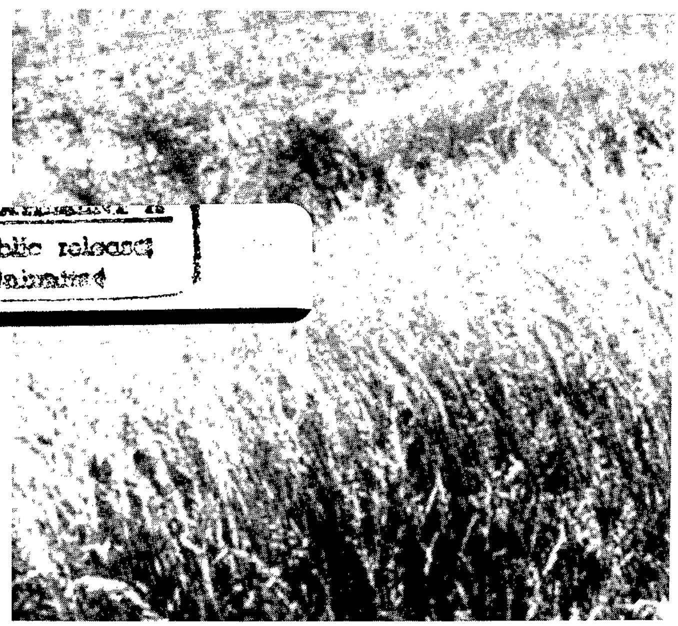
Resource Publication 148

Management of Seasonally Flooded Impoundments for Wildlife



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MANAGEMENT OF SEASONALLY FLOODED IMPOUNDMENTS FOR WILDLIFE

By Leigh H. Fredrickson
T. Scott Taylor

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Contents

Foreword

Wildlife areas where wetland management is a primary objective often have sites that are too dry for management of aquatic plants; yet, these same sites may be too wet for management of row crops or upland vegetation on a regular basis. In the late 1960's, over 200 ha with a history of problems related to wet conditions on Mingo National Wildlife Refuge (NWR), Missouri, were converted from row-crop to natural vegetation management. The senior author had a unique opportunity to develop management procedures to maximize seed production and to provide habitats required by wildlife.

Much of the information that made this handbook possible was drawn from the Master's theses of four graduate students: Michael Huebschen, Dean Knauer, Scott Taylor, and Dean Rundle. Huebschen initiated intensive studies during summer 1968. His work established some basic hypotheses relating to seed germination and establishment and production of plants in relation to drawdown dates. Few data were collected on wildlife use. Knauer's work with vegetation and flooding further refined Huebschen's suggestions for promoting seed production. Knauer's tireless efforts in determining seed and biomass production were an important step in understanding the general relationships among successional stage, drawdown date, drawdown type, seed production, and seed banks. His work also pointed to the need to understand how and when the food resources on moist-soil areas are exploited by wildlife, especially birds.

Scott Taylor, the coauthor of this handbook, developed the first experimental approach toward understanding avian use of wetlands. He developed the outline for the handbook and wrote substantial portions of the first draft.

Much of Taylor's work dealt with waterfowl, but sufficient information was collected on other birds to formulate hypotheses about how shorebirds and rails responded to different moist-soil situations. Dean Rundle addressed these problems experimentally and provided refinement on manipulations that enhance bird use.

The success of these moist-soil studies reflects the opportunities possible through the operational framework at Gaylord Laboratory, where close cooperation among university, State, and Federal agencies is possible and where research findings become part of management strategies as the studies develop. This framework of cooperation allows the development and continuation of long-term efforts that best address constantly changing conditions related to long-term wetland cycles.

Management of Seasonally Flooded Impoundments for Wildlife[1]

by

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Abstract

The concepts and practices that make up moist-soil management were developed at Mingo National Wildlife Refuge in southeast Missouri from 1968 to 1982. Moist-soil management offers opportunities to attract and hold a wide variety of wildlife on man-made impoundments. Plant and animal species differ with latitude, and some specific management techniques that work well at southern latitudes may have little or no value at northern latitudes, or vice versa. Nevertheless, there are many ecological and management principles that are important in moist-soil management, regardless of location. Low sites where row crops are often lost to flooding are particularly well suited for moist-soil management. Optimum success requires good levees, control structures for precise water manipulations, and a pumping system to remove or add water. On some southern sites where annual rainfall is 100 cm or more, this management has been successful despite the lack of pumping potential. Precise water manipulations not only provide food and cover for many kinds of wildlife, but costs and energy consumption are less than for row-cropping, and native foods are more nutritionally complete. Growth of woody and undesirable herbaceous plants are expected problems that require regular inspections and corrective measures if food production and wildlife use are to remain high. A group of small impoundments provides more management flexibility than a single large one because control of vegetation or flooding to attract one group does not preclude options to attract other wildlife on adjacent areas.

Waterfowl, particularly dabbling ducks, often concentrate on wetlands where natural foods are abundant. Foods that attract waterfowl are produced regularly on exposed mudflats after a controlled drawdown or when surface water disappears from natural wetlands in spring or summer. Naturally occurring seeds from plants associated with wetlands regularly survive flooding for several months or even years, whereas grains such as corn, Japanese millet, domestic rice, and soybeans deteriorate rapidly when flooded continuously for 90 days or more. Viable seeds of wetland plants readily germinate in moist habitats when favorable conditions occur – usually when moisture is at or slightly below field capacity.

Work with seasonally flooded impoundments in the 1950's indicated that the production of different types of vegetation was related to the timing of water removal in spring. However, plant species composition varied considerably from year to year, even though drawdown dates were similar. Reasons included yearly changes in seed availability, plant succession, and weather.

Plant response to wet, cool conditions differs from the response to dry, warm conditions. In one year impoundments may drain within a few days, but in another year the drawdown may extend over several weeks. The resulting vegetation differs accordingly. Vegetation response is affected by the degree of soil drying that follows a drawdown.

In his early work in the Illinois River Valley, Frank Bellrose used the term "moist-soil" plants to refer to species that grew on exposed mudflats. This handbook has resulted from our efforts as well as those of Bellrose and others who developed an understanding of the plant communities associated with mudflats or similar habitats. Although the title of this handbook reflects our research on seasonally flooded impoundments, "moist-soil" is used in the text because the term is widely recognized by wetland managers throughout the Midwest and is less cumbersome than, for example, "man-made seasonally flooded impoundments."

[1]Contribution from Gaylord Memorial Laboratory (School of Forestry, Fisheries, and Wildlife, University of Missouri–Columbia and Missouri Department of Conservation cooperating) and Missouri Agricultural Experiment Station Projects 170 and 183. Journal Series No. 8915. Financial assistance was provided by the U.S. Fish and Wildlife Service's Division of Refuges (Contracts USDI 14-16-0002-3044 and 14-16-0003-13,683) and Accelerated Research Program (Contract USDI 14-16-0009-78-038) administered by the Missouri Department of Conservation.
[2]In cooperation with U.S. Fish and Wildlife Service, Refuges and Wildlife – Mingo National Wildlife Refuge and Missouri Cooperative Wildlife Research Unit.

Our goal is to discuss techniques that can be used by managers to develop and maintain wildlife food production in both man-made and natural wetlands. We encourage the use of management schemes based on the migration or breeding phenology of wildlife species and their food requirements to maximize use of habitat and available funds. For ease of reading, we do not cite references in the text, but provide a list of suggested readings, which immediately follows the text. Scientific names of plants and animals mentioned in the text or tables are given in Appendices 1 and 3.

Advantages and Disadvantages of Moist-soil Management

Many species of plants satisfy nutritional requirements and provide suitable habitats for waterfowl and other wildlife throughout the year. Until recently, the seeds of only a few moist-soil plants were recognized as valuable food sources for wildlife, but evidence now suggests that many plants provide essential nutrients and energy. Before 1970, waterfowl food studies relied heavily on bird gizzard samples obtained from hunters in the fall. Such studies, though valuable in determining foods eaten, often overlooked the importance of different plants in the diet. Local availability of plants may have been an important factor in these earlier studies. That is, many of the important wild plant species may not have been abundant or even present at the locations where waterfowl were collected for food analyses.

Esophageal samples obtained from ducks that fed on moist-soil impoundments in Missouri have shown that soft seeds such as those of crabgrass, panic grass, and beggarticks are eaten readily when available. Often these naturally occurring seeds, which are not generally recognized as important foods for ducks by the public, have higher overall nutritive qualities than many of the cereal grains.

At mid and southern latitudes, row-cropping is an integral part of wildlife and waterfowl management. Row crops are particularly important in providing high-energy foods for large concentrations of waterfowl during winter, but the grains are suitable only for a select group of the larger species—primarily geese, mallards, and a few others. Row crops fail to provide adequate shelter for many species of waterfowl and other wildlife. In addition, grains alone do not satisfy nutritive requirements because many essential amino acids are lacking.

When weather is favorable and management is intensive, more food per unit area is consistently provided by row crops than by naturally occurring vegetation. Where row crops are produced by sharecroppers on public lands, typically much of the grain is removed as the tenant's share. In many situations, the grains left for wildlife by sharecroppers are available to only a few species because habitat requirements for many species are lacking. Even though the potential agricultural production is great, adverse weather conditions that result in floods or droughts often reduce production. Adverse weather has a lesser effect on production of naturally occurring plants because a diverse natural flora includes species that produce well under a variety of conditions. Different species or groups of plants are adapted to different climatic conditions and site characteristics, such as specific water depths or degree of soil saturation (Fig. 1). For example, water-tolerant or wetland-adapted plants such as smartweeds, barnyardgrasses, and spikerushes are productive during wet years; beggarticks are productive on drier sites; and crabgrasses and panic grasses do well under more intermediate moisture conditions. Because naturally occurring plants often are productive despite weather conditions that restrict production of row crops, crop failures are less likely to occur in moist-soil management.

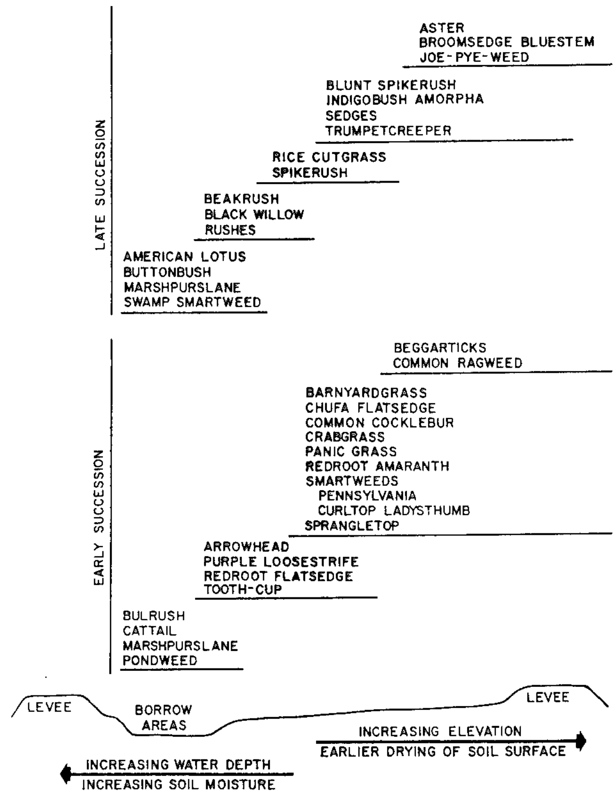

Fig. 1. Distribution of common moist-soil plants along a flooding gradient.

Naturally occurring foods may be particularly important on stopover or wintering areas where waterfowl often ingest lead shot and are subject to lead poisoning. Studies of lead-dosed mallards have shown that mortality rates were lower in birds fed wild foods or part-grain diets than in those fed only grain.

The total energy in moist-soil foods often is as high as or higher than that in corn, milo, or soybeans (Table 1).

