Moist-Soil Management Guidelines for the U.S. Fish and Wildlife Service Southeast Region

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These guidelines have been prepared to provide the moist-soil manager with some basic information that can be used to manage and evaluate moist-soil management units for wintering waterfowl foraging habitat. The contents are intended to improve moist-soil management on national wildlife refuges in the Southeast Region. The contents are not intended to be mandatory or to restrict the actions of any agency, organization, or individual. Literature citations and scientific names are purposefully kept to a minimum in the text. A listing of many common and scientific names of moist-soil plants is included in APPENDIX 1. References to seed sources are provided for information purposes only and do not represent an endorsement.

A note of appreciation is extended to the following individuals who reviewed and provided comments to improve this handbook: Frank Bowers, Mike Chouinard, Richard Crossett, Tom Edwards, Whit Lewis, David Linden, Don Orr, and John Stanton of the U.S. Fish and Wildlife Service; Ken Reinecke of the U.S. Geological Survey; Scott Durham of the Louisiana Department of Wildlife and Fisheries; Rick Kaminski and Jennifer Kross of Mississippi State University; Ed Penny of Ducks Unlimited; and Jimmy Grant of Wildlife Services.

TABLE OF CONTENTS

LIST OF TABLES AND FIGURE

LIST OF APPENDICES

Introduction

Moist-soil impoundments provide plant and animal foods that are a critical part of the diet of wintering and migrating waterfowl and have become a significant part of management efforts on many refuges and some private lands projects. Preferred moist-soil plants provide seeds and other plant parts (e.g., leaves, roots, and tubers) that generally have low deterioration rates after flooding and provide substantial energy and essential nutrients less available to wintering waterfowl in common agricultural grains (i.e., corn, milo, and soybeans). Moist-soil impoundments also support diverse populations of invertebrates, an important protein source for waterfowl. The plants and invertebrates available in moist-soil impoundments provide food resources necessary for wintering and migrating waterfowl to complete critical aspects of the annual cycle such as molt and reproduction.

The purpose of these guidelines is to provide the moist-soil manager on national wildlife refuges in the Southeast Region with some basic information that can be used to manage and evaluate moist-soil management units for wintering waterfowl foraging habitat. The basis for much of the information presented is from the *Waterfowl Management Handbook* [Cross, D.H. (Compiler). 1988. Waterfowl Management Handbook. Fish and Wildlife Leaflet 13. United States Department of the Interior, Fish and Wildlife Service. Washington, D.C.] and supplemented with the observations of the authors and personal experience of wetland managers working mostly in Louisiana and Mississippi. The guidelines are presented in nine sections, representing some of the most critical aspects of moist-soil management and evaluation: 1.) management objectives; 2.) moist-soil plant management; 3.) a list of plants by their relative foraging value to waterfowl; 4.) nuisance plant control; 5.) procedures for quantifying the foraging value of moist-soil units to migrating and wintering waterfowl; 6.) supplemental planting; 7.) flood schedule; 8.) integrating management for other wetland-dependent birds; and 9.) keeping records and reporting.

More detailed information on moist-soil plant management and foraging values for migrating and wintering waterfowl is presented in the *Waterfowl Management Handbook*, available on-line or as a CD available from the Publications Unit, U.S. Fish and Wildlife Service, Department of the Interior, 1849 C Street NW, MS 130 Webb Building, Washington, D.C. 202440 (FAX 703/358-2283). Several of the most pertinent articles in the *Waterfowl Management Handbook* are included in a publication titled *Wetland Management for Waterfowl Handbook* edited and compiled by Kevin Nelms in 2001 (most refuges and Migratory Bird biologists should have a copy of this handbook).

Management Objective

For moist-soil impoundments, the average foraging value varies tremendously depending on factors affecting food availability, production, and quality. Samples collected from a few selected refuge impoundments in the Lower Mississippi Valley

(LMV) from 2001 through 2004 using the sampling technique provided in APPENDIX 2 indicated moist-soil seed production ranged from 50 to almost 1,000 pounds per acre. A realistic goal should be to achieve at least 50% cover of "good" or "fair" plants as listed in APPENDIX 1 and/or produce a minimum of 400 pounds of readily available moist-soil seeds per acre in each impoundment, realizing some impoundments will be undergoing necessary or planned management treatments that will reduce waterfowl food production that year.

This moist-soil objective of 400 pounds per acre is at least partially derived from the Lower Mississippi Valley Joint Venture (LMVJV). In calculating the acreage needed to meet waterfowl foraging habitat objectives in the LMV, that Joint Venture established wintering waterfowl foraging habitat capabilities by habitat type. These capabilities are derived from the daily energy requirements of mallards (ducks) and represent the number of ducks that could obtain daily food requirements (duck use-days) from each acre of major foraging habitats, including various agricultural grains (harvested and unharvested), moist-soil habitat, and bottomland hardwoods (Table 1). In calculating the duck use-day value for moist-soil habitat, the LMVJV assumed an average of about 400 pounds per acre of native seeds were available to waterfowl.

