W/AEAG-84/W05
AUGUST 1984

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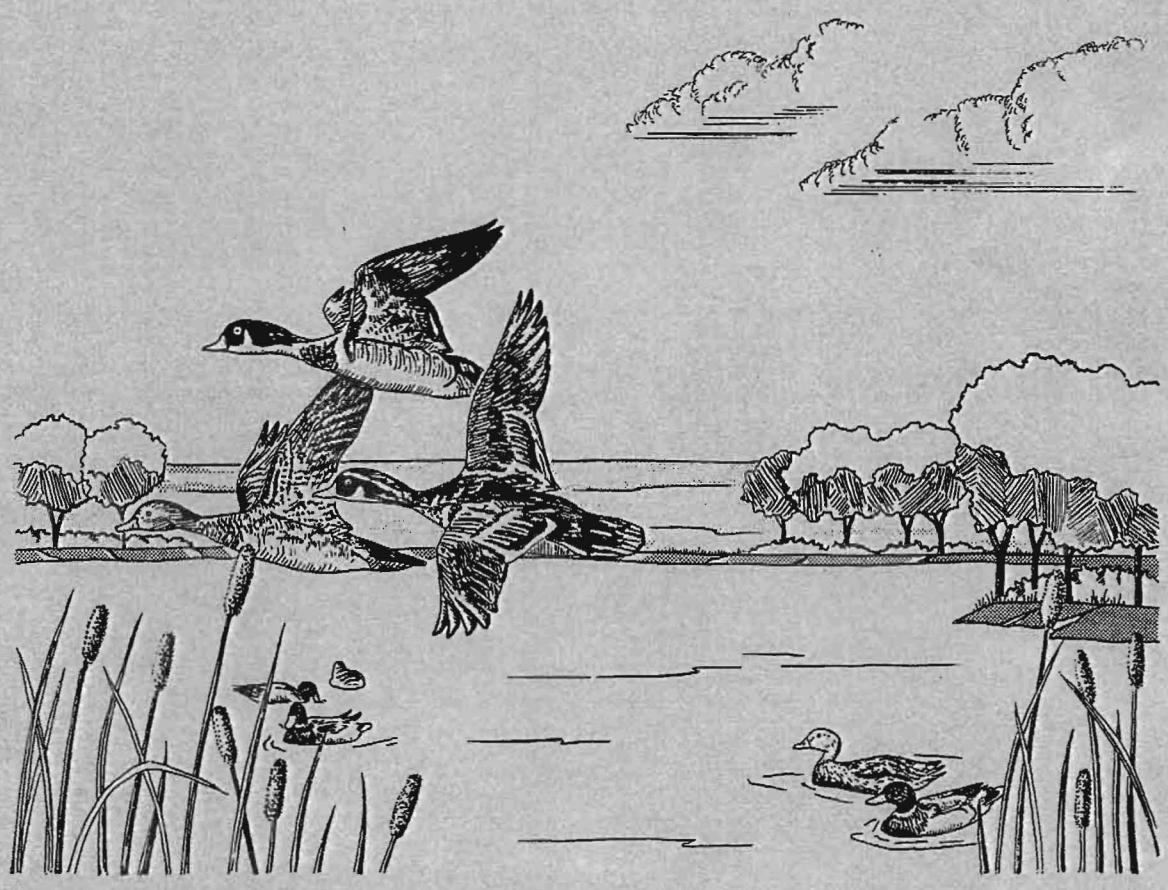

Fish and Wildlife Service

U.S. Department of the Interior

W/AEAG-84/W05
August 1984

REFUGE MANAGEMENT ANALYSES: RESEARCH NEEDS FOR MUSCATATUCK NATIONAL WILDLIFE REFUGE

by

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Performed for
Refuge Division, Region 3
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This report should be cited as:

Roelle, J. E., G. T. Auble, and D. B. Hamilton. 1984. Refuge management analyses: Research needs for Muscatatuck National Wildlife Refuge. U.S. Fish Wildl. Serv. Western Energy and Land Use Team, Ft. Collins, CO. W/AEAG-84/W05. 30 pp.

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INTRODUCTION

Muscatatuck National Wildlife Refuge, located in southeastern Indiana, was established by the Migratory Bird Conservation Commission in 1966. Land use planning for the Refuge formally began in 1971, and development of facilities designed in that planning effort is now nearing completion. As these facilities become operational, Refuge personnel will be manipulating water (both spatially and temporally) and other habitat components to achieve the joint Refuge goals of natural resource conservation and public use. This situation offers a unique opportunity to institute research and management studies designed to evaluate and enhance the effectiveness of the management regime in providing for the needs of migratory waterfowl and other wildlife resources.

WORKSHOP OBJECTIVE

Recognizing this opportunity, personnel from Region 3 of the U.S. Fish and Wildlife Service (FWS) convened a small workshop on February 7-9, 1984. The objective of the workshop was to prepare a list of specific research and management study needs essential to initiation of a management regime at Muscatatuck National Wildlife Refuge. This report documents the results of that workshop.

APPROACH

The authors of this report, as members of the Western Energy and Land Use Team, FWS, were asked to organize and direct the workshop. This request was

based on the authors' previous experience in conducting similar workshops where construction of a model (either conceptual or computerized) of a natural resource system was used as a means of achieving a better understanding of the system components and their interactions.

The workshop was organized around construction of a conceptual model of the Refuge and the ways that it contributes to the needs of the wildlife species that use it. Initial discussions identified the primary Refuge outputs and the management actions available to Refuge personnel in their efforts to achieve these outputs. Subsequent discussions focused in greater detail on the specific ways in which management actions influence the level of production of Refuge outputs. A large number of uncertainties were identified in this process. These uncertainties were used as the basis for outlining information needs that might be addressed through research and management studies. Finally, potential studies were defined and discussed in terms of their perceived importance.

Participants at the workshop included the following individuals:

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These individuals contributed the vast majority of the ideas and information contained in this report. In documenting the results of the workshop, we have attempted to retain both the content and sense of the discussions, but accept full responsibility for errors of fact or interpretation.

