below
1.1	1a.	Forest Inventory	By 2015		2013: Develop partnership and coordinate inventory work with Region 4 foresters in year one. 2014: Conduct at least inventory 2015: Discuss inventory results and acquire recommendations
1.2	9.				
1.1	1b.	Forest Management Plan	By 2017		2014-2015: Write plan 2016: Submit draft for review 2017-Final Draft and approvals
1.2	10.				
1.1	1c.	Partner with GoZero or similar organization of forest plantings	By 2017		2013: Develop GIS layers of proposed planting sites 2014: Contact such organizations and begin dialogue 2015: Invite selected organization to refuge for site visit and share forest inventory recommendations

					2016: Develop formal agreements for planting projects **2017-2027: Facilitate fulfillment of agreements**
1.1	**1e.**	**Create site specific planting plans**	**By 2027**		**2017-2027: Create annual planting plans for approximately 30 acres each year (in cooperation with FWS foresters) or create one larger planting plan in cooperation with partnering organization**
1.1	**2.**	**Removal of invasive plants in upland forests using IPM**	**Ongoing**		**See strategies below**
1.1	**2a.**	**Invasive species Inventory**	**By 2014**		**2012: Ensure completion of data collection** **2013: Ensure completion of data analysis and distribution maps**
1.1	**2b.**	**Integrated Pest Management Plan**	**By 2019**		**2013:Begin writing background info using inventory data and map products** **2014: Complete prioritization of areas for treatement using Decision Support tool developed by EBF Bio Network and Adaptive Management Project** **2015-2019: Develop protocols for treatments of each species and complete IPM plan**

1.1	**4.a,b,c**	**Use TSI to achieve desired conditions on a minimum of 150 acres of upland forest**	**By 2027**		**2017-2027: Use TSI as outlined in Forest management plan on 15 acres per year**
1.1	**5.a,b,c**	**Artificially Replicate small forest openings (1 acre or less) as prescribed in the forest management plan**	**By 2027**		**2017-2027: Use small-scale clearcuts as indicated by forest management plan and FWS forester recommendations to complete 1% of the total desired openings per year**
1.1	**6.**	**Fill existing vacant tractor operator position and add a biotech**	**By 2018**		
1.2		**Revert/restore 650 acres and maintain 4,135 acres of bottomland hardwood forest**	**By 2027**		**See strategies below**
1.2		**Restore natural hydrology of GTRs including G1, G2, and Moss Lake and the moist soil units 8,9,10.**	**By 2027**		**See strategies below**
1.2		**Stop Maintianing Mallard and Display ponds allowing reversion back to bottomland hardwood forest**	**2012**		**No longer fix breaches or maintain dikes/levees**
1.2	**1.a,b,c,d,e;**	**Moss Lake Restoration Plan**	**By 2018**		**2012-2015: Acquire topographic data, either through LIDAR or through manual data collection in cooperation with Regional Hydrologists; also begin**

					developing planning document. 2016: Create time series flood models for Moss Lake and complete restoration plan 2017: Facilitated discussion with partners and experts 2017-2018: Complete restoration plan
1.2	**2.**	**Discontinue prescription flooding in GTR units except for low level flooding of Moss Lake**	**2012**		
1.2	**2.a. and 6.a,b**	**Remove sections of dikes and water control structures at G1, G2, and Moss Lake**	**By 2017**		**2012: Remove estimated 300 ft stretch of Moss lake dam west of the main outflow structure 2012-2017: remove sections of south, east, and west dikes of G2, south and est dikes of M10, south, east and west dikes of M9 2012-2017: replace stoplog structure leading from G1 to G2 with open culvert at least 30 in. diameter 2012-2017: Remove small section of Moss lake dam between Moss Lake and G1 to flowline in effort to restore a portion of Myers Branch**
1.2	**2.b.**	**Monitor GTRs for regeneration**	**Ongoing**		**2012-2013: Develop regeneration survey protocols, pilot test, modify, and**