Table 1. LMVJV waterfowl foraging capabilities by habitat type [expressed as duck use-days (DUD) per acre].[a]

Habitat type	DUD/acre
Moist-soil	1,386
Harvested crop	
Rice[b]	131
Soybean	121
Milo	849
Corn	970
Unharvested crop	
Rice	29,364
Soybean	3,246
Milo	16,269
Corn	25,669
Millet	3,292
Bottomland hardwood	
30% red oak	62
60% red oak	191
90% red oak	320

[a] From the LMVJV Evaluation Plan, page 15.
[b] From Stafford, J.D., R.M. Kaminski, K.J. Reinecke, and S.W. Manley. 2005. Waste grain for waterfowl in the Mississippi Alluvial Valley. Journal of Wildlife Management 69:in press.

Moist-Soil Plant Management

Moist-soil management is often referred to as more of an art than a science. However, through adaptive management and evaluation, moist-soil management is being science directed and, as such, positive results can be repeated. <u>There is no easy formula for success across the southeast beyond the need to develop a **plan**; frequently **monitor** plant and wildlife responses; and **keep detailed records** of natural conditions, management actions, and plant and wildlife responses</u>. The most important factors that determine plant responses to moist-soil manipulations are:

1.) amount of sunlight reaching the ground/plant;
2.) soil temperature;
3.) soil moisture;
4.) soil chemistry (pH, nutrients, etc.);
5.) seed bank; and
6.) successional stage of the plant community.

<u>Sunlight</u>. Moist-soil management involves managing early successional, herbaceous vegetation that typically requires full sunlight to maximize growth and seed production. Thus, moist-soil management should be focused in impoundments with little or no woody vegetation.

<u>Soil temperature</u>. Soil temperature, as it relates to the timing of the drawdown, has a great effect on the species of plants that germinate. Often the timing of the drawdown is presented in moist-soil management literature as early, mid-season, and late. These are relative terms that vary depending on location. In the *Waterfowl Management Handbook*, Chapter 13.4.6., "Strategies for Water Level Manipulations in Moist-soil Systems," Dr. Leigh Fredrickson describes early drawdowns as those that occur during the first 45 days of the growing season, late drawdowns as those that occur during the last 90 days of the growing season, leaving mid-season drawdowns as a variable length depending on the location and length of time between average first and last frosts. A description of soil temperature, moisture conditions, and expected plant response is provided in generic terms in Table 2 and are generally applicable regardless of your location.

<u>Soil moisture</u>. <u>Maintaining high soil moisture (or true moist-soil conditions) throughout the growing season is key to producing large quantities of desired waterfowl food (e.g., smartweed, millet, sedge, sprangletop, etc.) on a consistent basis</u>. A slow drawdown is an effective way to conserve soil moisture early in the growing season. In most cases, frequent, complete to partial re-flooding or flushing the impoundment throughout the growing season is desirable, followed by fall and winter shallow flooding to ensure food availability.

Table 2. A general description of soil temperature, moisture conditions, and expected plant response.

Drawdown date	Soil temperature	Rainfall	Evaporation	Expected plant response
early (first 45 days after average last frost)	cool to moderate	high	low	smartweed, chufa, spikerush, millet *(E. crusgalli)*
mid-season	moderate to warm	moderate	moderate to high	red rooted sedge, panic grass, millet *(E. colonum and walteri),* coffeebean, cocklebur
late (last 90 days before average first frost)	warm	moderate to low	high	sprangletop, crabgrass, beggarticks
shallow flood through-out growing season				duck potato, spikerush

The importance of complete water control or the ability to flood and drain impoundments as needed cannot be overstated when managing moist-soil. This is not to say that moist-soil impoundments cannot be successfully managed without complete water control, but management options are certainly increased with the ability to flood and drain when necessary, especially if each impoundment can be flooded and drained independent of all other impoundments. Stoplog water control structures that permit water level manipulations as small as 2 inches provide a level of fine tuning that facilitates control of problem vegetation or enhancement of desirable vegetation. If 6-inch and 4-inch boards are used to hold water behind stoplog structures, 2-inch boards need to be available to facilitate water level management during drawdowns.

Without the ability to re-flood or irrigate an impoundment during the growing season as needed, it has been our experience that a better plant response is achieved by keeping water control structures closed to hold winter water and additional rainfall, allowing water to slowly evaporate through the growing season. The practice of opening structures to dewater the impoundment during the spring and leaving it dry all summer generally results in poor moist-soil seed production.