Table 1. *Gross energy, fat, fiber, ash, and protein content of plant seeds commonly encountered in moist-soil impoundments.*[a]

Species	Energy (calories/kg)	Component Crude fat (%)	Crude fiber (%)	Ash (%)	Protein (%)
Gramineae					
Crabgrass	3,717	3.1	10.0	20.8	9.94
Hairy crabgrass[b]	4,380	—	—	—	—
Common barnyardgrass	3,635	2.6	22.7	13.9	7.56
Common barnyardgrass[b]	4,422	—	—	—	—
Rice cutgrass	3,738	2.0	10.7	10.2	11.0
Fall panicum[b]	4,647	—	—	—	—
Glaucous bristlegrass	3,833	—	—	—	—
Yellow bristlegrass[b]	4,494	—	—	—	—
Bread wheat	4,347	—	—	—	—
Indian corn	4,317	—	—	—	—
Milo	4,400	3.1	2.2	2.7	11.94
Cultivated rice[c]	3,560	1.7	0.6	1.1	7.5
Cyperaceae					
Redroot sedge[b]	5,196	—	—	—	—
Straw-colored flatsedge	3,686	—	—	—	—
Fox sedge	—	6.6	23.2	5.9	9.63
Sedge (*Carex tribuloides*)	—	5.4	20.2	7.9	9.63
Sedge (*Carex brevoir*)	—	7.0	18.2	7.3	10.63
Polygonaceae					
Curltop ladysthumb	4,264	2.7	22.7	13.9	7.56
Pennsylvania smartweed	4,183	—	—	—	—
Pennsylvania smartweed[b]	4,514	—	—	—	—
Curly dock	4,024	1.2	20.4	6.9	10.38
Curly dock[b]	4,786	—	—	—	—
Amaranthaceae					
Redroot amaranth[b]	4,623	—	—	—	—
Malvaceae					
Prickly sida[b]	4,946	—	—	—	—
Onagraceae					
Creeping marshpurslane	—	10.0	41.8	4.3	14.25
Convolvulaceae					
Morningglory sp.[b]	4,945	—	—	—	—
Compositae					
Common ragweed[b]	5,286	—	—	—	—
Devils beggarticks	5,177	18.0	20.8	5.6	23.5

[a]Usable energy varies, depending on proportion of crude fiber and other factors.
[b]Estimates from Kendeigh and West (1965).

Total energy values in the table do not reflect the differences in metabolizable energy precisely because the caloric value of indigestible crude fiber is unavailable to most birds. Unfortunately, little information is available on the true metabolizable energy in naturally occurring foods. However, many naturally occurring foods are known to contain essential nutrients that are not present in domestic grains.

In addition to plant foods, diverse populations of invertebrates, reptiles, and amphibians regularly occur in moist-soil impoundments. These animals are desirable components of wildlife areas and serve as important prey species for waterfowl, raptors, herons, and other wildlife. In contrast, aquatic invertebrates and cold-blooded vertebrates are virtually nonexistent in agricultural areas. The presence of aquatic invertebrates may partly explain why diverse populations of waterfowl are more attracted to moist-soil impoundments than to flooded row crops.

Managers of public lands can no longer consider management for one or two waterfowl species as adequate. Public interest and pressure are gradually shifting toward enhancement of more natural habitats and multispecies management. Habitat quality and vegetative diversity largely determine the number of wildlife species that can occupy an area. Well-managed row crops often attract some species in great numbers, but relatively few different species are attracted to these monocultures. In contrast, moist-soil sites provide diverse habitats that continuously support a multitude of wildlife species, including waterfowl. In some moist-soil units, over 80% more species are accommodated than on adjacent row crops. Herons, rails, prairie and marsh passerines, and upland game birds and mammals that are rare or lacking on agricultural fields concentrate on moist-soil sites.

Development of Moist-soil Impoundments

Initial development of moist-soil impoundments is expensive if heavy equipment is required for dike construction and if elaborate water-control structures are needed. Permanent levees and inner dikes must be constructed (preferably on contours) and water-control structures installed that allow precise water-level control. However, developmental costs are no greater than those for row-crop fields that are flooded to attract wildlife.

Man-made wetland habitats can be only as good as the design, construction characteristics of the impoundment, and soil types permit. Areas are often developed by State, Provincial, or Federal agencies that can employ engineers capable of designing suitable structures. Private individuals and organizations should solicit advice from or hire trained, competent designers and construction firms. Before projects are begun, advice should be sought from local conservation agencies, and State and local zoning authorities should be consulted.

Levee Construction

An understanding of the soil texture on a moist-soil site is required to ensure sound construction, as well as the potential for efficient management. Suitable material for levee construction is essential. For example, gravelly or coarse sandy soil is poorly suited for levees because the material erodes readily or fails to hold water. Water seepage on sandy sites makes the costs of maintaining water levels prohibitive. Local Soil Conservation Service offices can provide assistance in these matters.

We prefer levees that are large enough to support equipment capable of mowing woody growth (Fig. 2). Muskrats readily burrow through small levees and allow water to escape. The construction of larger levees facilitates the control of muskrat damage. Ideally, the major outer or peripheral levees should be at least 3 m across the top. A slope of 3:1 to 4:1 generally suffices for the sides, but because this slope varies with soil type, an engineer's advice should be sought. A levee with a 4:1 slope is easier to maintain and mow, and deters muskrats more effectively, than a levee with a steeper slope.

Fig. 2. Exterior levees constructed on Mingo National Wildlife Refuge have a top of at least 3 m with a slope of 3:1. These large levees readily support vehicles and heavy equipment and facilitate control of woody growth and muskrat damage.

The actual width and height of the dike to be constructed depends on the size of the impoundment and the expected depth of flooding. Units of 3 to 50 ha have been managed effectively. Larger impoundments or impoundments with the potential for deep flooding require more substantial dikes. On large, deep impoundments wave action can cause considerable bank erosion and a small, low levee may be topped and cut in a single season — or during a single storm. Where major flooding never occurs, levee tops should be at least 0.6–1.0 m above the maximum high water level. Where inundations occur regularly, as along large rivers, a low levee that is submerged quickly and uniformly is damaged less by flooding than a large protective levee.

Because inner levees also are affected by wave action, their size should be adjusted accordingly. Ideally, the inner levees should be as large as the outer levees. When this is not possible, smaller levees can be constructed with a rice dike plow or a road grader. Frequent repairs and annual maintenance may then be required. In 1977, costs for construction of a levee 1.2 m high and 3 m across on top averaged $30 per linear meter of levee constructed. Costs may vary considerably on each site because of factors such as differing distances between the levee and the borrow area. We advise against development on lands where the slope on a site requires many contour levees within a small area. Nevertheless, irregularities such as low ridges are advantageous in moist-soil areas because diverse water depths are present after the site is flooded.

Inner levees should be constructed on contours. We recommend a 15-cm contour interval when possible, to allow maximum water level control as a means of providing optimum conditions for vegetation and wildlife. Dur-

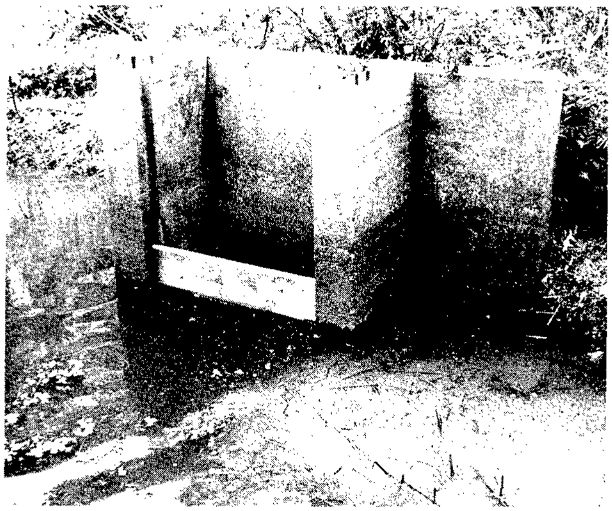

Fig. 3. Many permanent water-control structures on Mingo National Wildlife Refuge are of a box design and allow for precise water manipulations. Control structures should be installed at the lowest point in each impoundment to ensure complete drawdowns. The drainpipe must be of adequate size to facilitate a rapid drawdown.

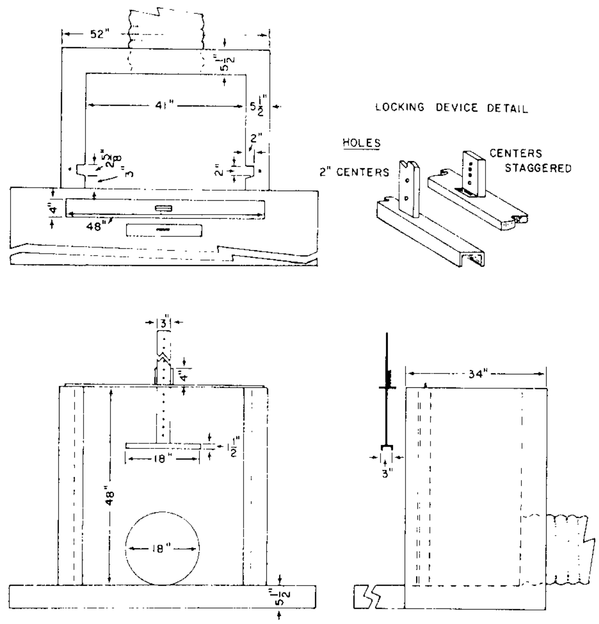

Fig. 4. Specifications for a box-type water-control structure that provides for effective water manipulations.

ing dry years when impoundments must be flooded by pumping, the highest contour level can be flooded first. This reservoir of water plus some additional pumping can then be used to flood the lower levels when dictated by increased wildlife requirements. Electricity costs for pumping in 1977 were estimated at \$0.27/ha-cm of water for electric turbine pumps (60 hp, 3 phase). Gasoline-powered pumps may have greater flexibility, but maintenance costs are higher.

Depending on the area, there may be advantages to establishing borrow areas either inside or outside the levees. Borrow areas inside the levees often provide deep, permanent water. An elevated access should be established across any borrow area inside a levee to ensure that equipment can be transported into the management unit if the borrow area remains flooded. Woody or other undesirable vegetation may become a problem within such a unit if the equipment required to disturb the vegetation cannot be moved across a flooded borrow area.

Water-control Structures

Permanent structures for water control should be installed on all major outer and inner dikes (Fig. 3). Structures should be situated low enough to enable the complete draining of both the impoundment and the borrow ditches. Structures should be large enough to drain the area quickly and to handle any anticipated surplus of water resulting from a flood. Inundation of the impoundment for extended periods during germination and early seedling development is detrimental to establishment of annual moist-soil plants. Other moist-soil plants will germinate later, but seed production may be decreased by the presence of undesirable plants, and the growing season may be shortened. An emergency spillway 30 cm below the top of the levee will aid in removing excess water in areas subject to flash flooding.

Our experience has shown that the best control structure is a stop-log type (Fig. 4) that resembles a concrete box lacking top and front panels. The back of the structure is fitted with a corrugated, galvanized-steel drain pipe at the bottom of the back wall. A pipe 46 cm in diameter and long enough to extend through the bottom of the levee is generally adequate for structures draining areas up to 16 ha. Walls and bottom should be at least 13–15 cm thick. Each side has a groove toward the inside front edge extending the entire height of the box and capable of accommodating a board (stop log) 5 cm thick. The sides, as well as the inside front-to-back distance with boards installed, should measure 46 cm. The bottom of the box extends beyond the front 15–20 cm, forming an apron that reduces soil erosion. The bottom of the structure should be as flat and level as possible to prevent water seepage when the stop logs are in place. The height of the structure is determined by the maximum water level desired and by the depth of any existing internal borrow ditches. An anti-seep collar around the structure may be necessary to control rodents.

Stop logs of several different widths (heights) are useful to enable water level changes as small as 1 cm. When such a change in water level is required, an appropriately sized board may be installed or removed. Stop logs should be sized and numbered so that changes can be made quickly and accurately. The best materials are rough-cut redwood or treated lumber. Ship-lapped edges should not be used because the wood will warp and the stop logs will then fit together poorly. If seepage occurs around and between the stop logs, plastic sheeting can be placed over the pool side of the boards and held in place with thumb tacks or bulletin board push-pins. Lower boards not subject to manipulations for minor water-level adjustments can be sealed with an oil-base caulk. A locking device may be required to prevent tampering (Fig. 4). Control structures are ideal sites for attaching water gauges.

Costs of Moist-soil Management

Because we assumed that capital investments for flooding either row crops or moist-soil areas are similar, the costs discussed here are related to management and not to development. The high costs of row-crop production are well known to wildlife managers who do their own farming. Because money and energy are used more efficiently, moist-soil management offers an economical alternative for management—particularly on sites where annual flooding results in only marginal row-crop production.

Costs of moist-soil management are primarily related to maintaining plant communities in early successional stages, where seed production is heavy and problem plants are few. The costs of reflooding by pumping to control undesirable vegetation and to set back succession are much less than the annual costs for seeds, chemicals, and tillage in row-crop management.

Most marsh systems contain ample quantities of chemical elements in various ionic forms that are essential for plant growth. Annual drainage of some natural-marsh units over an extended period may cause nutrient impoverishment because of runoff and leaching. This problem has not been documented on moist-soil impoundments, but the potential for the problem seems real. In contrast, an extended period of flooding may make nutrients unavailable in marshes because organic matter accumulates and holds nutrients that can be released only by decomposition when these areas are dewatered. Nitrogen is most likely to become limiting in this manner. When the bottom of an impoundment is exposed after a drawdown, the organic matter deteriorates quickly and nutrients are then available for new plant growth. The new vegetative growth may stimulate production of invertebrates when the area is reflooded.