					implement annually for the duration of this HMP
1.2	**2.c.**	**Prevent long duration and deep level impoundment of Moss Lake**	**Ongoing**		**Annually ensure stop log removal to a maximum setting of 539.32 ft MSL from Feb 1-March 1, 538.82 ft MSL March 1st-November 15 and 540.0 ft MSL from Nov. 15-Feb 1st.**
1.2	**3.a.**	**Modifications to Moss Lake water control structure**	**By 2027**		**Install screw gates, slide gates, or comparable designs to increase discharge, improve safety, and allow discharges from the entire water column instead of from the top of the water column over stoplog structures**
1.2	**4.a,b**	**Acquire tools necessary for accessing and removing beaver dams within the creeks/ditches in Moss lake**	**By 2013**		**2012-2013: Ensure one staff member receives proper training and certification in explosives** **2013-perpetuity: Maintiain certified staff member and acquire explosives**
1.2	**7,15**	**Annual water management plans**	**Ongoing/Annually**		**Each year complete an annual water management plan by February that will guide management for that calendar year.**
1.4	**1,2,4,5,6,7,8, 10, 11,14,15,**				
1.2	**9.**	**Conduct decennial forest surveys(starting ten years after**	**2025**		**2015: Initial Forest inventory** **2017: Forest Management**

		initial forest inventory)			**Plan- develop and include forest survey protocols for use in 2025 2025: Conduct decennial forest survey**
1.2	**11.**	**Bottomland forest small scale thinning and selective harvest as recommended in forest management plan**	**Ongoing**		**2018-2027: Annual treatments as outlined in forest management plan**
1.2	**12.a,b,c**	**Hydrogeomorphologic Study**	**By 2022**		**2012-2020: Acquire necessary data, i.e. detailed topographic data, inflow (preferably LIDAR) and outflow calculations; review and compile historic hydrology data, climatic data, habitat management actions etc. 2020-2022: Utilize Regional hydrologists, refuge biologist, and other staff to conduct HGM study or contract consultants to conduct the study**
1.2	**13.a,b,c**	**Restore hydrology and micro/macrotopography including vernal pools within reverting bottomland forest acreages**			**2012-2017: Enhance microtopography in M8, M9, and M10 prior to reversion of the units to bottomland hardwood forest. Provide vernal pools within these same areas.**
1.2	**14.**	**Allow east and west river trails to**	**2012**		**2012-2015: Passive process but**

		revert to bottomland forest to reduce fragmentation			**monitor for invasive species**
1.3	**1.**	**Grassland Management Plan**	**By 2017**		
1.3	**2.a,b,c,d,e; 6.,7.,8.,9.**	**Protect, restore, or enhance grasslands using adaptive management strategies**	**Ongoing**		
1.3	**4.**	**Inventory grasslands**	**By 2016**		**2013-2015: Develop or adopt a grassland inventory protocol 2015-2016: Conduct grassland inventory on all grasslands**
1.3	**5.**	**Remove invasives from grasslands**	**Ongoing**		
1.3	**6.**	**Promote soft/feathered edges within all grasslands**	**By 2022**		
1.3	**7.**	**Grassland soil testing on all grasslands**	**By 2016**		**2012-2013: Ensure farmer restores fertility within all croplands that will be removed from the farming program 2013-2016: Test all grassland soils 2017: Conduct fertility enhancing treatments as necessary based on findings and recommendations from grassland management plan 2026: Re-test grassland soils for fertility**
1.3	**8.**	**Remove linear edges (i.e. fencerows) from Grassland units 1,2, and 4**	**By 2027**		
1.4	**1.**	**Annually disturb on average 1/3**	**Ongoing**		

		of the moist soil unit acreage			
1.4	**3.a,b**	**Close public access on moist soil and emergent marsh dikes during peak migratory seasons (Oct. 1-April 30) except where vehicle traffic is permitted**	**By 2013**		**2012: Press release and other notifications as necessary. 2012: December-post signs at each dike in the northern waterfowl units and marshes 2013: Begin enforcement**
1.4	**8.c**				
1.4	**9.**	**Remove trees, stumps, logs, and woody debris from moist soil units M1-M6**	**By 2022**		
1.4	**11.a.**	**Switch to SWIM database**	**By 2013**		**2012: Biologist familiarized with SWIM and incorporates historical data if possible**
1.4	**11.a.,b.**	**Continue weekly waterfowl and waterlevel monitoring**	**Ongoing**		**Every week into perpetuity conduct the two surveys 2012: Establish benchmarks at Mutton Creek outflow side of Moss Lake dam, Hwy 50 bridges on Mutton and Storm Creek, Endicott North, Sandy Branch behind shop (2 locations-east and west) and Sandy Branch at Hwy 31.**
1.4	**11.c.**	**Moist soil vegetation surveys**	**Annually**		**Windshield surveys until new protocol developed with the Inventory and Monitoring plan**
1.4	**11.d.**	**Analyze waterfowl, water level, and vegetation datasets**	**Ongoing**		**2012: Investigate Integrated Waterbird Project and database**