Another option for impoundments with partial water control is to conduct an early drawdown and then replace boards to catch additional rainfall that may or may not occur at a rate fast enough to compensate for evaporation and transpiration later in the summer. If adequate rainfall is received, this option can result in a plant community important to waterfowl (e.g., barnyard grass and smartweed). However, if inadequate rainfall results in moist-soil seed production well below desired levels, other options (e.g., disk, plant a crop, etc.) should be considered. Remember that, as a general rule, desirable moist-soil plants can tolerate more flooding than nuisance plants such as coffeebean and cocklebur, two plant species that can dominate a site to the point of virtually eliminating more preferred species within an entire impoundment.

Soil chemistry. Salinity and pH have significant influences on plant response to management actions but do not receive much attention in the literature. Both are factors that must be considered where applicable. Soil tests should be conducted to assess pH and other nutrient levels and provide recommendations for lime and fertilization to address soil deficiencies. Particularly in coastal impoundments, water with moderate levels of salinity can be used as a management tool by timing the opening of structures to irrigate or flood an impoundment to control salt-intolerant plants.

Seed bank. In most cases, seeds of preferred moist-soil plants remain abundant in the soil, even following years of intensive agricultural activity. Where there is concern about the lack of available seed, supplemental planting (see below) could be considered until an adequate seed bank develops.

Successional stage. Generally, the most prolific seed producers and, therefore, the most desirable plants for waterfowl are annuals that dominate early successional seral stage. Without disturbance, plant succession proceeds within a few years to perennial plants that are generally less desirable for waterfowl food production. It is necessary to set back plant succession by disking, burning, or year-round flooding every 2 to 4 years to stimulate the growth of annuals. If the manager does not have the ability to re-flood following disking, the ground is usually dry, creating conditions that favor a flush of undesirable plants (e.g., coffeebean and cocklebur). In an effort to keep from having a year of low food production, it may be necessary to rotate a grain crop (e.g., rice, corn, milo, millet, etc.) by force account or cooperative farming. Another alternative would be to disk, re-flood, and dedicate that impoundment to shorebird foraging habitat during fall migration. Shorebird foraging habitat can be created by maintaining the re-flood for at least 2-3 weeks to allow invertebrate populations to respond before initiating a slow drawdown from mid-July through October (at this time of the year evaporation may cause a drawdown faster than desired, requiring some supplemental pumping to keep from losing water/moisture too fast). Deep disking (24-36 inches) is a tool that has been used to set back succession and improve soil fertility. Whenever disking is used, it is preferred to follow with a cultipacker or other implement to finish with a smooth surface. Large clumps will result in uneven soil moisture as the tops of clumps dry much faster and create conditions more conducive to less desirable species, such as coffeebean and cocklebur.

Traditionally, soil disturbance occurs in the spring followed by a grain crop or other management action(s) (e.g., re-flooding) with the objective of good waterfowl food production that same year. Some units, or at least in wet springs, remain too wet to till until early summer and can be planted to a relatively quick maturing crop such as millet. In extreme cases, tillage is completed so late that foraging habitat is essentially foregone in that year to improve production of preferred moist-soil plants or crops the following year(s).

To maintain a dominance of annual plants, managers should set up a 2 to 4-year rotational schedule for disturbing moist-soil impoundments based on site specific objectives, capabilities, control of nuisance plants, and knowledge of the area. Simple examples include:

Year 1	early season drawdown followed by disking and either 1) planting a grain crop, 2) frequent flushing of water for moist-soil plant production, or 3) shallow re-flood and hold until late summer drawdown for shorebirds;
Year 2	slow drawdown in early/mid season keeping soil moist for as long in the growing season as possible; and
Year 3	either early season drawdown or maintain shallow water throughout growing season, if monitoring indicates a less than desirable plant response, then conduct a late summer drawdown for fall migrating shorebirds, then disk (an alternative would be to have a late summer drawdown for fall migrating shorebirds, then disk).

or

Year 1	maintain 12-inch depth until July 15, then allow water to drop with evaporation and hold a shallow flood until winter or release any remaining water on September 15 to disk if needed (encourages delta duck potato);
Year 2	early drawdown by March 1 then close structure to catch rainfall or pump to flush impoundment, monitor for coffeebean and overtop to control if necessary, flood October – December (encourages wild millet);
Year 3	maintain 36-inch depth through the growing season and winter until the following July (encourages recycling of plant debris by invertebrates and provides diving duck habitat);
Year 4	maintain 36-inch depth until July1, then stagger drawdown for shorebirds, pump as necessary to maintain mudflats, re-flood November 1 (provides fall shorebird habitat).