REFUGE RESOURCES AND MANAGEMENT

REFUGE OUTPUTS

The Muscatatuck National Wildlife Refuge Master Plan (U.S. Fish and Wildlife Service 1982) identifies a number of objectives that contribute to the broad goals of resource conservation (e.g., use-days by marsh birds, shorebirds, raptors, ducks, and geese and wood duck production) and public use (e.g., activity-hours devoted to environmental education, wildlife observation, hunting, and fishing). However, because of the need to begin operating the water management facilities, there was unanimous agreement among participants that the most pressing requirement was for better understanding of the relationships between water management, habitat conditions, and the needs of nesting and migrating waterfowl. The remainder of the workshop, therefore, focused on two Refuge outputs: wood duck production and waterfowl maintenance. The wood duck production output is measured in terms of number of young fledged. The waterfowl maintenance output is, for the purposes of this report, defined in terms of duck use-days throughout the year. There is also a Refuge waterfowl maintenance objective that is measured in terms of use-days by geese and swans, but this output was not considered at the workshop.

MANAGEMENT ACTIONS

The next activity of the workshop was to define the management actions available to Refuge personnel in trying to meet their objectives for wood duck production and waterfowl maintenance (Table 1). Management actions are listed separately for the two objectives, but there are many similarities between the two lists. Most of the actions deal, of course, with ways in which habitats

Table 1. Management actions that can be used to achieve wood duck production and waterfowl maintenance objectives.

Wood duck production

- Nesting and brood habitat
  - Regulate water in Moss Lake
  - Regulate water in green tree reservoirs
  - Maintain water in moist soil unit borrow ditches
  - Modify existing nest cavities
  - Construct artificial nest boxes
  - Create additional nesting habitat
  - Create additional brood habitat
  - Manage timber
- Predation
  - Manage predator populations
- Public use
  - Regulate hunting
  - Regulate activities to minimize disturbance

Waterfowl maintenance

- Feeding and resting habitat
  - Regulate water in Moss Lake
  - Regulate water in green tree reservoirs
  - Regulate water in moist soil units
  - Control succession in moist soil units (mowing, discing, burning, flooding)
  - Regulate farming practices (type of crop, number of acres, method of harvest)
  - Create additional habitat (dike agricultural fields, plant desirable mast producing trees)
- Public use
  - Regulate hunting
  - Regulate activities to minimize disturbance

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can be manipulated. These actions provided the basis for a more detailed discussion of the ways in which the Refuge can be managed to provide for the needs of wood ducks and other migratory waterfowl.

WOOD DUCK PRODUCTION

While wood ducks probably use the Refuge to some extent for all phases of their annual cycle, the principal uses are for nest site selection (breeding pair habitat), nesting, and brood rearing (Figure 1). Discussions at the workshop, therefore, focused on the habitat requirements of wood ducks during each of these stages and the ways in which the refuge might be managed to meet these requirements (see subsequent section on WATER MANAGEMENT).

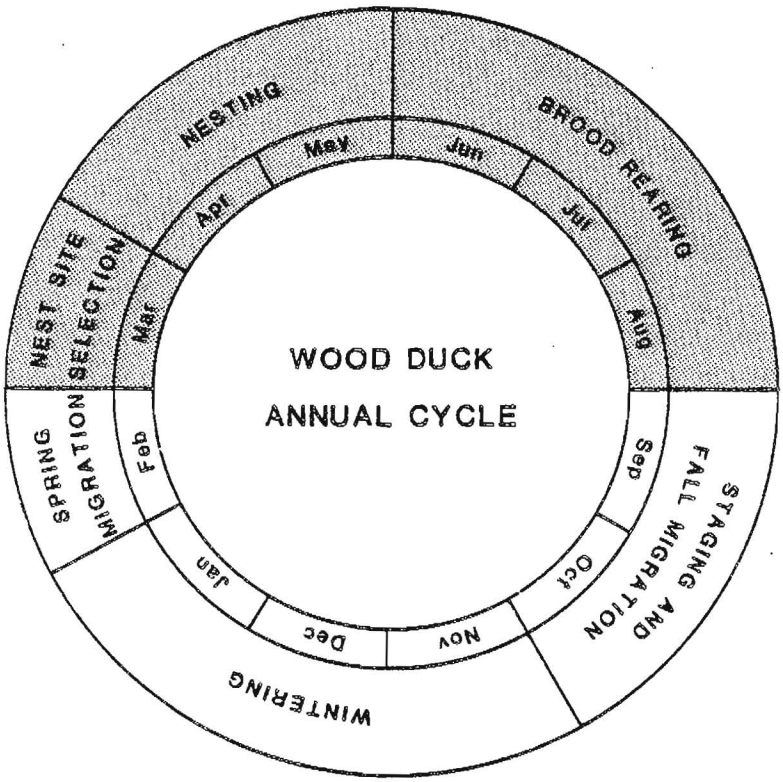

Figure 1. Generalized annual cycle for wood ducks. Shaded portion indicates principal uses of Muscatatuck National Wildlife Refuge.

Breeding Pair Habitat

In the spring, migrating wood ducks arrive at Muscatatuck National Wildlife Refuge during February and March. Attracting potential breeding pairs for nest site selection is the primary management objective during this time. The process of nest site selection can be lengthy, during which time an adequate food supply allows the birds to build and maintain sufficient energy reserves for nesting. Shallow, freshly flooded, forested wetlands, rich in invertebrates and seeds and catkins of species such as ash, cottonwood, and river birch, are the preferred habitat, although almost any wetland will be used to some extent. The margins of Moss Lake, the green tree reservoirs, and temporary forest pools offer the best opportunities to provide this habitat, although management control over water levels is often precluded by spring floods.

Two principal uncertainties were raised concerning this phase of the wood duck annual cycle. First, to what extent is homing of females fledged on the Refuge a determinant of the number of breeding pairs? Second, to what extent does the temporal pattern of flooding influence invertebrate production in forested wetlands? More specifically, are forested wetlands that have been flooded all winter any less productive in the spring than those that are flooded in fall and early winter, dried out in mid- to late winter, and reflooded in early spring?