Efficient row-crop production often requires regular applications of fertilizer, herbicides, insecticides, and lime. Although the benefits of fertilization for moist-soil plant production are not known, production on unfertilized sites in Missouri has been good—undoubtedly because natural plant communities have evolved and been maintained without fertilization.

Efficiency of energy use is clearly higher under moist-soil management than in row-cropping in terms of production costs per unit of area (Table 2). Our studies suggest that moist-soil management requires only one-third as much fuel per unit area as row-cropping. Our estimates include fuel for mowing, dike maintenance, vehicles, and flooding the units by pumping. Because our units were dewatered by gravity, no fuel was necessary to remove water.

A more accurate method of describing differences in energy use in the management of row crops and moist-soil areas requires a comparison of the return of energy (kcal of food) for each unit of energy input (kcal of fuel, chemicals, etc.). At Mingo NWR, the return for each kcal invested in moist-soil management is as high as 7.17 kcal in wildlife foods during the early successional stages on intensively managed moist-soil units. This ratio for moist-soil efficiency is twice the 2.82-kcal return for each kcal invested in corn, nationwide (Table 2). During recent wet years, corn produced by sharecroppers on the Mingo Refuge has been 12.4 million kcal/ha. The Refuge's share is 25%, which is about 3.09 million kcal/ha plus grain not recovered during mechanized harvest. Because of harvest methods, timing of harvest, and condition of the crop, agriculturalists estimate that the loss during harvest may be 13% on the Mingo Refuge. Therefore, at least 4.7 million kcal/ha are available for wildlife on each hectare of sharecropped corn, as compared with 6.4 million kcal/ha on moist-soil sites that are in early successional stages. These ratios and total energy available vary at each locale and should be examined by managers when making decisions about the value or extent of moist-soil management on a given area.

Table 2. *Estimated energy costs (thousands of kcal per acre) and gross energy production for corn and for moist-soil seeds during early successional stages at Mingo National Wildlife Refuge, Missouri.*

Item	Crop: Corn	Crop: Moist-soil seeds
Energy costs		
Labor	4.9	0.2
Machinery	420.0	105.0
Fuel	797.0	263.0
Nitrogen	940.0	0.0
Phosphorus	47.1	0.0
Potassium	68.0	0.0
Seeds	63.0	0.0
Total	2,340.8	368.2
Energy production		
Yield[a]		
National average	8,164.0	
Mingo	5,039.5	2,640.0[b]
Kcal return/kcal input		
National average	2.82	
Mingo	2.15	7.17

[a]Average production of corn (bushels per acre) is 81 nationwide and 50 on the Mingo Refuge (one bushel = about 35.2L).
[b]Represents production of 660 kg (1,450 lb) of moist-soil seeds.

The dynamic nature of moist-soil management demands that the manager have a special expertise, and requires that he regularly inspect each unit to ensure proper monitoring of the system. The manager must understand the interplay between wildlife and ecosystems, and spend the time required on each moist-soil area to make manipulations when needed.

Management of Seasonally Flooded Impoundments

Good management decisions require regular inspections of management units to monitor subtle changes in habitat conditions that influence the potential for attracting wildlife. When impoundments are flooded, they should be inspected weekly to ensure that correct water levels are maintained. They should be checked more often during and after a drawdown to monitor germination and plant growth. (Our use of "drawdown" refers to total dewatering, whether rapid or incremental, to promote growth of plants adapted to germinate in saturated soils, and not to a reduction of water levels like that often used to stimulate true aquatics in more permanently flooded marshes and lakes.) Depending on weather and other factors, soils may or may not be completely dry after a drawdown. Regular inspections allow a manager to stimulate growth of food-producing plants or to control problem species by prompt irrigation and shallow reflooding.

Ideally, several moist-soil impoundments should be available on each management area. Each impoundment can then be managed individually for different types of wildlife. A master plan involving a group of impoundments can provide a maximum diversity of wildlife continuously by rotating management options among the different units.

In the following sections we describe management options for maximizing vegetative growth and attracting different kinds of wildlife. For convenience, we discuss plants first and then describe how to attract wildlife to these sites.

Vegetation Management

Plants regularly encountered on moist-soil areas are categorized by their desirability as food and habitat (Table 3). Plants that provide habitat, energy, or nutritive requirements for wildlife are considered desirable, and plants that interfere with such production are classed as undesirable. Undesirable species are usually those that tend to become dominant in later successional stages after repeated annual drainage of impoundments. Species such as cattails, trees, shrubs, and vines create management problems on some sites when flooding is regular. Even though plants have been placed in these categories, we emphasize that some plants classed as undesirable for seed production might provide excellent cover.

An important factor that determines the species composition of moist-soil plants that pioneer on exposed mudflats is the composition of seeds in the soil at a site. Most soils contain ample seeds to produce dense stands of desirable moist-soil plants native to a locality. This is true whether the site was previously in row crops or in moist-soil management. The actual species composition of the seeds available in the soil is related to the previous plant composition and seed production. That is, if environmental conditions are similar, an impoundment with a good stand of desirable species in a given year will probably produce seeds that result in a similar vegetative composition the next year. However, the same probability applies to undesirable species; consequently, management to control their germination, growth, and seed production is essential.

Herbicides have a residual effect on some desirable moist-soil plants. The extent of the detrimental effects depends on the chemical, the application rate, and time elapsed since the chemical was last used. Managers should not expect maximum production on such sites until the herbicides have decomposed or been flushed from the soil.

Two important factors that determine plant responses to moist-soil manipulations are (1) the timing of annual drawdowns and (2) the stage of succession (number of years since the area was disturbed by disking or plowing or the number of years since the impoundment was flooded continuously). For example, early drawdowns tend to stimulate germination of smartweeds on early successional sites. However, smartweeds are less likely to respond to early drawdowns by the third year after a soil disturbance such as disking or continuous flooding. Mid-season drawdowns result in millets, and late-season drawdowns result in sprangletop, beggarticks, panic grass, and crabgrass.

Once areas have been under moist-soil management for 4 or more years, there is a gradual increase in perennial species, including some excellent seed producers. Perennials like rice cutgrass and marsh smartweed not only produce seeds, but (like most other fine- or multi-leaved plants) also provide excellent habitats for invertebrates. These invertebrates are consumed directly by waterfowl, rails, herons, and other birds and indirectly by raptors, herons, mammals, etc., that eat such other direct consumers as fish, reptiles, or amphibians. Invertebrate populations are important to many wildlife species, either directly or indirectly, throughout the year.

Two general types of drawdowns that we describe as slow or fast usually produce different results. In slow drawdowns, impoundments are gradually drained during a period of 2 weeks or more. Fast drawdowns occur within a few days and produce similar conditions over the entire impoundment simultaneously.

Early in the season a slow drawdown usually produces a more diverse vegetative cover than a fast drawdown; fast drawdowns normally produce excellent and extensive stands of similar vegetation, but the rapid dewatering forces wetland wildlife from the area almost immediately. Slow draw-

Table 3. *Characteristics of selected moist-soil plants, including successional stage, germination dates, potential seed production, and food and habitat value.*

Plant	Successional stage		Germination			Value[a]		Best seed production						
								Drawdown				Moisture		
	Early	Late	Early	Mid	Late	Food	Habitat	Early	Mid	Late	None	Dry	Moist	Wet
Pondweeds						+	0				✓			
Common burhead		✓		✓		+	+						✓	✓
Sprangletop	✓				✓	+	+			✓			✓	
Rice cutgrass		✓				+	+		✓	✓				✓
Crabgrass	✓					+	+		✓	✓		✓		
Panicum	✓					+	+		✓	✓		✓		
Common barnyardgrass	✓		✓	✓		+	+	✓	✓				✓	
Barnyardgrass[b]	✓			✓	✓	+	+		✓	✓			✓	
Broomsedge bluestem		✓			✓	0	+					✓		
Redroot sedge	✓				✓	+	+			✓				✓
Spikerush	✓	✓	✓	✓	✓	+		✓	✓	✓			✓	
Beakrush		✓			✓	+	+						✓	✓
Fox sedge		✓			✓	+	+						✓	
Common rush		✓			✓		+	✓					✓	✓
Poverty rush		✓			✓		+	✓					✓	✓
Black willow	✓		✓			0	0	✓					✓	
Dock	✓		✓		✓	+		✓				✓		
Pennsylvania smartweed	✓		✓		✓	+	+	✓					✓	
Curltop ladysthumb	✓		✓		✓	+	+	✓					✓	
Swamp smartweed		✓				0								✓
Tooth-cup	✓				✓	+	+			✓			✓	✓
Purple loosestrife	✓		✓	✓	✓	0	0	✓	✓	✓		✓	✓	
Marshpurslane	✓	✓	✓			+			✓	✓	✓		✓	✓
Red ash	✓					+							✓	
Swamp milkweed		✓			✓		+			✓			✓	
Morningglory		✓		✓	✓	+			✓	✓		✓	✓	
Lippia	✓			✓					✓			✓	✓	
Trumpetcreeper		✓				0	0					✓	✓	
Buttonweed	✓			✓		+			✓	✓			✓	
Common buttonbush		✓				+	+			✓				✓
Joe-pye-weed		✓			✓	0	+		✓			✓		
Aster		✓			✓	0	+					✓		
Common ragweed	✓			✓	✓	+			✓			✓		
Common cocklebur	✓			✓	✓	0	+		✓	✓			✓	
Beggarticks	✓			✓	✓	+			✓	✓		✓	✓	
Sneezeweed		✓		✓	✓	0			✓	✓		✓	✓	

[a]A plus sign indicates substantial value, and a zero little or no value, as food or habitat.
[b]*Echinochloa muricata.*

downs may produce vegetation of greater density and diversity than fast drawdowns late in the season when soils dry quickly because soils near the receding water remain saturated long enough for germination to occur. Fast drawdowns late in the season may produce less desirable vegetation than those early in the season. This is especially true when temperatures exceed about 32°C and where rainfall is required for flooding because little germination occurs when saturated soils become dry within a few days. Regardless of whether a drawdown is slow or fast, total seed production usually is higher on impoundments after early drawdowns, but late drawdowns result in higher stem densities and greater species diversity.

Encouraging Desirable Vegetation

Many annual grasses and sedges consistently have the highest seed production during early successional stages (Table 4). Many herbaceous plants, and especially cockleburs, are also high-volume seed producers, but they should be controlled. Each species must be regarded on its own merits. At the Mingo Refuge, some areas with undesirable forms such as cockleburs had unusually heavy use by filter-feeding ducks such as shovelers. Experimental evidence is lacking, but possibly the leaf litter from herbaceous plants provides an ideal substrate for invertebrates. Some herbs—

Table 4. *Responses of selected moist-soil plants on Mingo National Wildlife Refuge immediately after row-cropping.*

		Management goal					
		Habitat: Upland wildlife—summer Food: Wetland wildlife—fall, winter			Habitat: Wetland wildlife—summer Food: Wetland wildlife—summer, fall, winter		
Year	Unit[a]	Season of drawdown[b]	Vegetation	Estimated production (kg/ha)[c]	Manipulation	Vegetation	Estimated production (kg/ha)
1	A-1	Early	Smartweed	1,350			
			Barnyardgrass	340			
			Beggarticks	225			
1	B-1	Mid	Barnyardgrass	1,350			
			Panicum	110			
			Crabgrass	110			
			Beggarticks	110			
1	C-1	Late	Sprangletop	1,575	Deep flooding	Sprangletop	1,575
			Barnyardgrass	225	to mid-summer	Barnyardgrass	225
			Tooth-cup	110		Tooth-cup	110
			Spikerush	50		Spikerush	50
2	A-1	Early	Smartweed	900			
			Barnyardgrass	225			
			Panicum	110			
			Spikerush	50			
2	B-1	Mid	Barnyardgrass	785			
			Panicum	225			
			Beggarticks	110			
			Cocklebur	50			
			Woody growth	—			
2	C-1	Late	Sprangletop	785	Deep flooding	Sprangletop	785
			Flatsedge	450	to mid-summer	Flatsedge	450
			Tooth-cup	110		Tooth-cup	110
			Barnyardgrass	50		Barnyardgrass	50
			Rice cutgrass	50		Rice cutgrass	50
3	A-1	Early	Panicum	450			
			Beggarticks	225			
			Barnyardgrass	110			
			Smartweed	50			
3	A-2	Late	Sprangletop	785	Shallow flooding	Sprangletop	785
			Barnyardgrass	225	to mid-summer	Barnyardgrass	225
			Flatsedge	110		Flatsedge	110
			Spikerush	50			
3	B-1	Mid	Panicum	450			
			Beggarticks	340			
			Crabgrass	110			
			Barnyardgrass	50			
			Woody growth	—			
3	B-2	Late	Beggarticks	450	Shallow flooding	Beggarticks	450
			Panicum	225	to mid-summer	Panicum	225
			Sprangletop	110		Barnyardgrass	110
			Barnyardgrass	50		Sprangletop	50
			Woody growth	—		Woody growth	—
3	C-1	Late	Flatsedge	900	Shallow flooding	Flatsedge	900
			Rice cutgrass	340	to mid-summer	Rice cutgrass	340
			Sprangletop	110		Sprangletop	110
			Tooth-cup	110		Tooth-cup	110
3	A-1	Early	Pancum	450			
			Beggarticks	225			
			Barnyardgrass	110			
			Smartweed	50			