The 4-year rotation is a simplified version of the one used at the Cox Ponds moist-soil complex on Yazoo NWR. These scenarios may be modified to find rotation(s)/practices that best meet specific management objectives. Consistently acceptable moist-soil seed production requires intensive management by managers who are perceptive, flexible, and able to adjust quickly to various situations. To achieve best results, it is critical that plans be developed, plant and animal responses monitored, and records maintained and reviewed.

Moist-Soil Plants

Hundreds of plant species would be found in moist-soil units across the southeast if complete plant inventories were conducted. Some of these plants provide good food value to waterfowl and some are of little or no value to waterfowl. A listing of some plants and relative food values for waterfowl is attached (APPENDIX 1: A Waterfowl Food Value Guide for Common Moist-Soil Plants in the Southeast). The plants on that list are given relative food values of good, fair, or none (little or no known value) as an arbitrary classification based on several plant guides and professional judgment.

Fortunately, impoundments on most refuges will be dominated by 25 or fewer species depending upon the successional stage of the plant community. Knowledge of those plants and their ecology is critical to successful moist-soil management. In meeting moist-soil objectives, the manager must be sensitive to plant species tolerance to dry or wet soil conditions, whether it can tolerate flooding, if it is an annual or perennial, its usefulness to waterfowl, etc. Species composition of a plant community is a product of past and current site conditions. The moist-soil manager must create the conditions necessary to produce and maintain the most valuable plants to waterfowl and other waterbirds.

Typically, preferred moist-soil plants are valued for the above-ground seed production. <u>Plants such as duck potato and chufa provide valuable underground tubers that present a viable alternative</u>. Promotion of these plant species can provide additional diversity to waterfowl/wetland habitats that should not be overlooked in developing and monitoring a moist-soil management program. David Linden reports that duck potato can be promoted in selected impoundments by maintaining a shallow-flooded (12 inches) condition through the growing season where tubers exist or tubers have been planted to colonize an impoundment. Once established, duck potato production typically increases for several years or until other plant species begin to dominate the site. Chufa tubers can reportedly be promoted by drying, shallow (2 inches) disking, and flushing an impoundment. Chufa tubers are commercially available and can be planted to colonize an impoundment (additional information is available in “Chufa Biology and Management,” Chapter 13.4.18. in the *Waterfowl Management Handbook*).

Undesirable Plant Control

In “Preliminary Considerations for Manipulating Vegetation” (*Waterfowl Management Handbook*, Section 13.4.9., page 2), Drs. Leigh Fredrickson and Fritz Reid stated that,

> “‘Undesirable’ plants are not simply ‘a group of plants whose seeds rarely occur in waterfowl gizzard samples.’ Rather, plants that quickly shift diverse floral systems toward monocultures, are difficult to reduce in abundance, have minimal values for wetland wildlife, or out compete plants with greater value should be considered less desirable.”

Coffeebean (a.k.a., *Sesbania*), cocklebur, and alligatorweed are three of the most prevalent undesirable species in actively managed moist-soil units in the southeast that can dominate a site to the point of virtually eliminating preferred species within an entire impoundment. Once these species germinate, they can be difficult to control.

Coffeebean, a legume, is a particularly common problem following disking, which scarifies seed otherwise lying dormant in the seed bank. Refuge Biologist David Linden (Yazoo NWR) has had good success controlling coffeebean by flooding over the top of young plants. It may take 10 days or more of flooding above the top of the coffeebeans before the apical meristem softens and the plants are killed depending on temperature. If coffeebean plants are not flooded early enough and grow ("stretch") to keep the top of the plant above the water surface, the water can be raised to kill the lateral meristems for some distance up the stem. After the impoundment is drained, the coffeebean can be mowed below the height of the surviving meristems to effectively eliminate the undesirable plants and encourage the growth of preferred plant species.

Cocklebur is a common product of late spring or early summer drawdowns (higher soil temperatures). It is a serious problem at St. Catherine Creek NWR where late spring/early summer floods from the Mississippi River do not recede from much of the refuge until June or July in some years. According to David Linden, cocklebur can be controlled using the flooding method described above for coffeebean. Eliminating cocklebur generally requires shorter flood duration than coffeebean and, even if the plant is not overtopped, growth can be arrested by flooding and allowing more moisture-tolerant plants to gain competitive advantage and mature.

Dr. Rick Kaminski reports that he will reverse steps in this control technique by first mowing and then flooding over the clipped stubble to kill coffeebean and other undesirable vegetation. Under either scenario, it is important to inspect the flooded undesirable plants and drain the water soon after they are killed. If the water is held too long after the undesirable plants are killed, the manager runs the risk of killing desirable plants in the impoundment, which then requires disking and flushing to stimulate germination of more seeds for a moist-soil crop or managing the area as a mudflat for shorebirds.