Nesting Habitat

Wood duck nesting activity on the Refuge probably occurs mostly during April and May, although renesting may extend well into summer. The preferred habitat seems to be a suitable cavity over water, although cavities near water are also used. Suitability of a cavity is apparently related to the size of the tree, the size of the opening, and the depth of the cavity itself. The number of nesting pairs and their success are related to factors such as the total number of breeding pairs, the number of suitable cavities, competition with other species for those cavities, nest predation rates, and the frequency of renesting.

Uncertainties identified during the discussion of nesting habitat included the following: What is the total nesting population of wood ducks on the Refuge and is it sufficient to meet the production objective? Are nest densities significantly different in flooded and unflooded habitats? Is the nesting population on the Refuge limited by the number of suitable cavities? What are the specific criteria (e.g., size of opening, depth, size of tree, proximity to water, and forest stand characteristics) that determine suitability of cavities? What are the important nest predators and do predation rates differ for flooded and unflooded nest sites? What is the rate of renesting? If the renesting rate is high, can the water management regime be altered to better accommodate late broods? Can predator management reduce nest predation rates and, therefore, influence the frequency of renesting? And, finally, does human activity significantly affect nesting success?

Brood Rearing Habitat

Brood rearing habitat is that habitat used from the time the young leave the nest to the time they reach flight stage. At Muscatatuck National Wildlife Refuge, it is thought to be of primary importance in June and July, although some later broods may not reach flight stage until August. It quickly became apparent that a precise definition of the characteristics of brood habitat is not currently possible for the Refuge. In a general sense, however, it is known that broods are dependent on an adequate invertebrate food supply during the first few weeks of life and that the food resource must be located in relatively shallow water near escape cover. The best opportunities for providing brood habitat at Muscatatuck National Wildlife Refuge appear to be the flooded portions of Moss Lake, flooded borrow ditches internal to the moist soil units, temporary forest pools, small isolated ponds without water control structures, and, possibly, a few other areas, such as the Muscatatuck River itself and the margins of Richart and Stanfield Lakes.

The principal uncertainties concerning brood rearing at the Refuge are the kinds and amounts of habitat available and the adequacy of the habitat relative to production objectives. The following questions were raised during

the workshop: What specific food resources are utilized by young wood ducks and how is production of those resources influenced by water management? How many broods hatched on the Refuge are reared off the Refuge? Conversely, are broods hatched elsewhere reared on the Refuge? Is there significant movement of broods on the Refuge and, if so, how does it influence census or survey results? What are the rates of loss of ducklings to various predators, and do these rates differ in different habitats? And, finally, does water management (e.g., drying out green tree reservoirs in May) induce brood movement and increase vulnerability to predation?

WATERFOWL MAINTENANCE

It is expected that the waterfowl maintenance objective for Muscatatuck will be achieved primarily through use of the Refuge by migratory birds for feeding and resting in the fall and, to a lesser extent, in the spring. Fall use is expected to occur from September through December, with a peak in early December. Spring use is likely to occur from February through April. Some birds may remain throughout the winter when the weather is mild, but it is unlikely that there will be active management efforts to maintain open water that would hold birds on the Refuge.

The extent to which Muscatatuck National Wildlife Refuge will be used by migratory waterfowl is largely unknown at this time, because the amount of use depends on many factors external to the Refuge (e.g., size of the flyway population, amount of habitat available elsewhere, and chance "discovery" of the Refuge). However, it is likely that the amount of use in the fall is influenced by several factors, including: the total area inundated (an attractant to migratory birds); food production on the Refuge (mast, seeds, agricultural crops, and invertebrates); food availability on lands surrounding the Refuge; the flooding regime (shallow, freshly flooded areas seem to be preferred); and the amount of human disturbance.

The amount of use at the Refuge in the spring is determined by a similar set of factors, with two possible exceptions. First, the total area inundated is less important, because spring flooding usually results in a great deal of temporary wetland habitat. Second, high protein food sources, such as invertebrates, are likely to be more important in spring.

Uncertainties raised during the discussion of waterfowl maintenance centered around the impact of a flooding regime on waterfowl food production and the consequent use of the food by migrating birds. The questions asked were: How much total food is needed, both on and off the Refuge, to achieve the waterfowl maintenance objective and what are the best ways to produce this food? What are the most important determinants of the amount of use received by moist soil units and green tree reservoirs? In particular, do moist soil units that are flooded for the entire fall and winter receive any less use in the spring than those that are flooded in the fall, drawn down in the winter, and reflooded in the spring?

WATER MANAGEMENT

Storage and Delivery System

The present water management system at Muscatatuck National Wildlife Refuge (Figure 2) consists principally of three lakes (Moss, Richart, and Stanfield), 10 moist soil units (MS 1-10), and three green tree reservoirs (GT I-III). Additional proposed facilities include a storage reservoir east of MS 10; two moist soil units and a green tree reservoir west of Storm Creek; and a reservoir, moist soil unit, and green tree reservoir near Mini Marsh. The majority of the system, excluding Richart Lake, Stanfield Lake, and (perhaps) MS 1, lies within the 1-year floodplain of the Muscatatuck River and thus is inundated at least once nearly every year by winter or spring floods.