Table 4. Continued

		Management goal					
		Habitat: Upland wildlife—summer Food: Wetland wildlife—fall, winter			Habitat: Wetland wildlife—summer Food: Wetland wildlife—summer, fall, winter		
Year	Unit[a]	Season of drawdown[b]	Vegetation	Estimated production (kg/ha)[c]	Manipulation	Vegetation	Estimated production (kg/ha)
3	A-2	Late	Sprangletop	785	Shallow flooding	Sprangletop	785
			Barnyardgrass	225	to mid-summer	Barnyardgrass	225
			Flatsedge	110		Flatsedge	110
			Spikerush	50			
3	B-1	Mid	Panicum	450			
			Beggarticks	340			
			Crabgrass	110			
			Barnyardgrass	50			
			Woody growth	—			
3	B-2	Late	Beggarticks	450	Shallow flooding	Beggarticks	450
			Panicum	225	to mid-summer	Panicum	225
			Sprangletop	110		Barnyardgrass	110
			Barnyardgrass	50		Sprangletop	50
			Woody growth	—		Woody growth	—
3	C-1	Late	Flatsedge	900	Shallow flooding	Flatsedge	900
			Rice cutgrass	340	to mid-summer	Rice cutgrass	340
			Sprangletop	110		Sprangletop	110
			Tooth-cup	110		Tooth-cup	110
3	C-2	Early	Panicum	340			
			Barnyardgrass	170			
			Smartweed	110			
			Flatsedge	50			

[a]Units with the same letter designation have similar features such as soils, topography, and management histories. The numerical designation indicates the results of different management practices on units with similar soils and topography.
[b]Drawdown dates are those for Mingo National Wildlife Refuge: early = before 15 May; mid = 15 May–1 July; and late = after 1 July.
[c]Conversion: 100 kg/ha = 89 lb/A.

e.g., beggarticks—have a high nutritive quality and are considered desirable seed producers.

After germination and early growth, plants should attain a height of 10–15 cm before impoundments are reflooded (Fig. 5). Barnyardgrasses, sedges, and smartweeds respond well to shallow flooding (2–5 cm), but panic grasses, crabgrasses, and beggarticks are less tolerant. Identification of seedlings is essential if desirable species are to be encouraged or undesirable plants controlled (see Appendix 2 for key characteristics of seven common moist-soil plant seedlings). Water depths should be 2–5 cm over as much of the area as possible so that the newly established plants will not be completely submerged for extended periods. Complete submergence for longer than 2–3 days can retard the growth of millets, other grasses, and smartweeds. Water levels must be lowered if the majority of the desirable plants that are submerged do not reach the surface within the 2- to 3-day limit. With experience a manager can estimate the water tolerance of plants on an area and manipulate the water level accordingly.

Fig. 5. Shallow reflooding of newly established barnyardgrass stimulates rapid growth.

Water levels can be increased gradually to a maximum of 15–20 cm as the desired plants grow, but water levels should generally equal only about one-third of the total height of newly established moist-soil plants. If plants develop a light-green cast, the water is probably too deep and should be lowered immediately.

Controlling Undesirable Vegetation — Herbaceous Growth

Undesirable vegetation can be controlled by using some of the same techniques that are used to encourage desirable vegetation. Timing of reflooding is particularly important if undesirable herbaceous plants such as cocklebures or asters germinate before desirable species. Reflooding to shallow depths should then begin as soon as desirable species are established and begin to grow. Initially, water levels should be kept low (1 cm or less) so that growth of the desired vegetation is not inhibited by flooding.

Cockleburs are controlled easily by shallow flooding. When the root systems and bases are submerged, cockleburs either die or are stunted and produce few seeds. As the desirable species grow in response to the flooding, water levels can be increased so that higher contours are inundated before cockleburs become dominant and shade out the desirable plants. Some perennials can also be controlled by well-designed flooding schedules. Broomsedge bluestem is readily controlled by shallow flooding (10 cm) until midsummer and joe-pye-weed can be eliminated by flooding in late summer and early fall, when the plants are in bloom. If extensive stands of cockleburs, asters, and other undesirable plants develop within an impoundment where few desirable plants are established, we suggest that the area be disked and then reflooded to set back succession to an earlier and more productive stage of seed production.

The extended period required to flood an area without damaging desirable plants, or to control undesirable species, emphasizes the importance of frequent inspections. Only by inspecting units regularly can a manager make the timely decisions necessary for effective control and enhancement of seed production. Contour intervals of 15–20 cm are optimal for immediate control of undesirable plants because large areas can be flooded to shallow depths with little water.

In areas where late spring rains are common, a little patience may save the cost of pumping water. Rainfall may flood the areas naturally, but total dependence on rain to reflood moist-soil areas is a risky substitute for pumping water. In situations where impoundments cannot be flooded by pumping, managers can replace stop logs after plant germination and early growth to hold runoff water within the impoundment until midsummer grasses become dominant and cockleburs are stunted. The shade of dense stands of desirable species restricts late-germinating cockleburs. Because the growth of many woody species adapted to wetlands is stimulated by flooding, we caution southern managers to examine each unit closely for woody seedlings before they begin summer flooding.

If the accumulation of plant litter in an impoundment becomes excessive, germination and growth of desirable plants may be reduced because of shading. This litter can be burned and the soil exposed — a practice used extensively in the southern coastal regions to set back succession. When possible, a burn should be conducted in early spring, after the vegetation dries and before new germination occurs.

Mowing, mechanical chopping, and shredding or crushing, followed by burning or flooding or both, have been used to eliminate various types of low-value vegetation. Grazing has also been used in special situations with moderate success.

Purple loosestrife causes management problems in the Northeast, where wetlands have naturally occurring or man-made drawdowns. This hardy, exotic perennial is widely distributed on numerous wetlands throughout North America, but the most critical problems are on wetlands within the area of the Wisconsin glaciation and particularly in the Northeast. The dense growth of this species chokes wetlands and reduces its value for wildlife. Seed production is heavy, and once plants reach the seed-producing stage, control is difficult. On sites within the region covered by the Wisconsin glacier, managers should become familiar with this serious problem before initiating a moist-soil management program.

Controlling Undesirable Vegetation — Woody Growth

The control of undesirable woody vegetation is difficult and techniques vary considerably with latitude. At northern latitudes, woody growth can be controlled by shallow flooding. In southeastern Missouri, impoundments must be dried and disked to remove unwanted woody species because shallow flooding merely stimulates growth of wetland-adapted forms and worsens the problem. Additional diskings may be required to completely destroy heavy herbaceous and woody growths of willows, ashes, and cottonwoods.

Impoundments on areas where moist-soil management has been initiated within the last 5 to 7 years should be disked once every 3 years to control woody growth and to stimulate seed production of annuals. Once an area has been managed for moist-soil plants for 5 to 7 years, there appears to be less need for soil disturbance every 3 years. Apparently the soil condition and seed availability gradually change, so that management for maintaining high seed production is easier and more effective (Table 5). One obvious difference in units that have been managed for moist-soil plants for several years is the increase in seed-producing perennials. Seed production from these forms usually occurs early in the season. Perennial seeds are resistant to flooding and appear to be readily available in the following spring.

Table 5. *Responses of selected moist-soil plants on Mingo National Wildlife Refuge, 7 years after row-cropping.*

		Management goal					
		Habitat: Upland wildlife – summer Food: Wetland wildlife – fall, winter			Habitat: Wetland wildlife – summer Food: Wetland wildlife – summer, fall, winter		
Year	Unit[a]	Manipulation[b]	Vegetation	Estimated production (kg/ha)[c]	Manipulation	Vegetation	Estimated production (kg/ha)
7	A-1	Early-season drawdown	Beggarticks	225			
			Flatsedge	225			
			Panicum	170			
			Barnyardgrass	50			
			Spikerush	50			
			Broomsedge bluestem	–			
7	A-2	Mid-season drawdown	Beggarticks	450			
			Flatsedge	110			
			Panicum	110			
			Spikerush	50			
			Cocklebur	50			
			Broomsedge bluestem	–			
7	B-1	Mid-season drawdown	Marshpurslane	225			
			Flatsedge	170			
			Spikerush	50			
			Rushes	50			
			Woody growth	–			
7	C-1				Shallow flooding all summer	Flatsedge	1,250
						Marshpurslane	340
						Rice cutgrass	340
						Rushes	110
						Smartweed	50
						Lotus	–
8	A-1	Farming	Rowcrop	2,700			
			Panicum	225			
			Spikerush	25			
8	A-2	Mid-season drawdown	Barnyardgrass	1,250	Deep flooding to mid-summer	Barnyardgrass	1,100
			Beggarticks	340		Beggarticks	340
			Marshpurslane	110		Marshpurslane	170
			Smartweed	110		Smartweed	110
			Flatsedge	110		Flatsedge	110
			Spikerush	50		Sprangletop	110
8	B-1	Disking – August	Crabgrass	170			
			Spikerush	110			
9	A-1	Early-season drawdown	Smartweed	675			
			Barnyardgrass	550			
			Beggarticks	450			
			Flatsedge	110			
			Spikerush	50			
9	B-1	Mid-season drawdown	Barnyardgrass	785			
			Smartweed	450			
			Beggarticks	340			
			Rushes	110			
			Panicum	110			
			Flatsedge	110			
			Spikerush	50			
9	C-1				Shallow flooding all summer	Flatsedge	1,000
						Rice cutgrass	450
						Marshpurslane	340
						Rushes	225
						Smartweed	50
						Spikerush	50
						Lotus	–

Table 5. Continued

		Management goal					
		Habitat: Upland wildlife—summer Food: Wetland wildlife—fall, winter			Habitat: Wetland wildlife—summer Food: Wetland wildlife—summer, fall, winter		
Year	Unit[a]	Manipulation[b]	Vegetation	Estimated production (kg/ha)[c]	Manipulation	Vegetation	Estimated production (kg/ha)
9	C-2	Early-season drawdown	Smartweed	1,100			
			Barnyardgrass	340			
			Beggarticks	225			
			Flatsedge	170			
			Spikerush	50			
9	C-3	Mid-season drawdown	Barnyardgrass	1,250			
			Beggarticks	340			
			Rice cutgrass	225			
			Flatsedge	225			
			Smartweed	110			
			Marshpurslane	50			

[a]Units with the same letter designation have similar features such as soils, topography, and management histories. The numerical designation indicates the results of different management practices on units with similar soils and topography.
[b]Drawdown rates are those for Mingo National Wildlife Refuge: early = before 15 May; mid = 15 May–1 July; and late = after 1 July.
[c]Conversion: 100 kg/ha = 89 lb/A.

Early drawdowns restrict the germination of woody species adapted to wet sites at southern latitudes; however, irrigation may then be required to stimulate germination of seed-producing plants during dry seasons. In the northern United States, late drawdowns and shallow flooding preclude the establishment of woody growth.

Manipulations of Water Levels for Wildlife

Management practices often revolve around a set calendar date, though exact timing varies with latitude, local climatic conditions, or hunting seasons. Even though adherence to the same drawdown date does not necessarily produce the same kinds and quantities of foods annually, the diversity of natural vegetation probably attracts and provides food and cover for a diversity of waterfowl and other wildlife. Because environmental variations are an inherent part of habitat management, we recommend a flexible framework for manipulating moist-soil sites that is based on climatic and ecological variations in life histories of plants and animals rather than on a set calendar date, and makes use of plants or wildlife as indicators for specific habitat manipulations. For example, the arrival of a shorebird species might be used as a cue that a series of habitat manipulations should be started, to provide a set of new habitat conditions for the next migrants.