Alligatorweed is a common undesirable plant in some areas. Information collected by Migratory Bird Biologist Don Orr (retired), indicates that, in the more southerly portions of the region, alligator flea beetles are an effective control mechanism. (A source for beetles is Charlie Ashton, U.S. Army Corps of Engineers, Jacksonville, FL, phone: 904.232.2219.) Where alternate methods are needed, the best control method is to spray with glyphosate (other herbicides such as 2,4-D may also be effective) at the recommended rate. Two applications may be needed the first year and spot application to control residual plants thereafter. After spraying, the area can be disked and planted to a crop to achieve some food production. As an alternative, biologists at Cameron Prairie NWR in southwest Louisiana have had some success in controlling alligatorweed by drying infested fields and disking or, if conditions require, water buffaloing (a.k.a., roller chopping) shallow-flooded fields, then draining. Note that, in southwest Louisiana, the water table remains high and fields rarely dry to the extent they do in non-coastal areas of the southeast.

"Tools" available to set back the plant community successional stage or to control problem vegetation include: maintaining moist soil conditions with irrigation throughout the summer, flooding/re-flooding, disking, water buffaloing, mowing, continuous flood, and spraying approved herbicides (APPENDIX 3). Disking can be highly effective tool for setting back plant succession and controlling woody plants (e.g., black willow and common buttonbush) but can stimulate coffeebean as well as be the vector for the spread of other undesirable plants. Mowing is an effective management tool, particularly for controlling dicots (e.g., coffeebean and cocklebur) and promoting monocots (e.g., millets and sedges) in fields dominated by early successional species. <u>Herbicides are often the easiest and most effective method to control undesirable plant response</u>. The manager should select the appropriate "tool" based on the objective, local effectiveness, and available resources.

Sampling Techniques

Plant species composition in moist-soil units should be monitored throughout the growing season. Cursory samples should be conducted at least weekly early in the growing season to detect undesirable plant response that can be addressed in favor of more desirable species. Later in the growing season, it is important to conduct quantitative samples of vegetation to determine if management objectives (e.g., 400 pounds of seed per acre) are being met, monitor plant response (spring, summer, and fall) to management actions, identify plant species composition, monitor vegetation trends, complete habitat evaluations for the current year, and develop habitat plans for the following year, etc. <u>It is critical that management actions and plant response be recorded and archived in a format that others can understand so the successes can be replicated and failures avoided, data can be analyzed to establish long-term trends, and good, efficient management can be maintained following personnel changes</u>.

A sampling strategy must be developed to gather the data needed within the available time. The following plant sampling recommendations are made for the purposes stated above. If more detailed information is needed, additional time will be required to collect the data. In some cases, other sampling methods may more efficiently/effectively meet stated objectives.

<u>Seed estimator</u>. One useful tool that can be used to quantify seed production is discussed in the *Waterfowl Management Handbook*, Chapter 13.4.5., entitled "A Technique for Estimating Seed Production of Common Moist-Soil Plants" (APPENDIX 2). That technique involves the collection of data from plants that occur in a 25 cm x 25 cm sample frame and use of regression analyses to calculate pounds per acre of seed produced by individual species and cumulatively across species for

the moist-soil unit. The software and other information needed to use the seed production estimator can be downloaded from the web address (or search for "seed estimation software"): *http://www.fort.usgs.gov/products/software/seedyld/seedyld.asp.* This is a fairly simple program and data can be collected fairly quickly once the biologist gets familiar with the data needs. Drawbacks of this method is that regression formulas are only available for 11 plant species that are among the most common in moist-soil units and only for plants that produce seeds. Several users of this software have gotten unreasonably high seed estimates for red-rooted sedge (*Cyperus erythrorhizos*), bringing to question the reliability of the software for this species. Herbaceous plant parts, roots, and tubers are not considered in this methodology. A sample data sheet is attached to this guide (APPENDIX 4).

Plant densities. Visual estimates of the percent cover of the 5 or 6 most common species at each sample site in management units usually provide an adequate index of herbaceous plant composition for most moist-soil management needs. This information is most easily collected by estimating percent cover on a 0 to 100 percent scale within relatively small plots (e.g., 1-meter square or circular plots). Remember that dense herbaceous plant cover can be layered such that percent cover estimates could frequently exceed 100 percent. An alternative would be to estimate plant cover, by species, into classes, such as 0-5%, 6-25%, 26-50%, 51-75%, and >76%. Samples can be totaled and averaged by species. The line-intercept method (measured length of the line that each plant shades or touches) for determining plant cover of a unit can be used but data collection typically requires much more time.

Sampling schemes. It is preferred that two vegetation samples be collected each year. A sample should be taken one-third to nearly half way into the growing season to capture any early germinating species (e.g., spikerush) that could be gone and missed by a later, once-a-season vegetation sample. Another advantage of an early sample would be to allow time to plan and implement major management actions, such as herbicide treatments or disking and planting millet, to address developing problems and meet desired moist-soil production objectives.