					2013: Develop or adopt new protocols for conducting the monitoring and implement new database for housing all three datasets **2014: Develop methods of analysis of these data sets**
1.4	**15.b.**	**Install culverts and/or crossings, within the borrow pits of M2, M6, and McDonald North and South, to facilitate equipment entry into the units.**	**By 2022**		
1.4	**16.**	**Repair damaged and eroded dikes and levees of Moist soil units and marshes**	**As staffing and budgets allow**		
1.4	**17.**	**Remove or cut the southern M9 and M10 dikes and the cross dikes**	**By 2014**		**2011: Remove M10 water control structure and cut dikes on that unit** **2013-2014: Remove M9 water control structure at northeast corner (not the northwest corner) and cut dikes on that unit except western dike.**
1.4	**18.**	**Remove small levee between M4 and G4**	**By 2012**		**2011: make cut in levee** **2012: monitor site and determine need for further action**

1.4	**19.**	**Education and outreach about wetland management and dike closures**			**2012: Develop water management news releases and factsheet for staff and volunteers, and post at VC 2012: Host public presenation's at visitor center on wetland management 2013:Host public presentation on wetland management 2015: Public presentation on wetland management and every two years after**
1.6	**9.**				
1.4	**24.**	**Marshland rapid assessment monitoring**	**By 2016**		**2012-2015: Lit review and protocol development and/or selection 2016: final protocol as outlined in approved inventory and monitoring plan**
1.5	**1.,3.**	**Constructed wetland inventory for annual monitoring and restoration**	**By 2022**		**2012-2013:Develop GIS inventory of all constructed wetlands 2013-2018: Visit 20% (approx. 15-20) of identified wetlands per year to identify those that require annual monitoring and those that can be returned to ephemeral streams**
1.5	**2.**	**Conuct annual inspections of constructed wetlands identified in the inventory**	**Annually**		**Remove beaver dams or obstructions; control aquatic nuisance animals as necessary,**

					document problems and conditions
1.5	**4.**	**Breech levees as funding and staff levels permit**	**By 2022**		**2019-2022: Restore ephemeral streams where feasible and/or necessary**
1.6	**1.**	**Bathymetric investigations of Rihart and Stanfield Lakes**	**By 2014**		**2011: Acquire bathymetry data** **2012: Develop time series flood models in GIS and calculate volumes** **2012: Implement hydrologic changes as outlined in objective**
1.6	**1.**	**Bathymetric investigation of Moss Lake**	**By 2016**		**2012: Develop a plan in cooperation with Regional hydrologists** **2013-2015: Acquire data** **2016: Create GIS models, topographic maps, and time series flood models**
1.6	**4.a., 5.**	**Encourage expansion of American Lotus within Richart lake**	**Annually**		**2012: Annual partial drawdowns in late summer and fall as outlined in objective and monitor response**

1.7	**1., 2.**	**Monitor Creek/Ditch Waterlevels as part of weekly water level monitoring; monitor for beaver dams and obstructions to flow**	**Weekly into perpetuity**		**2012: Establish benchmarks at Mutton Creek outflow side of Moss Lake dam, Hwy 50 bridges on Mutton and Storm Creek, Endicott North, Sandy Branch behind shop (2 locations-east and west) and Sandy Branch at Hwy 31.**
1.7	**3.**	**Regularly remove impediments to flow (dams and log jams) within the creeks and ditches, especially in Moss lake portions**	**Monthly (Feb-Nov) into perpetuity**		
1.7	**4.**	**Control aquatic nuisance animals within the creeks/ditches**	**Minimum of Monthly operations**		**2013: Review policy and make determination on trapping** **2014: If trapping is accepted, create Trapping Plan, Compatibility determination, Section 7, NEPA** **2015: Advertise and select trappers and begin trapping of beaver and muskrat**