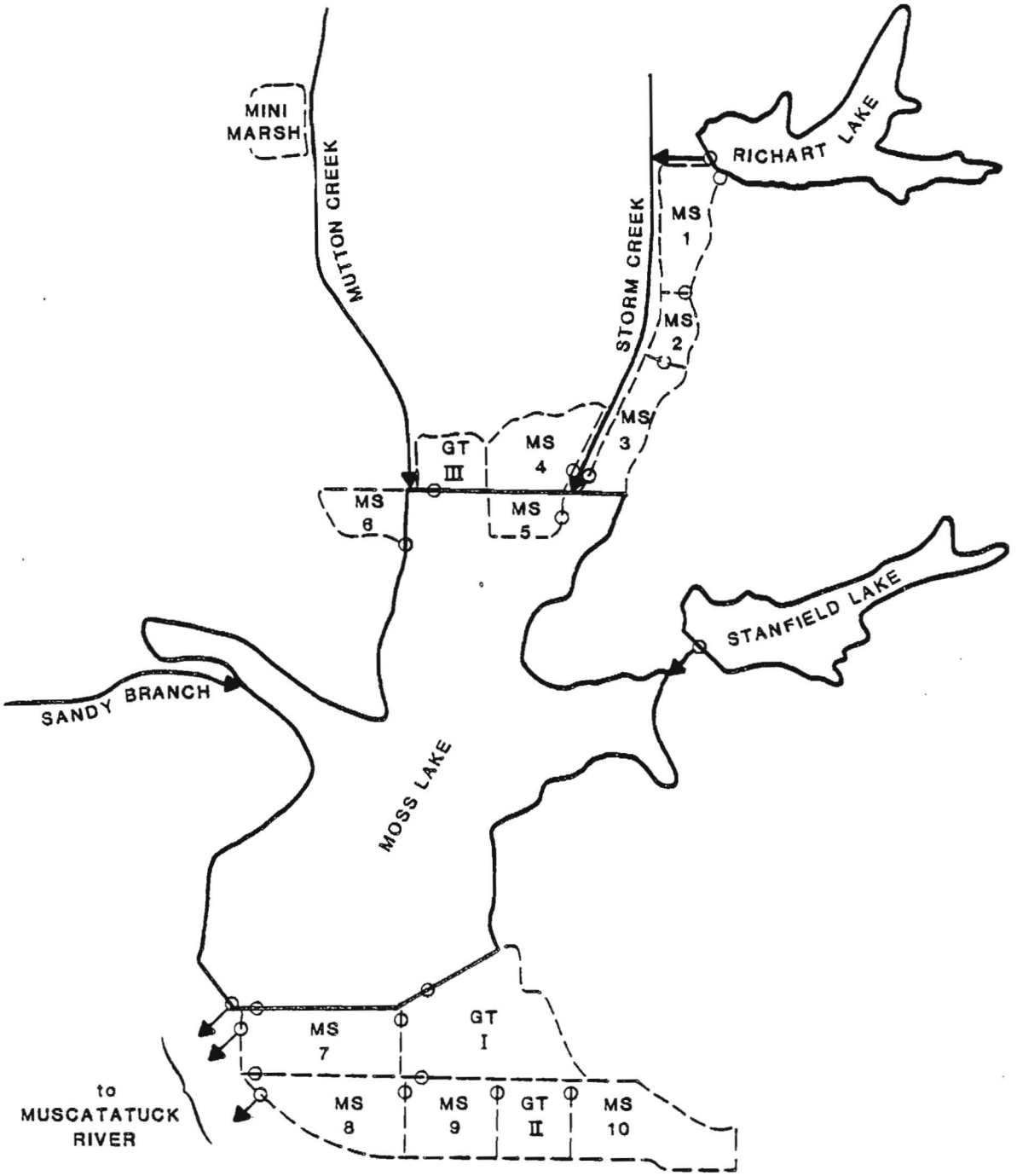

Figure 2. Water management system at Muscatatuck National Wildlife Refuge. MS = moist soil unit; GT = green tree reservoir; circle = water control structure.

The delivery system to various moist soil units and green tree reservoirs depends on the water levels in certain critical impoundments, the orientations between inlets and outlets, and elevational differences between impoundments. Base physical characteristics for the managed impoundments at the Refuge are presented in Table 2. Under a gravity flow system, discharges from Richart Lake can either be used to fill MS 1-3 or passed directly through Storm Creek to Moss Lake. Water from Moss Lake can be backed up to varying degrees into units MS 5-9 and GT I-III, depending on the pool level in the lake. When Moss Lake is at pool stage, 543.0 msl, units MS 5, MS 6, MS 7, MS 8, and GT I can be filled completely, while units MS 9 and GT II and III require seasonal precipitation to complete filling. MS 4 and MS 10 are completely above the pool level of Moss Lake and can be filled only during storm events. Drainage via gravity flow can be accomplished for all units; however, some restrictions exist on drainage patterns due to orientation of inlets and outlets, the ground elevation between units, and the elevation of Moss Lake. The level in Moss Lake is most critical for those units where the water control structure serves as both inlet and outlet to Moss Lake and the minimum field elevation of the unit is below the pool level in Moss Lake.

Given the annual rainfall regime at Muscatatuck National Wildlife Refuge, water supplies available for waterfowl management can become critical during the fall. At this time, water management options are limited by the pool level in Moss Lake and the amount of seasonal precipitation. Supplemental waters to help alleviate this situation also are limited. Minor releases from Richart Lake can be passed directly through Storm Creek to Moss Lake. Water from Stanfield Lake can be released into Moss Lake, but Stanfield Lake is used for public fishing and, therefore, must be maintained as close to capacity as possible until October 15th each year. If Moss Lake is at an elevation of 539.5 msl (approximately 200-275 surface acres), some of the released water can be routed to MS 5, MS 7, and GT I. In order to influence other units, released water first has to be used to increase the level of Moss Lake. Because of the size of Moss Lake, virtually none of the released water is then left for use in MS 6, MS 8, MS 9, or GT II-III. Therefore, very little supplemental water is actually available for effective waterfowl management under a gravity flow system.

Table 2. Impoundment elevations.[a]

Unit	Maximum pool elevation	Maximum field elevation[b]	Minimum field elevation[c]	Outlet floor elevations	Acreage	Subtotal
Richart Lake	555.0			547.0	87	
Stanfield Lake	559.0			546.0	123	
Moss Lake	543.0			538.0	428	
						638
MS 1	549.3		546.5	544.0	20	
MS 2[d]	547.3	546.5	544.5	541.0	23	
MS 3	545.4			539.0	18	
MS 4	545.3	544.8	543.5	539.0	35	
MS 5	543.8		541.2	539.0	15	
MS 6	544.0	542.5	541.6	541.5	13	
MS 7	543.0		538.5	534.5	50	
MS 8	543.3	543.0	541.5	536.6	50	
MS 9	543.8	543.6	542.3	539.3	35	
MS 10	544.3		543.1[e]	540.5	30	
						289
GT I	543.8	542.3	541.0	540.0	90	
GT II	543.6	543.6	542.4	540.0	40	
GT III	544.9	544.0	542.4	541.0	70	
						200
Grand total						1,127

[a]From 1983 Water Management Plan.