Our experience suggests that waterfowl initially respond best to units with some open water, such as borrow ditches, flooded roads, or areas with short or sparse vegetation (Table 6). These open-water areas often result from uneven topography or from discontinuous plant distribution. After several days of use, ducks drop directly into or swim into rank or dense vegetation.

Fall Flooding and Winter Impoundment

Although waterfowl may be the primary species on impoundments during fall and winter, management for dabbling ducks also provides conditions attractive to many wildlife species (Table 6). The deeper water used by most diving ducks (0.5 m or more) excludes most non-waterfowl species and requires substantial, costly levees.

The fall flooding of moist-soil areas can be timed on the basis of the arrival of waterfowl. Blue-winged teals and pintails usually arrive first. If no impoundments are flooded, or if the impoundments already flooded for summer wetland wildlife are deemed too small to provide feeding areas for the expected teal and pintail populations, other impoundments should be flooded to provide the maximum amount of area with water 10 to 25 cm deep (Table 6). These water depths are ideal for most dabbling ducks as well as for Canada geese. As waterfowl numbers increase, more impoundments can be flooded.

An irregular topography within an impoundment results in ideal water depths for a variety of species. On Mingo NWR, some sites are not flooded whereas others may be flooded to depths of 30 to 50 cm. This irregularity is important because these diverse depths create different conditions that are compatible with the preferred feeding modes of many bird species.

Table 6. *Habitat conditions that attract vertebrates to moist-soil impoundments.*

	Foods					Openings		Vegetative cover			
Vertebrate group	Vertebrates	Invertebrates	Seeds	Browse	Water depth (cm)[a]	Water	Mudflat	Rank	Short	Dense	Sparse
Amphibians		✓			0-20	✓	✓		✓		✓
Reptiles	✓	✓			0-50	✓		✓	✓	✓	✓
Grebes	✓				25 +	✓			✓		✓
Geese			✓	✓	0-10	✓	✓		✓	✓	✓
Dabbling ducks		✓	✓		5-25	✓	✓	✓			
Diving ducks		✓	✓		25 +	✓					
Hawks	✓				NA				✓	✓	✓
Galliforms		✓	✓		D-M			✓	✓	✓	✓
Herons	✓	✓			7-12	✓			✓		✓
Rails		✓	✓		5-30			✓	✓	✓	
Coots			✓	✓	28-33	✓			✓		✓
Shorebirds		✓			0-7	✓	✓		✓		✓
Owls	✓				D-M				✓	✓	✓
Swallows		✓			NA	✓			✓		✓
Sedge wrens		✓			NA			✓		✓	
Nesting passerines		✓	✓		NA			✓	✓	✓	✓
Winter fringillids			✓		NA			✓	✓	✓	✓
Rabbit				✓	0			✓		✓	
Raccoon	✓	✓	✓		0-10	✓	✓	✓	✓	✓	✓
Deer				✓	0			✓			

[a]D-M = dry to moist; NA = not applicable (use of units is not dependent on flooding or specific water depths).

American coots often dive for food and are most abundant where water is about 30 cm deep (Fig. 6). Deeper areas also attract muskrats. Northern shovelers use a variety of water depths, but usually strain invertebrate foods from near the surface in water that can be deeper than that used by most dabbling ducks. Both mallards and pintails feed extensively on the bottom, but mallards generally dabble from the surface in shallow water 10 to 15 cm deep, whereas pintails tip-up in deeper water. Teals prefer intermediate depths of 12 to 20 cm. Blue-winged teals frequent areas with submerged vegetation.

American bitterns and other wading birds often use depths of 7 to 12 cm, preferably where emergent vegetation is present. Dense emergent vegetation is apparently attractive to rails, common snipes, and passerines such as swamp, white-crowned, white-throated, and song sparrows (Table 6). Rails prefer water depths of 5 to 10 cm but snipes use areas that are flooded to depths of only 1 to 3 cm. White-tailed deer, turkeys, and ring-necked pheasants heavily use areas of abundant, dense, rank cover when the sites are dry. Passerines often use sites whether or not they are flooded.

Raptors are attracted to the abundant prey present on moist-soil impoundments. Golden and bald eagles are attracted by waterfowl, marsh hawks by frogs and small ducks, and red-tailed and red-shouldered hawks by ducks and small mammals. Short-eared owls are regularly seen on some areas.

Manipulations to Attract Wildlife in Spring

The major management options for the desired group of birds in the spring involve manipulations to provide their preferred water depths when they arrive. Shorebirds require mudflats or shallow water of 5 cm or less. Wading birds are attracted to water 7 to 12 cm deep, whereas migratory and breeding waterfowl prefer water 10 to 25 cm deep.

Early Spring Drawdown

Early spring drawdowns should be timed to shorebird migration. For example, in southeastern Missouri, lesser yellowlegs and pectoral sandpipers arrive from early to mid April. The timing of the drawdown at other locations will vary with latitude and with the phenology of species that migrate through or nest on an area. After an early spring drawdown, most areas within an impoundment are nearly devoid of old vegetation. This situation is ideal for shorebirds because they respond well to shallow water zones that are interspersed with mudflats. The most attractive water depths are between 1 and 5 cm. However, on some sites within each impoundment, especially on sites that are flooded to shallow depths, new growth of spikerushes and old clumps of soft rushes, bulrushes, and stems and blades of grasses and sedges provide concealment for rails and late-

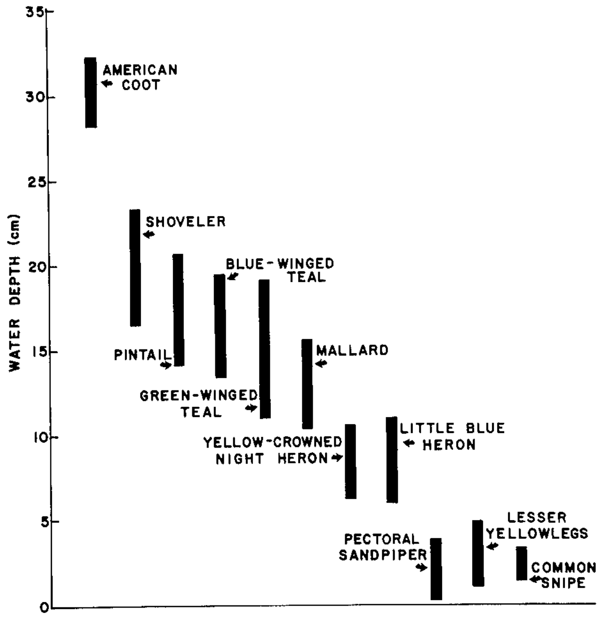

Fig. 6. Water depths used by 11 common water birds, in seasonally flooded impoundments.

wintering passerines. Like waterfowl, shorebirds appear to have preferred feeding depths; the larger, longer-legged birds frequenting deeper water than the smaller, shorter-legged birds (Fig. 6). Because most of the emergent vegetation has often been flattened by wind and wave action or waterfowl activity, or eaten by waterfowl, shorebirds often find an ideal habitat when they arrive.

Gradually fluctuating water levels provide maximum potential for maintaining shorebird use. For example, a slow drawdown concentrates shorebirds in the zone of shallow water near mudflats. The largest effective area of this zone can be provided by changing water levels daily or continuously. As water levels drop and habitat conditions deteriorate, water levels in other impoundments can be gradually lowered to maintain shorebird concentrations for longer periods. Observation towers positioned near the lowest point of the impoundments—so they face up the slope or gradient—will provide excellent viewing for the entire period of the drawdown.

When the topography of a moist-soil impoundment varies, sites that were flooded shallowly during winter still provide enough emergent cover for rails. The deeper waters of impoundments—especially those in which the drawdowns were late—contain submerged, decaying, and regenerating vegetation with scattered emergents that are ideal for wading birds, rails, and late-migrating or resident waterfowl. Invertebrates, amphibians, and fish are usually concentrated in or near submerged vegetation such as marshpurslane, water-starwort, or regenerating swamp smartweed. Grasses, rushes, sedges, arrowheads, and waterplantains provide emergent cover. These flooded sites with diverse vegetative cover are ideal for insect production. Swallows, chimney swifts, and eastern kingbirds feed over these areas and rest on the emergent vegetation. Exposed mudflats are used by foraging passerines such as American goldfinches.

Spring drawdowns that expose mudflats make impoundments unavailable for nesting coots or ducks, and these impoundments are not available as brood habitat later in the season. However, spring drawdowns make lower vertebrates and invertebrates, especially crustaceans, available to a variety of wildlife, including blackbirds, crows, raptors, egrets, herons, and raccoons. Mudflats exposed by spring drawdowns are excellent feeding sites for young killdeers and spotted sandpipers as well.

Late Spring Drawdown

A late or delayed spring drawdown is most effective if it is divided into two phases. Initially water levels should be lowered to 5 to 15 cm and maintained at this level until plant germination and growth occur on the mudflats in impoundments managed for shorebirds. Once germination begins, the drawdown can continue until completion.

The initial phase of a late-spring drawdown should be timed with the arrival of herons or other bird groups such as rails or swallows to derive maximum wildlife benefits from all moist-soil sites. In our study area in southeastern Missouri, we begin our drawdown with the arrival of little blue and yellow-crowned night herons. Herons prefer open water with an abundance of submerged and floating vegetation but only sparse emergent vegetation. Rails prefer emergent vegetation and use both shallow and deep water. Some late spring migrating and resident waterfowl feed on insects and other invertebrates. Swallows are attracted to the areas to feed on emerging insects.

Coordinated Timing of Early and Late Drawdowns

Both early and late spring drawdowns are needed in an optimal moist-soil management plan. The most effective management requires that sites intended to attract herons or rails be kept flooded until impoundments that were drawn down early are revegetated and the new vegetation can tolerate reflooding. The impoundments managed for herons can then be drained without permanently displacing wetland wildlife. Herons are attracted to the newly revegetated and reflooded impoundments.

Because environmental conditions vary from year to year, manipulations should be coordinated with the arrival and departure of wildlife species or with habitat conditions, not with a calendar date. We emphasize the importance of keeping good records on each moist-soil situation so that continuity of management is possible as personnel changes occur (Appendix 4).

Manipulations to Attract Summer Wildlife

In the summer, as in the spring, the major options are to attract either upland or wetland wildlife. At this point, the decision to attract certain wildlife depends on the types and growth of the vegetation present after the drawdown. Management for upland wildlife is possible only when that vegetation will meet the management goals for wetland wildlife in the upcoming fall and winter. The growth of woody species or extensive germination of cocklebur or other noxious forms sometimes makes control of this vegetation more important than considerations for upland wildlife.

Management for Upland Wildlife

Areas intended for upland wildlife are not reflooded until fall as long as rainfall is adequate to stimulate optimum vegetative growth. These areas typically are vegetated with plants like aster, ragweed, beggarticks, crabgrass, and panic grass. During dry summers, the vegetation will require irrigation by shallow reflooding. Adequate irrigation requires that soils become saturated at the highest sites within the impoundments. Water can be removed within 1 to 2 h after complete soil saturation is achieved. If the area with the highest elevation is watered first, overflow water can be reused to irrigate areas at lower elevations.

Cottontails and other small mammals are able to find food and cover on sites managed for upland wildlife, but their breeding is tenuous because flooding may eliminate nests and young if irrigation is required. However, new vegetative growth on impoundments that are not flooded will attract many different passerines, the species varying with location. Common yellowthroats, indigo buntings, and sedge wrens are especially abundant at mid-continent locations. Dewatered moist-soil areas also provide brood and foraging habitats for game birds such as bobwhites, turkeys, and pheasants. Deer use the sites as nurseries and for feeding.

Management for Wetland Wildlife

Wetland wildlife species that depend on shallow water respond well to moist-soil areas. Impoundments that are selected to attract wetland wildlife should be reflooded as soon as the desirable vegetation can tolerate flooding. Plants on sites that are flooded in summer are less likely to be barnyardgrasses, smartweeds, or beggarticks, and more likely to be sedges, rushes, rice cutgrass, or even lotus. Once the plants are tall enough, we recommend continuous flooding to depths of 5 to 15 cm.

Herons, rails, resident waterfowl, and some passerines such as redwinged blackbirds and marsh wrens feed and often breed on these wetter sites. Yellowthroats, indigo buntings, and dickcissels tend to breed on the drier sites. Marsh hawks and other raptors hunt for prey; turkeys, pheasants, and deer, typically considered more upland, wander out in the impoundments to feed and obtain water. Raccoons, minks, muskrats, and other furbearers also benefit from these flooded areas.

Migrant shorebirds begin returning by mid to late summer. Moist-soil sites that have been disked and then flooded with surface water provide ideal habitat. At the latitude of Missouri, units are revegetated extensively if they are disked in July, and plants like spikerush respond well if disking is in August. Geese concentrate on units that are disked in late summer and have some surface water; they loaf on the mudflats and graze on the newly sprouted spikerush.