A more comprehensive sampling and perhaps more critical sample effort should be done at least once, about two-thirds to three-fourths into the growing season. It is recommended that the sampling be conducted as described in "A Technique for Estimating Seed Production of Common Moist-Soil Plants" (APPENDIX 2) for estimating seed production and/or percent cover. It is recommended that, as a general rule, one sample be taken for every 2 acres in a moist-soil unit. Collecting 20 or 30 samples from across the entire moist-soil unit should account for variation and be adequate for most moist-soil work. Sample variability can be greatly reduced by conducting samples within homogeneous plant communities such that, if a moist-soil unit contains several distinguishable plant communities or zones, sampling should be conducted within each zone and analyzed independently. If time does not allow for sampling at this level of detail, the number of samples in each zone should be representative of its cover extent within the unit. For example, if a 10-acre moist-soil unit has two recognizable plant zones one dominated by millet (4 acres) and a second dominated by cocklebur (6 acres), a sample design should be established to get 2 samples from the millet zone and 3 from the cocklebur zone. Properly done, a random-systematic sample design, where the first sample is randomly placed and subsequent samples are equally spaced across a sample area, should accomplish the sampling needs. If the unit is digitized in ArcView or updated program, random or random-systematic points can be easily generated. Care should be taken to not follow and sample along treatments such as disked paths. If this is a potential problem, sample points can be randomly generated in the office using ArcView and located in the field using a GPS. Further assistance can be obtained from Migratory Bird Field Offices.

Vegetation sampling is important but can get time consuming. The number of samples is almost always a compromise between sample validity (representing what is actually there) and time and money constraints. Those conducting the field work usually have a good feel if the results accurately represent what is in the moist-soil unit. If time prevents sampling as described above, it is always better to collect and archive data at 5 to 10 properly spaced plots than not to collect data at all.

Management implications. Sample results should be used to determine if moist-soil objectives are being met and to help determine which, if any, management actions are necessary. It is recommended that seed production be at least 400 pounds per acre and/or “good” and “fair” plants (APPENDIX 1) comprise at least 50 percent of the cover estimate for the unit. If these objectives are not being met, then some alternative management action needs to be implemented. For example, suppose seed production (or percent cover of good plants) has been declining in a unit from 900 pounds of seed per acre 2 years ago to only 350 pounds per acre this year. Or, the percent cover of “good” and “fair” plants has similarly dropped from 85 percent to 40 percent with an increasing amount of perennials dominating the site, it is likely that the timing of drawdown and some mechanical disturbance (e.g., disking) needs to be scheduled for the following growing season. If the unit is really poor (seed production had fallen to 75 pounds per acre and only 20 percent cover of “good” or “fair” plants), consideration should be given to immediate mechanical disturbance followed by planting a grain crop or re-flooding and late summer drawdown for shorebirds. Either action would increase management options and productivity the following year.

Supplemental Planting

Rice, milo, corn, and millet are high-energy foods and the top choices as grain crops for ducks. It is important to select varieties and planting methods that will encourage quick germination and successful competition with the native plants. Most grain crops will produce much more acceptable results if nitrogen is added. Extension agents and agricultural experiment stations are good sources of information for varieties of grains and fertilization rates that will produce the best results in your area.

Rice is susceptible to depredation, sprouting, and rots following wet, warm fall conditions but is particularly resistant to decomposition once flooded in winter. Cypress and Lamont are two rice varieties that germinate quickly. Soaking rice seed prior to planting will encourage rapid germination, and keeping the soil shallowly flooded (0.1 to 8 inches of water) or at least very moist will facilitate growth and survival. Failure to maintain these moisture conditions after germination and 4-6 inches of growth will result in poor rice production. With some flooding, the addition of about 60 pounds of nitrogen fertilizer per acre and minimal broadleaf weed control, refuge grown rice on Morgan Brake NWR produced an average of about 1,500 pounds of seed per acre in addition to a good crop of moist-soil plants including sprangletop, millet, spikerush, and toothcup. Food production far exceeded the 400-pound per acre target for moist-soil plants.

Milo and corn are more suited to dry fields and can generally be kept above the water surface after fall/winter flooding. Depredation can be a problem and seeds degrade rapidly once the kernels are flooded. Short varieties of milo (~2 ft in height) are recommended so water levels can be managed to facilitate waterfowl gleaning grain from standing milo stalks. Large dabbling ducks, such as mallard and northern pintail, can readily obtain seeds from standing milo plants. Midges can be a major problem with milo and should be controlled if possible. Corn with an understory of barnyard grass and various other grasses can provide quality waterfowl foraging habitat. This is a fairly common crop planted or left for waterfowl in Tennessee and Missouri and is gaining popularity on private lands in the Mississippi Delta.