[b]Maximum field elevation is the elevation at which 90% of the surface acreage is flooded.

[c]Minimum field elevation is the elevation at which 10% of the surface acreage is flooded.

[d]Unit contains 2 ft contour interval. Minimum field elevation for the north half is 545.5 msl.

[e]Elevation determined by survey, all readings are relative until bench marks are established.

If limited pumping is considered, some additional flexibility could be gained for reflooding certain units while reducing the water needed for unit management. This reduction would occur because water would no longer have to be used just to fill Moss Lake to a level high enough to allow water to back up into some units. A central pump located in MS 7 could increase management flexibility in MS 8, MS 9, and GT I. A portable pump could be used for timely water management in units north of Moss Lake in the Central Waterfowl Area (MS 4, MS 6, and GT III). The following section on Management Regime assumes that some limited pumping capability would be available.

Management Regime

The next part of the discussion at the workshop focused on describing a management regime by which the storage and delivery system could be used to provide the habitat necessary to meet Refuge objectives for wood duck production and waterfowl maintenance. The results of this discussion are summarized in Figure 3. The intent of this diagram is to portray periods of filling and draining and dry vs. flooded conditions, rather than exact quantities of water. Thus, the narrowest lines represent dry conditions and the widest lines represent flooded conditions. The line of intermediate thickness for Moss Lake represents an elevation of 539.5 ft (200-275 surface acres). Lines of intermediate thickness for moist soil units represent partial flooding or dewatering.

Figure 3 begins with conditions in August when most of the moist soil units and green tree reservoirs would be dry to allow annual growth. Exceptions would be MS 10 and Mini Marsh, which would be left in a flooded condition for as much of the year as possible because of the difficulty in filling them. MS 6 and the borrow ditches around the moist soil units would also be flooded to provide brood habitat. Richart Lake and Stanfield Lake would be full. Moss Lake would be drawn down to an elevation of 539.5 ft (200-275 surface acres). This level would result in the loss of 150-210 acres of green trees but would still provide some habitat for wood duck broods. In addition, it would minimize the amount of water required from Stanfield Lake or Richart Lake in order to flood the impoundments south of Moss Lake in the fall.

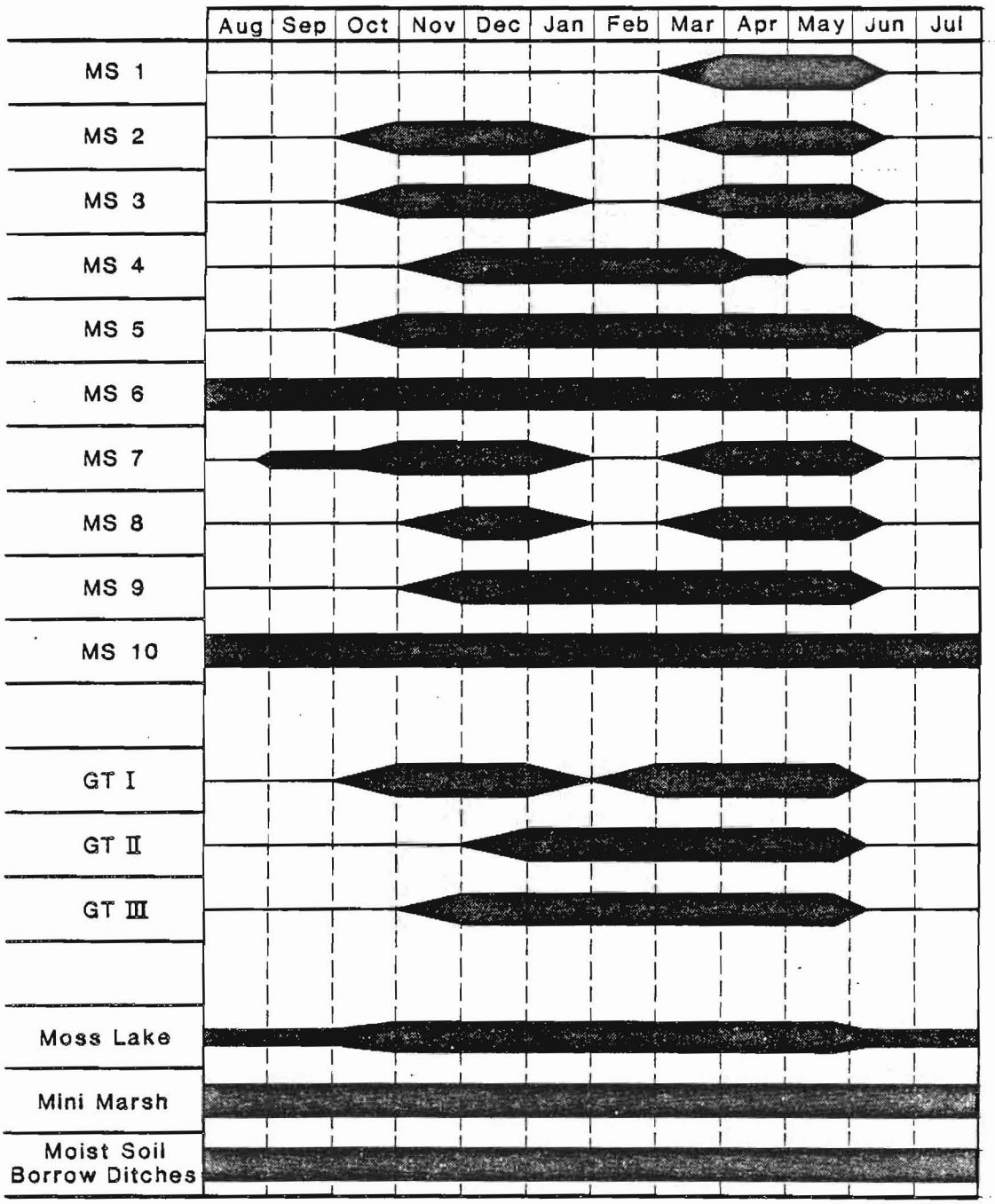

Figure 3. Schematic representation of the proposed water management regime for Muscatatuck National Wildlife Refuge.