Developing Integrated Management Plans

Ideally, management areas should have several impoundments that can be manipulated to promote the production of different foods or to attract different groups of wildlife. We have developed a flow chart as an aid to facilitate optimum use of impoundments for a variety of wildlife and to promote specific types of plant growth (Fig. 7). The chart is based on plant and wildlife responses over a 13-year period on Mingo National Wildlife Refuge.

Each manipulation adjusts the attractiveness of wetland conditions for different groups of wildlife. Grebes, coots, and diving ducks use fairly deep water; dabbling ducks, medium depths and shallow pools; herons, shallow water; shorebirds, shallow water and mudflats; rails, shallow water with upright emergent cover; and upland wildlife, dry ground. Much of the response by wildlife is related to the structural components of vegetation as well as to water depth: Rails require robust emergents that remain upright, whereas most shorebirds avoid dense vegetation and center their activities on mudflats; herons concentrate where some vegetation is present but visibility is not restricted; and waterfowl are more adaptable to a variety of habitats.

The attractiveness of the habitat for these different groups is adjusted by raising or lowering the water level and (when necessary) controlling undesirable vegetation in summer. For example (Fig. 7), a series of manipulations of waterfowl habitat (W) to make it attractive to shorebirds (S) would include a gradual dewatering (to a depth of 5 cm) in early spring; complete dewatering, disking to get rid of undesirable vegetation, and reflooding to a depth of 5 cm in summer; and increasing the water level (to the level of habitat W) in late fall and winter, after shorebirds have migrated to their winter ranges. The manager has a number of options (one of which is to take no action), depending on the perceived needs, for seasonal adjustments of habitats to attract the various bird groups. Different strategies are appropriate in different years.

The four water conditions depicted in Fig. 7—(1) deep (more than 15 cm), (2) medium (15 cm), (3) shallow-water

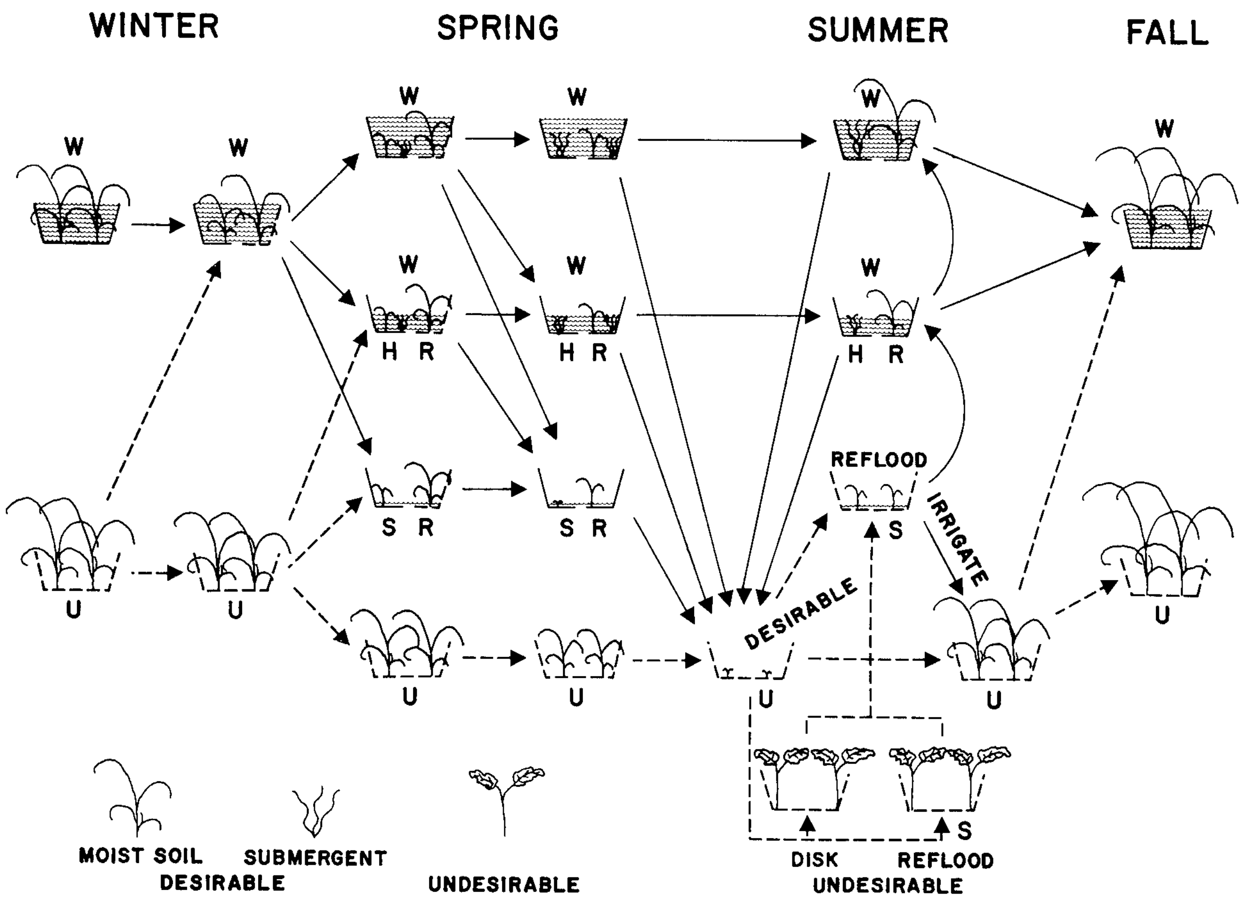

Fig. 7. Flow diagram showing manipulations resulting in seasonal habitat conditions that attract five wildlife groups (W = waterfowl, H = herons, R = rails, S = shorebirds, and U = upland wildlife, including deer, turkeys, raptors, small mammals, and passerines). Each manipulation adjusts the attractiveness of the habitat for the different wildlife groups by creating different combinations of water depth, food, and vegetative cover. Water depth is depicted by the level of shading in the stylized wetland basins, representing deep flooding (>15 cm), a medium level (15 cm), and a mud and shallow-water interface. Dashed arrows represent manipulations that flood dry basins. The result is depicted within the dashed portion of the succeeding basin. Solid arrows and basins represent manipulations and their results when flooding is continuous, with or without water level adjustments. Vegetative conditions within the basins are depicted by three stylized plant groups: (1) desirable moist-soil grasses, sedges, and herbs, (2) desirable submergent species, and (3) undesirable herbs and woody growths. The growth stage and robustness of the vegetation are depicted by the size of the plants relative to the basins and water depth. The vegetative condition within each half of a basin may be viewed as resulting from a different stage of habitat manipulation, such as early or delayed flooding or drawdown. As each wetland basin is successively subjected to its final stage of spring or summer drawdown, the type of manipulation to be performed depends on the development and composition of the plant community. Undesirable seedlings may be controlled by disking, reflooding, or both. Reflooding of impoundments may serve to irrigate desirable seedlings or to provide a continuous supply of wetland habitat for summer wildlife, once plant development is sufficient to tolerate higher water levels.

mudflat, and (4) dry—should be viewed as a continuum and are not necessarily desirable conditions to maintain for extended periods. We emphasize this point because wetland plants and wildlife are well adapted to the dynamic nature of water fluctuations in natural wetlands. Because the topography within the impoundment basins is usually uneven, water depths are variable and provide desirable depths for more than one group of species when the impoundments are flooded. The drawdown process provides constantly changing water conditions that (1) concentrate prey, (2) create habitat conditions that can be exploited by a variety of wildlife, and (3) provide soil and water conditions that promote the germination and growth of a wide variety of plants. For example, a gradual drawdown of a deeply flooded impoundment in spring provides suitable conditions for grebes, coots, diving ducks, dabbling ducks, herons, and shorebirds as water recedes from full pool to mudflat.

Moist-soil manipulations over a series of years tend to result in the predominance of annuals if disturbance has been frequent, or of perennials if disturbance has been lacking. Annuals are desirable where high seed production is the management goal. Impoundments must be disturbed regularly by practices such as disking or carefully timed flooding to promote maximum seed production. Perennials become increasingly common wherever moist-soil management has been practiced for several years. Some perennials are excellent seed producers and those that develop early in the season provide robust cover for spring migrants. On sites that are difficult to drain, however, the establishment of perennials with large underwater rhizomes may be undesirable because they often form dense stands and shade out food-producing species.

Our techniques for controlling undesirable vegetation require much refinement. Not all plants can be controlled effectively by disking and reflooding. Plants such as American lotus and yellow water lily, which are found in impoundments with low areas and more or less permanent water, cannot be satisfactorily controlled by disking. Not only do these species occur on sites that are difficult to drain, but when disks cut rhizomes into smaller sections, new shoots may develop from sections of rhizome having internal energy reserves and stem-forming tissue.

The most difficult decisions in moist-soil management are related to situations in which undesirable species are abundant, but the potential for food production is excellent because desirable seed-producing plants also are present in abundance. For example, the control of small woody seedlings such as willows or oaks in an impoundment with an excellent stand of a good food-producing plant like millet may be a difficult decision. Disking the impoundment would result in the immediate loss of the potential for seed production but is also the most effective control of the undesirable woody growth. Although food production would probably be reduced in the year of disking, the disturbance would enhance the production of annual seeds in the next growing season. If this situation were to occur on Mingo Refuge, our decision would be to control willow immediately but delay the control of oaks until the following season. The decision is based on our experience with plant responses in relation to soils and temperature, as well as other factors, in southeastern Missouri. The experience we have gained over the years has facilitated our decision making and refined what might best be called the art of moist-soil management on Mingo Refuge. Development of these refinements in management is necessary for each management area and provides opportunities for managers to optimize use of resources on areas they oversee.

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Selected Readings

Much published information related to moist-soil plants and water management is available from widely scattered sources. Information in the handbook as well as management recommendations are based on these published materials and on our own studies. For those who wish to read further, we have prepared a list of selected readings for 11 topics. Some reports provide material pertinent to two or more topics. Detailed references are given in the next section.

Impoundment Development

Addy and MacNamara 1948 Chabreck 1960
Bradley and Cook 1951 Linde 1969

Soil Types, Condition, and Nutrients

Arner et al. 1974
Bouldin et al. 1973
Cook 1958
Cook and Powers 1958
Green et al. 1964
Harris and Marshall 1963
Kadlec 1962, 1979
Lathwell et al. 1969

Water Turbidity

Anderson 1950
Black 1946
Cahoon 1953
Chabreck and Hoffpauir 1962
Chamberlain 1948
Joanen and Glasgow 1965
Low and Bellrose 1944
Martin and Uhler 1939
Moyle and Kuehn 1964
Robel 1961*a*, 1961*b*
Threinen and Helm 1954
Tryon 1954

Plant Identification and Nomenclature

Fassett 1960
Fernald 1950
Gleason 1968
Hitchcock 1950
Hotchkiss 1967
Martin and Barkley 1961
Mason 1957
Scott and Wasser 1980

Seedbanks, Viability, Germination, and Production of Moist-soil Seeds

Bedish 1967
Burgess 1969
Crail 1951
Davis et al. 1961
Emerson 1961
Ermacoff 1969
George and Young 1977
Goss 1924
Green et al. 1964
Harmon et al. 1960
Jahn and Moyle 1964
Jemison and Chabreck 1962
Kadlec and Wentz 1974
Knauer 1977
Low and Bellrose 1944
McClain 1957
McGinn and Glasgow 1963
Meeks 1969
Meyer and Anderson 1952
Miller and Arend 1960
Munro 1967
Neely 1956
Palmisano and Newsom 1967
Penfound 1953
Reid 1961
Shearer et al. 1969
Singleton 1951
Taylor 1977
Uhler 1955
van der Valk and Davis 1976, 1978
Welch 1952
Weller 1975
Wills 1970

Plant Response to Water Manipulation

Bednarik 1962, 1963
Burgess 1969
Cook and Powers 1958
Crail 1951
Dane 1959
Harris and Marshall 1963
Hunt and Lutz 1959
Joanen and Glasgow 1965
Kadlec and Wentz 1974
Keller and Harris 1966
Knauer 1977
Lathwell et al. 1973
Linde 1969
Low and Bellrose 1944
Meeks 1969
Neely 1960
Robel 1961*a*, 1962
Rundle 1980
Taylor 1977

Control of Vegetation by Pumping, Disturbance, and Fire

Crail 1951
Ermacoff 1969
Green et al. 1964
Griffith 1948
Hoffpauir 1967
Kadlec and Wentz 1974
Knauer 1977
Linde 1969
Lynch 1941
Martin et al. 1957
McGilvrey 1964
McNease and Glasgow 1970
Miller and Arend 1960
Neely 1967
Rundle 1980
Steenis et al. 1955
Taylor 1977
Uhler 1955

Problem Plant Species

Bednarik 1963
Bull 1965
Gagnon 1953
Givens and Atkeson 1957
Green et al. 1964
Harris and Marshall 1963
Kadlec and Wentz 1974
Knauer 1977
Linde 1969
Low and Bellrose 1944
Malecki and Rawinski 1979
Martin and Uhler 1939
Martin et al. 1957
Meeks 1969
Rundle 1980
Shamsi and Whitehead 1974*a*, 1974*b*; 1977*a*, 1977*b*
Singleton 1951
Steenis and Warren 1959
Taylor 1977
Thompson et al. (Unpubl. rep.)