1.7	**7.**	**Stream Restoration Plan and begin implementation**	**By 2027**		**2012-2020: collect necessary information and data 2020-2022: Utilize Regional hydrologists, refuge biologist, and other staff to conduct HGM study or contract consultants to conduct the study 2022-2024: Develop Stream Restoration Plan 2025-2027: Begin implementation of stream restoration plan**
1.7	**8.**	**Increase discharge capacity of Hydrologic cell 2**	**By 2022**		**2012-2018: Develop and test hydrologic model of inflow and outflows of the Refuge 2016: Determine locations for new low water crossings, box culverts, or large diameter culverts to be installed on County Roads 400 and 500 2017: Develop project plan 2018: Find funding mechanism for project 2019-2022: Complete project**
1.10	**4., 5.**				
1.8	**1.**	**Eliminate farming of the remaining 215 acres of cropland**	**By 2013**		**2013: Do not renew farming contracts**

1.8	**2.**	**Stop annual haying practices with exception of use as a management tool for crane habitat fields where conditions should be optimized for cranes**	**By 2013**		**2012: Determine best management practices for timing of treatments and desired conditions to provide annual sandhill crane habitat within the southeastern field in grassland unit 3 and within all of grassland unit 2 2013: Begin enhancing vegetative composition and structure based on findings from 2012**
1.9	**1., 2., 3.**	**Inventory former crop and old field habitats on the Refuge based on grassland and forest management plan recommendations and protocols; analyze information and recommend management actions**	**by 2027**		**2017-2026: Conduct inventory 50-75 acres per year 2026-2027: Analyze inventory data and prescribe management actions Post-2027: Implement management actions**
1.10	**1.**	**Develop Watershed scale hydrologic model**			**2012: Install monitoring stations at Mutton and Storm Creeks in cooperation with Regional hydrologists 2012-2016: Acquire data for hydro model purposes 2016: Develop model**
1.10	**3.**	**Monitor hydrology within Hydrologic cells following Moss Lake dam modifications to monitor success**	**2012-2015**		**2012: Develop monitoring plan in cooperation with Regional Hydrologists and implement monitoring**

1.10	**4.**	**Modify CR400 and CR500 bridges**	**By 2020**		**2018-2020: When bridges are replaced increase overall span of each bridge to allow at least doubling the discharge capacities on all bridges over Mutton and Storm Creeks**
1.7	**8.d.**				
1.11	**1.,2.,3., 4., 6., 7., 10.**	**Develop Integrated Pest Management Plan with treatment protocols for all known species and thresholds for action, annual monitoring and mapping strategy, early detection and rapid response strategy; develop invasive plans and strategies within context of local, regional, and landscape scale perspectives**	**By 2015**		**2011-2012: Invasive species inventory, distribution maps, and decision support tool completion for prioritization 2013-15: Create IPM plan with cooperation from partners and other federal and state agencies 2015: Review and approval of plan**
1.12	**2.**	**Construct access routes for equipment and personnel along Mutton Creek between County Road 550 North into Moss Lake**	**By 2015**		**2012-2015: Create access route using interns, YCC, and staff to allow access for monitoring, beaver dam, removal and aquatic nuisance animal control**
1.12	**4., 5.**	**Restore drainage capabilities for Seep Spring RNA and M6**	**By 2014**		**2010:Remove berm at southern end of Seep Spring RNA 2010-2013: Remove beaver dams within the Seep Spring RNA 2013: Remove silt from borrow ditches and internal drains within the two areas**

1.12	**6.**	**Install backflow preventer on M6 outflow**	**By 2011**		
1.12	**7.**	**Install water level gauges in Seep Spring RNA to allow water level monitoring**	**By 2013**		
1.12	**8.**	**Form a working group to collaboratively assist in restoration of the Seep Spring**	**By 2013**		**2012: Make initial contacts of potential cooperators, stake holders, etc.** **2013: Host cooperator meeting to develop a plan of action**
1.12	**9.**	**Seep spring historic water regime study and develop monitoring/rapid assessment protocol**	**By 2015**		**2013: At cooperator meeting develop research protocols** **2013-2015: conduct research**
1.13	**5.**	**Begin controlling nuisance animals at the Restle unit**	**By 2012**		**Make at a minimum two trips annually into perpetuity to the Restle unit to control aquatic nuisance animals**
1.13	**6.**	**Develop Restle Unit management agreement/partnership with academic institution (e.g. Indiana University- Bloomington) or other partner (e.g. Bloomington Parks and Recreation or Sycamor Land Trust) to handle day to day management of water levels, beaver dam removal, waterlevel, waterfowl, and vegetation monitoring**	**By 2014**		**2012: Begin dialogue with Regional supervisors and potential management partners** **2013: Draft and sign agreements** **2014-perpetuity: Coordinate annual planning and management activities with designated partner**