By late August, partial flooding of one moist soil unit, perhaps MS 7, would begin in order to provide habitat for early migrating teal and wood ducks and to conduct waterfowl banding operations. MS 2, MS 3, and MS 5 could also be used for this purpose. Additional experience may indicate which of these units is most nearly commensurate with the number of birds using the Refuge early in the fall migration. In any case, water for filling the chosen moist soil unit would probably come from Richart Lake, because Stanfield Lake would need to be maintained at or near capacity for fishery purposes.

The elevation of Moss Lake and MS 7 would be raised during October to allow maximum flexibility in managing the other impoundments. Three additional moist soil units (probably MS 2, MS 3, and MS 5) and a green tree reservoir (probably GT I) would be flooded gradually to provide habitat for migrating waterfowl. Water from Stanfield Lake could be used after October 15th. The same pattern would be repeated in November (using MS 4, MS 8, MS 9, and GT III) in order to produce a continuous distribution of freshly flooded wetlands.

Natural flooding in late December normally inundates all of the impoundments except MS 1. Thus, GT II is shown as filling during December, but this could occur earlier if water levels were high enough. There was considerable discussion of the management regime during December and January. This discussion centered around two issues: (1) flood control; and (2) the question of whether or not impoundments flooded in the fall, dried out in the winter, and reflooded in the spring are more productive or attractive to waterfowl in the spring than those that remain flooded all winter. Figure 3 shows Moss Lake as remaining full during December and January. This alternative would, in theory, provide maximum habitat and minimize the potential for damage to dikes from floods originating from the Muscatatuck River. Another opinion was that Moss Lake should be maintained about one-half full during the flood season. This would have two potential benefits. First, it would provide maximum capacity to discharge flood waters originating in the drainage upstream of Moss Lake. Second, it would allow reflooding of the periphery in early spring to provide (perhaps) more attractive habitat to wood ducks.

The same discussion of relative productivity was also extended to moist soil units and green tree reservoirs. Figure 3 shows that an experimental approach would be possible. MS 2, MS 3, MS 7, MS 8, and GT I, all of which are fairly easy to reflood, would be dried out during January. MS 4, MS 5, MS 9, GT II, and GT III, all of which are more difficult to flood, would be left flooded. GT I would be reflooded during February to provide maximum habitat for migrating wood ducks. Similarly, MS 2, MS 3, MS 7, and MS 8 would be reflooded in March to provide maximum habitat for other migrating species and to control growth of woody species. Waterfowl use of the impoundments in the spring would be compared to see if there appears to be any advantage to drying out in the winter and reflooding in the spring. A further comparison would be provided by MS 1, which would be flooded in March after being dry (barring uncontrollable floods) throughout the fall and winter. Water for flooding these impoundments in February and March is expected to be available as natural runoff, which would also refill Richart and Stanfield Lakes.

Moss Lake and all of the green tree reservoirs would remain flooded until late May, at which time they would be drained (Moss Lake would be drawn down to 200-275 surface acres) to minimize killing of live trees. Unfortunately, this would reduce the amount of potential brood habitat available for wood ducks. Most of the moist soil units would be drained in early June to allow annual growth of vegetation. One exception would be MS 4, which would be partially dewatered in April to gather phenological data associated with the shorebird migration and would be drawn down by May to permit farming operations to control a cocklebur infestation. Water would be retained in MS 10 and Mini Marsh, because of the difficulty of reflooding these areas. Water would also be retained in MS 6 and the borrow ditches of all moist soil units to provide brood habitat.

It is anticipated that this management regime would be followed as closely as possible for 2-3 years. This would allow time to evaluate its feasibility and effectiveness and provide a consistent background for ongoing research. Following this trial period, adjustments would be made based on the experience gained to that point. A rotation schedule would be established to allow control of natural succession in moist soil units using approaches such as mowing, burning, discing, or year-round flooding.

RESEARCH NEEDS

INITIAL IDENTIFICATION

A list of research needs (Table 3) was developed by having each participant at the workshop independently specify what he considered to be the five most important research needs. These ideas were reorganized and slightly reworded, but no attempt was made to eliminate duplication.

The majority of the research needs concern some aspect of the ecology of wood ducks. Many of these are focused on identifying or measuring the factors that most limit wood duck production at Muscatatuck National Wildlife Refuge. A large number of the needs are directed at estimating the nutritional requirements of wood ducks and other waterfowl and determining how the system could be managed to meet those nutritional needs (especially with respect to invertebrate production).

RESEARCH PROJECTS

Discussion of the research needs (Table 3) resulted in the preliminary specification of eight possible research projects. One research project on wood duck production is already underway at the Refuge. A brief description of this project (being conducted by Dr. Bookhout) is included here because it addresses a number of the research needs and is a logical starting point for any other research on wood duck production at Muscatatuck National Wildlife Refuge.

Table 3. Research needs identified at the workshop.

WOOD DUCK PRODUCTION

Nesting stage.

1. Determine acres of nesting habitat necessary to meet wood duck production objectives.

Brood stage.

2. Determine what management can or should be done for wood duck brood habitat.

3. Develop (or refine) Habitat Evaluation Procedures (HEP) criteria for wood duck brood habitat.

4. Evaluate the role of invertebrates in the quality (or suitability) of wood duck brood habitat.

5. Estimate how much (quality and quantity) wood duck brood habitat is required to achieve production objectives at the Refuge.

6. Determine how much (quality and quantity) wood duck brood habitat there is at the Refuge.

7. Evaluate movement patterns of wood duck broods on the Refuge and their possible effects on the results of census procedures.

8. Evaluate the effects of water drawdown on wood duck brood movement and habitat utilization.

9. Determine ingress and egress (on and off the Refuge) of wood duck broods.

Mortality.