Use of Wetlands by Birds

Andrews 1973
Benson and Foley 1956
Burgess 1969
Chabreck 1960
Chabreck et al. 1974
Davison and Neely 1959
Fredrickson and Drobney 1979
Gerstenberg 1979
Harrison 1974
Jordan 1953
Keith 1961
Knauer 1977
Kushlan 1976
Landers et al. 1976
Neely 1956
Palmisano 1972
Post and Browne 1976
Prevost et al. 1978
Rundle 1980
Taylor 1977, 1978
Watson and O'Hare 1979
Weller and Fredrickson 1973
White and James 1978

Production of Invertebrates

Arner et al. 1974
Burgess 1969
Kadlec 1962
Krecker 1939
Krull 1970
Swanson and Meyer 1973
Voights 1976
Wegener et al. 1974

Nutritive and Energy Content of Seeds

Bardwell et al. 1962
Drobney 1977
Holmes 1975
Irby et al. 1967
Jordan and Bellrose 1951
Kendeigh and West 1965
Knauer 1977
Robel et al. 1979
Rundle 1980
Taylor 1977

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Appendix 1

List of Scientific Names of Plants (from Scott and Wasser 1980)

Typhaceae
- Common cattail, *Typha latifolia*

Najadaceae
- Pondweed, *Potamogeton* sp.

Alismaceae
- European waterplantain, *Alisma plantago-aquatica*
- Common burhead, *Echinodorus cordifolius*
- Arrowhead, *Sagittaria* sp.

Gramineae
- Bread wheat, *Triticum aestivum*
- Red sprangletop, *Leptochloa filiformis*
- Cultivated rice, *Oryza sativa*
- Rice cutgrass, *Leersia oryzoides*
- Hairy crabgrass, *Digitaria sanguinalis*
- Fall panicum, *Panicum dichotomiflorum*
- Common barnyardgrass, *Echinochloa crusgalli*
- Barnyardgrass, *Echinochloa muricata*
- Foxtail bristlegrass, *Setaria italica*
- Glaucous bristlegrass, *Setaria glauca*
- Broomsedge bluestem, *Andropogon virginicus*
- Indian corn, *Zea mays*
- Milo, *Sorghum* sp.

Cyperaceae
- Chufa flatsedge, *Cyperus esculentus*
- Umbrella sedge, *Cyperus virens*
- Redroot flatsedge, *Cyperus erythrorhizos*
- Straw-colored flatsedge, *Cyperus strigosus*
- Squarestem spikerush, *Eleocharis quadrangulata*
- Blunt spikerush, *Eleocharis obtusa*
- Spikerush, *Eleocharis smallii*
- Longspike spikerush, *Eleocharis macrostachya*
- Fimbristylis, *Fimbristylis autumnalis*
- Common bulrush, *Scirpus atrovirens*
- Woolgrass bulrush, *Scirpus rubricosis*
- Beakrush, *Rhynchospora corniculata*
- Fox sedge, *Carex vulpinoidea*
- Sedge, *Carex tribuloides*
- Sedge, *Carex brevior*
- Sedge, *Carex lupuliformis*

Pontederiaceae
- Mudplantain, *Heteranthera limosa*

Juncaceae
- Common rush, *Juncus effusus*
- Poverty rush, *Juncus tenuis*

Salicaceae
- Black willow, *Salix nigra*

Fagaceae
- Pin oak, *Quercus palustris*

Polygonaceae
- Curly dock, *Rumex crispus*
- Marsh knotweed, *Polygonum coccineum*
- Pennsylvania smartweed, *Polygonum pensylvanicum*
- Curltop ladysthumb, *Polygonum lapathifolium*
- Swamp smartweed, *Polygonum hydropiperoides*

Amaranthaceae
- Redroot amaranth, *Amaranthus retroflexus*

Nymphaeaceae
- American lotus, *Nelumbo lutea*

Ranunculaceae
- Buttercup, *Ranunculus* sp.

Cruciferae
- Marsh yellow cress, *Rorippa islandica*

Leguminosae
- Indigobush amorpha, *Amorpha fruticosa*
- Common soybean, *Glycine max*

Callitrichaceae
- Water-starwort, *Callitriche heterophylla*

Lythraceae
- Tooth-cup, *Ammannia coccinea*
- Purple loosestrife, *Lythrum salicaria*

Malvaceae
- Prickly sida, *Sida spinosa*

Onagraceae
- Primrose willow, *Ludwigia decurrens*
- Creeping marshpurslane, *Ludwigia repens*
- Common marshpurslane, *Ludwigia palustris*

Oleaceae
- Red ash, *Fraxinus pennsylvanica*

Asclepiadaceae
- Swamp milkweed, *Asclepias incarnata*

Convolvulaceae
- Morningglory, *Ipomoea coccinea*

Verbenaceae
- Lippia, *Lippia lanceolata*

Labiatae
- American bugleweed, *Lycopus americanus*

Scrophulariaceae
- False pimpernel, *Lindernia anagallidea*
- Waterhyssop, *Bacopa rotundifolia*

Bignoniaceae
- Trumpetcreeper, *Campsis radicans*

Lentibulariaceae
- Bladderwort, *Utricularia* sp.

Rubiaceae
- Rough buttonweed, *Diodia teres*
- Buttonweed, *Diodia virginiana*
- Common buttonbush, *Cephalanthus occidentalis*

Compositae
- Joe-pye-weed, *Eupatorium serotinum*
- Aster, *Aster* sp.
- Common ragweed, *Ambrosia artemisiifolia*
- Common cocklebur, *Xanthium strumarium*
- Beggarticks, *Bidens comosa*
- Beggarticks, *Bidens cernua*
- Devils beggarticks, *Bidens frondosa*
- Beggarticks, *Bidens artistosa*
- Sneezeweed, *Helenium flexuosum*

Appendix 2.

Introduction to Moist-soil Plant Seedlings

Most taxonomic works have good descriptions and illustrations of mature plants, flowers, and seeds, but illustrations of seedlings and early stages are rarely shown. Moist-soil plant seedlings are difficult to identify, and the lack of keys and descriptions further complicates the problem of identification. Because the correct identification of seedlings is important in making management decisions, we have provided eight examples of common moist-soil plant seedlings. Since the seeds were planted and the plants raised under greenhouse conditions (30°C), the rate of growth indicated in these illustrations is not necessarily representative of growth under natural conditions.

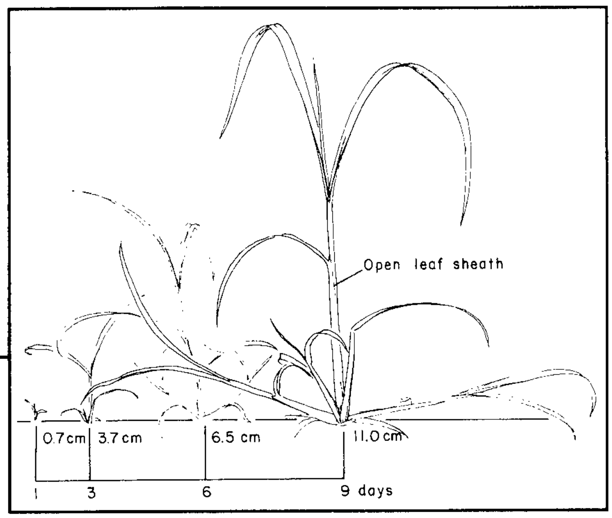
Sprangletop (*Leptochloa* sp.)

Range: Several species native to North America; widespread.

Characteristics: Seedlings — delicate, thin leaves, color medium dark green, open leaf sheath obvious by 1 week. Annuals or perennials — often associated with mid- and late-summer drawdowns. Seeds are soft.

Management: Germinates on wet sites. Responds well to late-season drawdowns and produces heavy seed crop.

Wildlife use: Seeds regularly eaten by waterfowl.



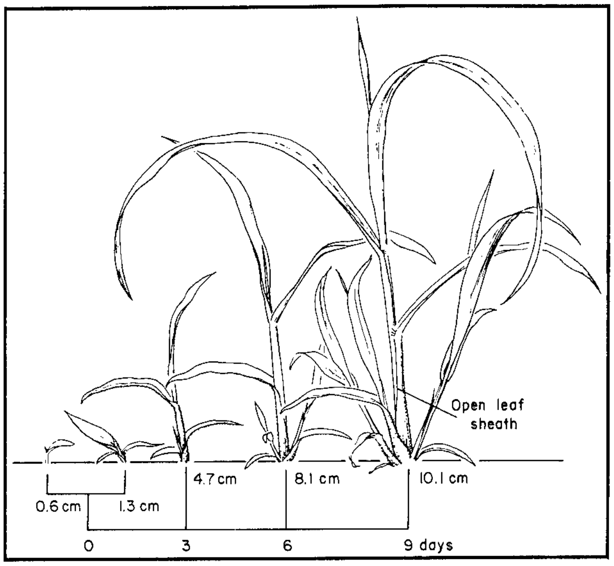
Curltop Ladysthumb (*Polygonum lapathifolium*)

Range: Native of Europe; widely distributed in North America.

Characteristics: Seedlings — two cotyledons of uniform size usually apparent for about 2 weeks. Cotyledon leaves with smooth margins. Annual — once established, plants can tolerate shallow flooding. Dark-colored seeds are small and have a tough seed coat.

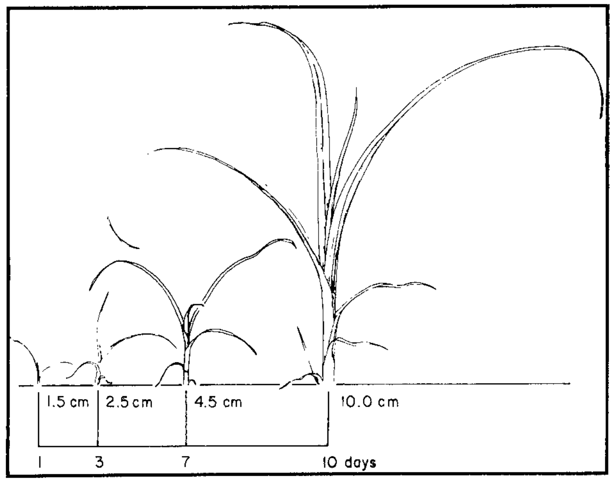
Management: Respond well to early-season drawdowns. Will germinate in muddy conditions. Most productive during the early successional stages, after drainage of permanent water or soil disturbance. Tall dense stands may require mowing to create openings to ensure fall use.

Wildlife use: Seeds eaten regularly by waterfowl.



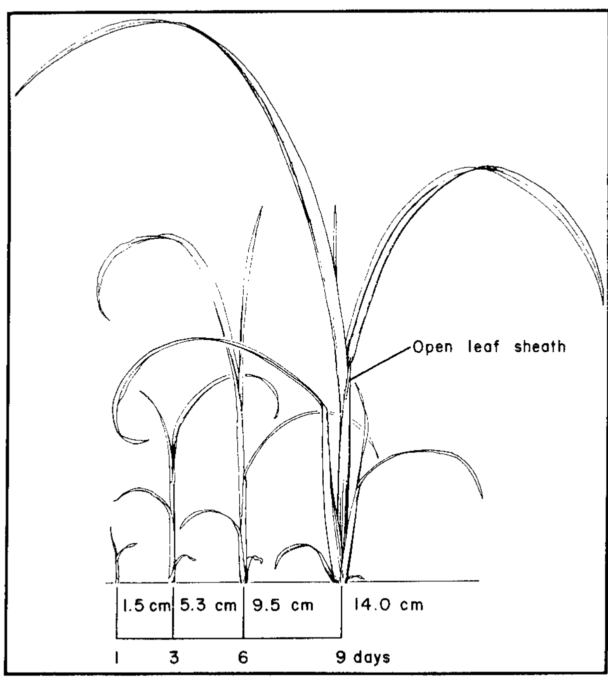
Fall Panicum (*Panicum dichotomiflorum*)

Range: Native; widespread in the United States.
Characteristics: Seedling—color medium dark green, open leaf sheaths obvious by sixth day. Annual—small soft seeds.
Management: Germinates on relatively dry sites. Responds well to mid- and late-season disking or drawdowns.
Wildlife use: Seeds eaten regularly by waterfowl.