Soybeans are generally considered a poor choice of waterfowl foods because they degrade rapidly after flooding and, like some other legumes, contain digestive inhibitors that reduce the availability of protein and other nutrients. Waterfowl will eat soybeans and derive about the same energy from beans as red oaks [R.M. Kaminski, J.B. Davis, H.W. Essig, P.D. Gerard, and R.J. Reinecke. 2003. True metabolizable energy for wood ducks from acorns compared to other waterfowl foods. Journal of Wildlife Management 67(3):542-550].

Millet is another commonly planted grain because it only takes about 60 days to mature, is adapted to perform well in conditions common in moist-soil units, and is highly desired by waterfowl. The short growing season make it a preferred crop following a mid-summer treatment (e.g., disking or drawdown) when it is unlikely that desirable moist-soil plants will dominate a site and mature. Browntop millet is recommended on slightly drier sites; Japanese millet is preferred on more moist sites. Barnyard grass is a wild millet present in most fields or impoundments and is commercially available (Azlin Seed, Leland, MS, 662.686.4507). This wild millet prefers moist to shallowly flooded conditions similar to rice or moist-soil plants discussed above. Improved varieties of barnyard grass are reportedly being developed.

If millets mature too early, they frequently shatter, germinate following early fall rains, and are virtually unavailable to wintering waterfowl. David Linden reports that on Yazoo NWR in central Mississippi a slow, mid-August drawdown will produce a wild millet crop with little competition from nuisance plants due to the shortened growing season. Once flooded, seeds of at least some species of millets deteriorate rapidly. The Natural Resources Conservation Service has reportedly developed Chiwapa millet. It is similar to Japanese millet but has a 120-day maturation period. Hence, it can be planted in mid-summer, and it will mature and not resprout as much as Japanese millet. A commercial source is Specialty Seed, Inc. (662.836.5740).

Flood Schedule

Migrating and wintering waterfowl are frequently found in the Southeast Region from August until May; however, September through early April is when key concentrations are most likely to occur. It is our responsibility to provide waterfowl habitat throughout that period and to match the amount of water and foraging habitat with the needs of waterfowl as dictated by migration chronology, local population levels, and physiological needs. It should also be kept in mind that the preferred water depth for foraging ranges from ½ to 12 inches. Food resources covered by more than 18 inches of water are out of the reach of dabbling ducks. These factors should be used to modify local flood schedules depending on the location of the moist-soil units.

In central Mississippi and much of the LMV, blue-winged teal begin arriving in August followed by several other early migrants. It is not until November or December when large numbers of ducks begin to accumulate, reaching peak numbers from mid-December through mid- to late January. Numbers remain high until early to mid-February when duck numbers steadily decrease until mid-March leaving relatively low numbers of late migrants. Blue-winged teal might linger until May.

Under this central Mississippi scenario (Table 3 and Figure 1), managers should flood about 5-10% of the impoundments by mid-August and hold until early November, increasing to 15-25% of the impoundments that should be flooded by late November. By mid-December, 50-75% of the impoundments should be flooded as waterfowl begin to accumulate in the area. Additional areas should continue to be flooded until mid- to late January when 100% of the area should be flooded. By mid-January, a slow drawdown should begin in those impoundments flooded earliest and/or scheduled for early drawdown to concentrate invertebrates for ducks that are beginning to increase lipid and protein reserves. The drawdown should continue such that only 80% of the impoundments are flooded by the end of January and only 20% are flooded in mid-March.