10. Compartmentalize (or partition) total mortality of wood ducks into various life cycle stages or times of the year.

11. Determine if predators are a major limiting factor on production of wood ducks at the Refuge.

12. Evaluate sources of predation on wood ducks and possible control measures.

Table 3. (continued)

General.

13. Determine most limiting factor for production of wood duck fledglings (e.g., number of breeding pairs, predation, brood habitat, or nesting habitat) and evaluate whether or not the current production objective can be attained.

14. Determine general needs for forest management and develop a forest management plan to maintain (or enhance) conditions for wood duck production.

WATERFOWL MAINTENANCE

Nutrition.

15. Estimate the food required in the fall and spring to meet the waterfowl maintenance objective.

16. Determine the best ways to provide the required food.

17. Determine additional facilities (e.g., impoundments or water control structures) necessary to achieve the required level of food production.

18. Determine the amount of off-Refuge feeding by waterfowl in the fall.

Moist soil units.

19. Determine the most important factors influencing utilization (in units of use-days) of moist soil units by waterfowl.

20. Estimate the total area of moist soil units needed to achieve the waterfowl maintenance objective.

GENERAL WATER AND HABITAT MANAGEMENT

Food production.

21. Determine how to increase mast production in bottomland hardwood habitats.

22. Determine how to achieve the highest levels of invertebrate production at times corresponding to the needs of waterfowl.

Table 3. (concluded)

Food production. (continued)

23. Obtain information on the production ecology of invertebrates corresponding to information on the nutritional requirements of waterfowl.

24. Measure abundance of invertebrates and determine the most influential factors in terms of invertebrate production in green tree reservoirs and Moss Lake.

Water management.

25. Evaluate the effects of dewatering moist soil units after natural flooding in the fall or winter (i.e., determine if they should be drained and refilled in the spring or just kept wet through late winter and early spring).

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1. Ecology of Wood Duck Production (Dr. Bookhout's current project)

This study concerns three primary aspects of wood duck ecology: (1) nesting habitat; (2) brood rearing habitat; and (3) the fledging rate. Data collection for the first field season is just beginning. The study will be continued for a second field season. Results from the second field season are expected to be more reliable because of modifications in the sampling design based on preliminary results from the first year. This project will provide information relative to research needs 1, 2, 3, 4, 5, 6, 7, and 9 of Table 3.

Nesting habitat. A stratified survey will be used to estimate the number of potential nesting cavities. These cavities will be resurveyed to determine the occupancy rate. Several variables will be measured for each cavity (e.g., size of cavity, location in tree, and distance to water) in an attempt to quantify what the characteristics are that determine a suitable nesting cavity. Extrapolation from the number of nesting cavities per unit area and their occupancy rates to the Refuge as a whole will provide an estimate of the total number of nesting pairs. Examination of nests after (and perhaps during) nesting will provide an estimate of nesting success rate. Estimates of clutch size and nest mortality from various sources will be difficult to obtain because of the need to avoid disturbing nests. Nesting hens (identified by brood patch) will be captured (using baiting) and fitted with transmitters during the nesting season. This will allow association of nests with specific broods whose movements can later be monitored by radiotelemetry. Hens that are recaptured after their nests are located will have the transmitters replaced with tags to increase the total sample size, given the constraint of approximately 20 transmitters.

Brood habitat. Radiotelemetry and general observation of marked and unmarked birds will be used to assess movement patterns of broods and the nature and location of brood habitat. Changes in brood sizes over time (especially broods of marked hens) may provide some estimate of brood mortality.

Fledging rate. A comprehensive census of broods near the time of fledging will provide an estimate of the number of fledglings produced at the Refuge. This total number of fledglings can be compared to the estimates of the total number of suitable cavities and nesting pairs described above and to an estimate of the total number of successful nests (total number of nesting pairs times the nesting success rate). These comparisons will help determine the most limiting factors to wood duck production at Muscatatuck National Wildlife Refuge.

2. Estimation of Waterfowl Food Production at Muscatatuck National Wildlife Refuge

Description. A preliminary calculation of waterfowl food production at the Refuge would be made based on currently available or easily obtainable information on areas of various cover types and the best available estimates from the literature of food production from those cover types under the anticipated Refuge management regime.

Problem. Muscatatuck National Wildlife Refuge has a number of recently constructed impoundments and other water control structures and the potential for developing additional water management facilities. Decisions about management of existing and possible future facilities need to be made in the context of the food production necessary to meet feasible waterfowl management objectives. This project corresponds directly to research need 15 in Table 3.

Use of research results in Refuge management. The preliminary calculations of food production potential would be compared to estimates of waterfowl nutritional requirements (from literature sources). This comparison might lead to one or more of the following actions: proposing additional facilities (e.g., more moist soil units or a reservoir draining into MS 10); revising waterfowl management objectives; focusing the water management strategy on better (in the sense of waterfowl requirements) food production; or initiating more detailed studies of actual food production and waterfowl requirements at the Refuge.

Implementation. Workshop participants felt that this calculation could and should be done relatively soon, perhaps by Refuge personnel. The estimated level of effort is 1-2 person weeks.

3. Waterfowl Habitat Utilization at Muscatatuck National Wildlife Refuge

Description. This project would involve systematic and detailed monitoring of habitat utilization by waterfowl under the preliminary strategy outlined in the WATER MANAGEMENT section of this report. Periodic observations of utilization (including type of use, species, numbers of birds per unit, and location within unit) for different management units or areas would be coupled with observations of water conditions in the units, vegetative composition (visual assessments and transects on an annual basis), and, perhaps, estimates of mast production in green tree reservoirs and crop production in agricultural units. After 2-3 years, an evaluation would be made of the pattern of waterfowl habitat utilization across different conditions of water and vegetation.

Problem. Information on the most effective and efficient management actions to meet waterfowl maintenance objectives at the Refuge is needed. However, time and funding to accomplish detailed, comprehensive research on waterfowl food habits and food production under various management regimes are not currently available. This study would attempt to identify desirable (as measured by waterfowl use) management activities and habitat conditions without a detailed understanding of the specific factors contributing to waterfowl use patterns. This project would address research needs 19, 20, 21, and 22 (and perhaps 25) in Table 3.