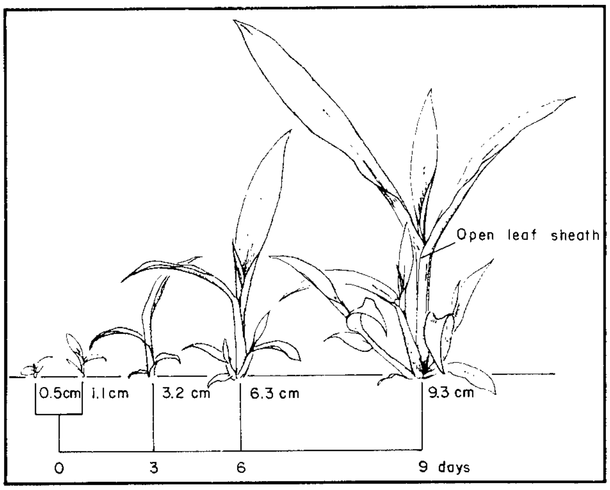
Sedge (*Cyperus* sp.)

Range: Many species common on moist-soil sites throughout North America.
Characteristics: Seedlings—triangular stem apparent by third day, color light green, apical growth is marked by several leaves of nearly equal size in triangular pattern, leaf sheath is closed. Annuals or perennials—annuals tend to respond to late-season management. Perennials typically develop early on moist-soil sites.
Management: On late successional sites, perennials are important in providing robust cover early in the season and some are excellent seed producers. Annuals such as red-rooted sedge respond to late-season drawdowns and provide excellent cover and food for rails.
Wildlife use: Rails use sedges for protective cover. Seeds are regularly eaten by waterfowl.



Barnyardgrass (*Echinochloa* sp.)

Range (of two common species): *Echinochloa crusgalli* is a native of the Old World, introduced into North America and now widespread; *E. muricata* is primarily in the midwestern and southeastern United States.
Characteristics: Seedlings—color medium dark green, leaves not hairy; open leaf sheath obvious by sixth day; stems flattened. Annual—occurs in early successional stages.
Management: Germinates when soil is moist but not flooded. Seed production is heaviest during first and second years after disturbance, but the plant responds well to water management on areas with advanced succession. Best response occurs with mid- or late-season drawdowns.
Wildlife use: Seeds regularly eaten by waterfowl.



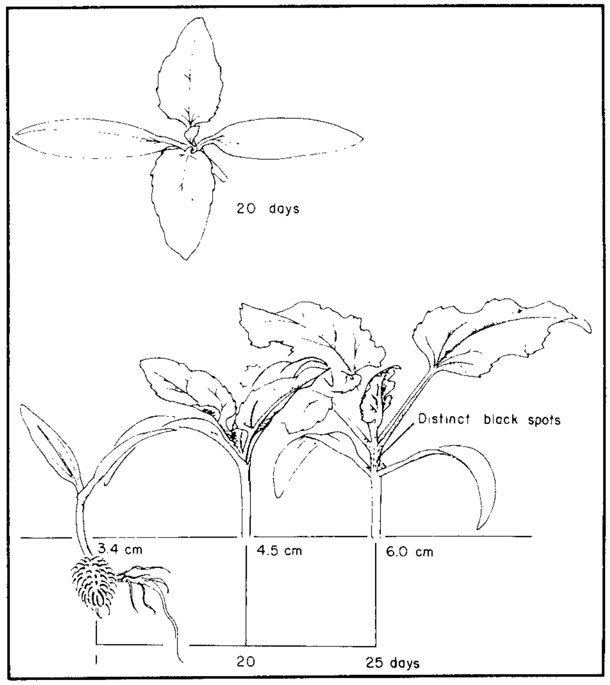
Hairy Crabgrass (*Digitaria sanguinalis*)

Range: Native of Europe; introduced in North America and now found throughout the United States and southern Canada.

Characteristics: Seedlings – in the greenhouse, leaves appear hairy by third day, and open leaf sheath obvious by the sixth day. Color medium dark green; apical growth marked by a single alternating dominant leaf. Annual – occurs in early successional stages. A common late-season, moist-soil plant. Roots from lower nodes of the stems, producing a large colony from one plant. Parts of the culms and sometimes of the leaf blades are purple or tinged with purple; the inflorescences are green or often turn dull purple. Small soft seeds.

Management: Germination occurs when soil is moist but not flooded. Responds well to mid- or late-season disking.

Wildlife use: Seeds regularly eaten by waterfowl and rails.



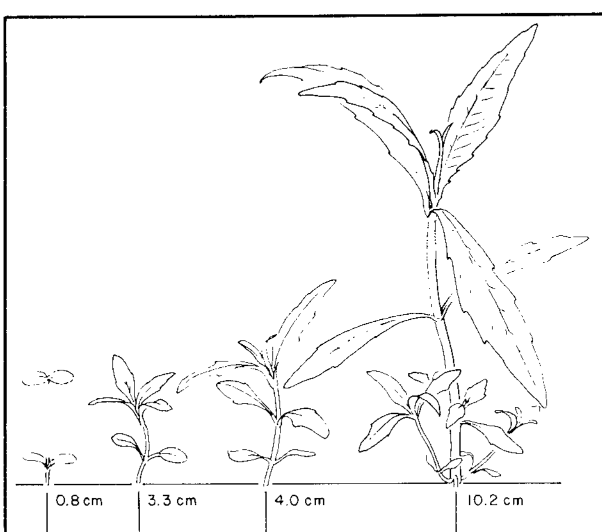
Common Cocklebur (*Xanthium strumarium*)

Range: Native; widespread in the United States.

Characteristics: Seedlings – two cotyledons of uniform size usually apparent for 2 weeks. Cotyledons have smooth margins. Annual – spiny seeds survive inundation. Under dry conditions, these robust plants grow faster than many moist-soil plants. This competition greatly reduces seed production of desirable plants.

Management: A severe problem on some sites previously planted to row crops. Best control is to flood seedlings to half their height soon after they germinate. Some mature plants that are flooded will die and all will have greatly reduced seed production.

Wildlife use: A problem plant; seeds are used by squirrels. Not important for waterfowl or other wetland species.



Beggarticks (*Bidens cernua*)

Range: Several species occur on moist-soil habitats; widespread in North America.

Characteristics: Seedlings – two cotyledons of uniform size usually apparent for about 2 weeks. Cotyledons have smooth margins. Annual – growth robust in fall; provides excellent cover for rails.

Management: Responds well to late-season drawdowns. Occurs in all successional stages. Germinates under dry conditions.

Wildlife use: Seeds regularly eaten by waterfowl.

Appendix 3.

Examples of Birds and Mammals that have Responded to Moist-soil Management in the Midwest

Common name	Scientific name	Common name	Scientific name
Pied-billed grebe	*Podilymbus podiceps*	Spotted sandpiper	*Actitis macularia*
Green heron	*Butorides virescens*	Solitary sandpiper	*Tringa solitaria*
Little blue heron	*Florida caerulea*	Greater yellowlegs	*Tringa melanoleuca*
Yellow-crowned night heron	*Nyctanassa violacea*	Lesser yellowlegs	*Tringa flavipes*
American bittern	*Botaurus lentiginosus*	Pectoral sandpiper	*Calidris melanotos*
Least bittern	*Ixobrychus exilis*	Least sandpiper	*Calidris minutilla*
Canada goose	*Branta canadensis*	Dunlin	*Calidris alpina*
Snow goose	*Chen caerulescens*	Short-eared owl	*Asio flammeus*
Mallard	*Anas platyrhynchos*	Barred owl	*Strix varia*
Pintail	*Anas acuta*	Chimney swift	*Chaetura pelagica*
Green-winged teal	*Anas crecca*	Eastern kingbird	*Tyrannus tyrannus*
Blue-winged teal	*Anas discors*	Tree swallow	*Iridoprocne bicolor*
Northern shoveler	*Anas clypeata*	Barn swallow	*Hirundo rustica*
Ring-necked duck	*Aythya collaris*	Common crow	*Corvus brachyrhynchos*
Hooded merganser	*Lophodytes cucullatus*	Sedge wren	*Cistothorus platensis*
Red-tailed hawk	*Buteo jamaicensis*	Common yellowthroat	*Geothlypis trichas*
Red-shouldered hawk	*Buteo lineatus*	Red-winged blackbird	*Agelaius phoeniceus*
Golden eagle	*Aquila chrysaetos*	Indigo bunting	*Passerina cyanea*
Bald eagle	*Haliaeetus leucocephalus*	Dickcissel	*Spiza americana*
Marsh hawk	*Circus cyaneus*	American goldfinch	*Carduelis tristis*
Bobwhite	*Colinus virginianus*	White-crowned sparrow	*Zonotrichia leucophrys*
Ring-necked pheasant	*Phasianus colchicus*	White-throated sparrow	*Zonotrichia albicollis*
Turkey	*Meleagris gallopavo*	Swamp sparrow	*Melospiza georgiana*
King rail	*Rallus elegans*	Song sparrow	*Melospiza melodia*
Sora	*Porzana carolina*	Muskrat	*Ondatra zibethicus*
American coot	*Fulica americana*	Raccoon	*Procyon lotor*
Killdeer	*Charadrius vociferus*	Mink	*Mustela vison*
Common snipe	*Capella gallinago*	White-tailed deer	*Odocoileus virginianus*

Appendix 4

Sample Data Sheet for Moist-soil Manipulations

Impoundment Number ____________ Year ____________

Type of Manipulation: (1) Flood (2) Drawdown

Season of Manipulation: (1) Winter (4) Summer
(2) Early Spring (5) Early Fall
(3) Late Spring (6) Late Fall

Notes on Manipulation:

Date	Water level	Stoplog elevation	Notes

Animal Response:

Species	Arrival	Departure	Notes

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A list of current *Resource Publications* follows.

133. A Handbook for Terrestrial Habitat Evaluation in Central Missouri, edited and compiled by Thomas S. Baskett, Deretha A. Darrow, Diana L. Hallett, Michael J. Armbruster, Jonathan A. Ellis, Bettina Flood Sparrowe, and Paul A. Korte. 1980. 155 pp.
134. Conservation of the Amphibia of the United States: A Review, by R. Bruce Bury, C. Kenneth Dodd, Jr., and Gary M. Fellers. 1980. 34 pp.
135. Annotated Bibliography for Aquatic Resource Management of the Upper Colorado River Ecosystem, by Richard S. Wydoski, Kim Gilbert, Karl Seethaler, Charles W. McAda, and Joy A. Wydoski. 1980. 186 pp.
136. Blackbirds and Corn in Ohio, by Richard A. Dolbeer. 1980. 18 pp.
137. Handbook of Acute Toxicity of Chemicals to Fish and Aquatic Invertebrates, by Waynon W. Johnson and Mack T. Finley. 1980. 98 pp.
138. Waterfowl and their Wintering Grounds in Mexico, 1937–64, by George B. Saunders and Dorothy Chapman Saunders. 1981. 151 pp.
139. Native Names of Mexican Birds, researched and compiled by Lillian R. Birkenstein and Roy E. Tomlinson. 1981. 159 pp.
140. Procedures for the Use of Aircraft in Wildlife Biotelemetry Studies, by David S. Gilmer, Lewis M. Cowardin, Renee L. Duval, Larry M. Mechlin, Charles W. Shaiffer, and V. B. Kuechle. 1981. 19 pp.
141. Use of Wetland Habitats by Birds in the National Petroleum Reserve—Alaska, by Dirk V. Derksen, Thomas C. Rothe, and William D. Eldridge. 1981. 27 pp.
142. Key to Trematodes Reported in Waterfowl, by Malcolm E. McDonald. 1981. 156 pp.
143. House Bat Management, by Arthur M. Greenhall. 1982. 30 pp.
144. Avian Use of Sheyenne Lake and Associated Habitats in Central North Dakota, by Craig A. Faanes. 1982. 24 pp.
145. Wolf Depredation on Livestock in Minnesota, by Steven H. Fritts. 1982. 11 pp.
146. Effects of the 1976 Seney National Wildlife Refuge Wildfire on Wildlife and Wildlife Habitats, compiled by Stanley H. Anderson. 1982. 28 pp.
147. Population Ecology of the Mallard. VII. Distribution and Derivation of the Harvest, by Robert E. Munro and Charles F. Kimball. 1982. 126 pp.

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