Use of research results in Refuge management. Direct measurement of relative habitat utilization would allow management to concentrate on providing the most heavily utilized types of habitat when they are needed. Needs for additional studies would be sharply defined and focused. Such studies might include detailed examination of invertebrate, mast, and crop production; off-Refuge feeding; and the effects of draining and reflooding areas subject

to natural fall flooding. Furthermore, detailed records of habitat conditions and utilization would ensure continuity of management should personnel changes occur (Fredrickson and Taylor 1982).

Implementation. Workshop participants agreed that such a monitoring program is important and should be implemented as soon as possible. It would be possible to accomplish much of the program as an enhancement to the existing censusing program conducted by the Refuge staff. However, manpower and funding constraints at the Refuge might limit the program in the following areas: concurrent data on vegetative composition and production; specification of type of habitat utilization (e.g., resting vs. feeding); and monitoring of areas other than those with good access and visibility (i.e., monitoring may be restricted to moist soil units and not include green tree reservoirs).

4. Increased Banding of Refuge Wood Ducks

Description. Banding of wood ducks at Muscatatuck National Wildlife Refuge would be increased and concentrated on local birds (birds nesting or born on the Refuge).

Problem. Refuge management concerns only a portion of the wood duck life cycle. Information on the strength of homing (i.e., the fidelity of the Refuge population segment), harvest mortality, and over-wintering mortality is necessary to place wood duck management and production objectives at the Refuge in a reasonable context. This study would address research needs 10, 12, 13, and 14 in Table 3.

Use of research results in Refuge management. If mortality off the Refuge limits Refuge production, management objectives might have to be revised. If harvest mortality is high and the Refuge population segment exhibits a high degree of fidelity (birds have a high probability of returning to the Refuge and tend to move and over-winter together), then off-Refuge harvest modifications might be recommended.

Implementation. Workshop participants thought that this project should be initiated as soon as possible because it would take a number of years to band a sufficient number of birds. At a minimum, existing banding activities (including those in Dr. Bookhout's study) could be more focused on local birds.

5. Enhancement of Dr. Bookhout's Study

Description. This would involve increasing the sample sizes in Dr. Bookhout's current study. This might include a larger number of birds marked and fitted with transmitters, a larger number of cavities and nests observed, and more extensive observations of broods with more intensive concurrent habitat measurements.

Problem. Dr. Bookhout's current study on the ecology of wood duck production at Muscatatuck National Wildlife Refuge is well directed at the most important research needs. However, sample sizes possible with the planned level of effort may limit the strength of the conclusions in several areas. Depending on the specific type of enhancement, the additional information might contribute to any or all of research needs 1 through 14 in Table 3.

Use of research results in Refuge management. More precise results from Dr. Bookhout's study would improve estimates of the relative importance of factors limiting wood duck production at the Refuge and the effects of management actions directed at alleviating those limitations.

Implementation. Increasing the number of transmitters seems to be the most important enhancement (approximately 10 additional transmitters at a cost of $1,000-2,000). Dr. Bookhout suggested that this enhancement be considered for the second field season after evaluating the capture techniques and reliability of the transmitters during the first season.

6. Mathematical Characterization of Wood Duck Brood Habitat

Description. The sections of the existing Habitat Evaluation Procedures (HEP) model (Sousa and Farmer 1983) concerning the suitability of wood duck brood habitat would be applied and refined to best fit conditions at the Refuge. Data on habitat utilization at Muscatatuck would be obtained from Dr. Bookhout's current study and additional field work, if necessary.

Problem. Better characterization of what constitutes good brood habitat is necessary to most effectively manage Muscatatuck National Wildlife Refuge to meet wood duck production objectives. This project would directly address research needs 4, 5, and 6 in Table 3.

Use of research results in Refuge management. Better estimates of the total available brood habitat and its suitability under different combinations of facilities and water management options would be used to guide decisions about new construction and management of existing Refuge facilities.

Implementation. Workshop participants thought that preliminary results from Dr. Bookhout's study should be assessed before initiating this project.

7. Predation on Wood Ducks at Muscatatuck National Wildlife Refuge

Description. This project would assess rates and sources of predation, concentrating on a comparison of nesting and brood stages.

Problem. Information on the relative importance of various factors limiting wood duck production at Muscatatuck National Wildlife Refuge (e.g., nest predation vs. brood habitat) is necessary to meet production objectives most efficiently. A predation study would directly address research needs 11 and 12 in Table 3 and would also provide information relevant to research needs 10, 13, and 14.

Use of research results in Refuge management. Results would be used to decide what, if any, predator management measures should be considered at the Refuge.

Implementation. Workshop participants thought that preliminary results from Dr. Bookhout's current study should be assessed before initiating this project.

8. Movement of Wood Ducks On and Off Muscatatuck National Wildlife Refuge

Description. Ingress and egress of wood ducks at Muscatatuck National Wildlife Refuge would be assessed by radiotelemetry.

Problem. Dr. Bookhout's study will be focused within the Refuge. Additional information on ingress and egress is needed to determine if wood ducks are selectively utilizing habitat at the Refuge (e.g., birds nesting off the Refuge and moving into the Refuge to utilize brood habitat). This project directly corresponds to research need 9 in Table 3.

Use of research results in Refuge management. Results would be used to focus Refuge habitat management (e.g., nesting vs. brood habitat) and to determine the importance of protecting habitat off the Refuge in order to meet Refuge production objectives.

Implementation. Workshop participants thought that preliminary results from Dr. Bookhout's current study should be assessed before initiating this project.

9. Wood Duck Food Habits and Food Production at Muscatatuck National Wildlife Refuge

Description. A detailed study of wood duck food habits over time would be combined with an examination of the production of important food items by various habitats and management units at the Refuge.

Problem. Better information on food habits and food production is necessary to ensure that adequate food is produced at the Refuge to meet wood duck production objectives. This study would directly address research need 4 in Table 3.

Use of research results in Refuge management. Results would be used to focus management activities on the production of food items most important to wood ducks.

Implementation. Workshop participants thought that preliminary results from Dr. Bookhout's current study should be assessed before initiating this project.

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