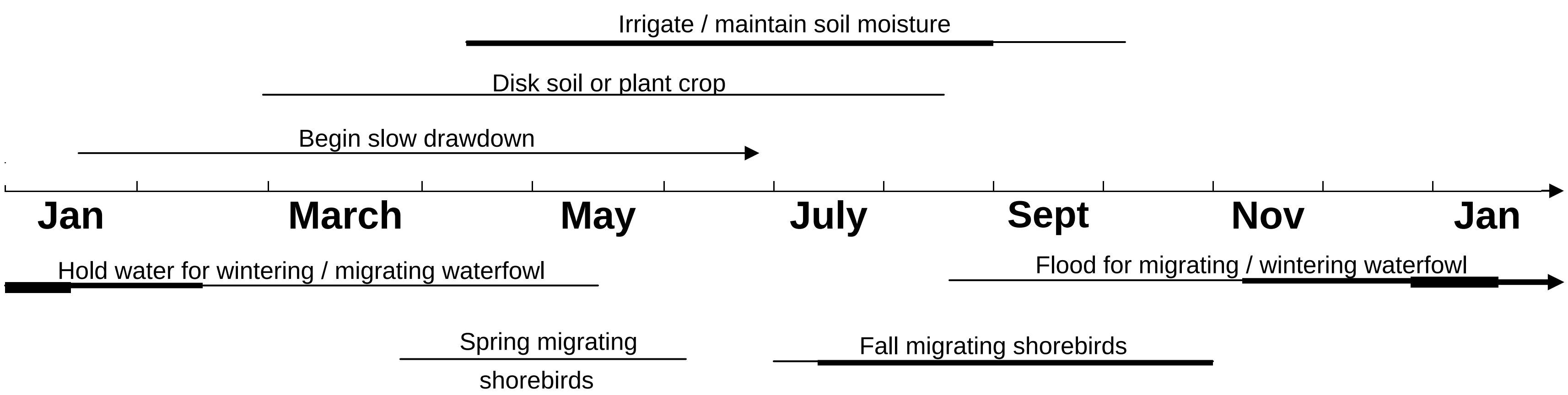
Typically, there is enough natural flood water available on and off of refuges for waterfowl after the hunting season and through the spring to meet those late migration needs so the emphasis from this point forward should be on managing water levels in moist-soil impoundments for seed production the following year. No more than 10% of the impoundments should be purposefully flooded for waterfowl after April 15 unless it is a management strategy (e.g., mid- to late season drawdown) to either improve seed production for the following year or integrate habitat conditions for other wetland-dependent birds (e.g., shorebirds, wading birds, and secretive marsh birds). It is imperative that managers be familiar with the topography in impoundments so that optimal water depths can be factored into the recommendations expressed in Table 3 as percent of area flooded. (Note: As stated previously, impoundments that cannot readily be re-flooded or irrigated may have a better plant response by keeping water-control structures closed in spring and summer to allow water to slowly evaporate through the growing season.)

Table 3. Suggested flood schedule to provide migrating and wintering waterfowl foraging habitat at the latitude of central Mississippi. The timing of water management may change depending on latitude, objectives, and target bird species.

Date	Area flooded (%) and comments
Mid-August until early November	5-10%; maintain flood
Early November - late November	15-25%; increase flood to support arriving ducks
Late November - mid-December	50-75%; increase flood to support arriving ducks
Mid-December - late January	80-100%; slow drawdown on some impoundments after January 15
Early February – mid-March	20-80%*; decrease flood to concentrate invertebrates
After mid-March	Water management should focus on food production for the following year and spring and fall shorebird migration.

* After early to mid-February, it may be more important to adjust flood schedules in preparation for moist-soil production in subsequent years. This management decision should be based on the availability of alternate, post hunting season habitat in the general vicinity and location relative to migration chronology. Refuges farther north in the flyway may want to delay late season management actions (e.g., drawdowns) until March or April.

Figure 1. Conceptual timeline for moist-soil management actions for the latitude of central Mississippi. The timing of water management changes depending on latitude, objectives, and target species.



Integrating Management for other Wetland-Dependent Birds

Sites with wetland complexes comprised of a number of impoundments having independent water management capabilities provide the manager the luxury of implementing strategies that accommodate a variety of vegetation, water regimes, and waterbird guilds in the same year. Often slight variations in management actions can provide significant benefits to other wetland-dependent birds. Shorebirds migrate through the Southeast Region in the spring from March through May and in the fall from July through October. During migration they are seeking mudflat to shallowly flooded (<4" deep) areas varying in size from small pools for foraging to larger sites providing a minimum of 40-100 acres of suitable habitat for foraging and roosting. Vegetation must be absent or very sparse. Matching drawdowns on moist-soil impoundments to coincide with migration can provide habitat for impressive numbers of shorebirds. Shorebird habitat is generally considered to be much more limiting during fall migration and, therefore, higher priority than spring habitat in the LMV.

Moist-soil management can produce abundant crops of crawfish and other invertebrates, herps, and can trap small fish following flood events. Slow drawdowns are typically best for moist-soil management and tend to concentrate food for wading birds for an extended period of time. Standing water under wading bird rookeries is critical to limiting predation and enhancing nest success. Draining impoundments while wading birds are actively nesting is strongly discouraged, regardless of other management needs.

Secretive marsh birds (e.g., rails, gallinules, etc.) seek permanently flooded marsh habitats that are typically dominated by tall emergent vegetation (e.g., rushes and cattail). These plant communities generally represent the next seral stage succeeding desired moist-soil habitat conditions (annual plants). Where space or management opportunities/limitations allow, consideration should be given to managing some units for tall emergent vegetation, which also provides preferred habitat for numerous species of amphibians and reptiles, and wood duck broods. Rails require areas within marsh habitats that naturally dry during the summer for brood foraging. The drying marsh often produces desirable moist-soil plants.

Records/Reporting

It is important that records for each impoundment be kept through the year and include management objective, management actions, natural events/conditions (e.g., rainfall), water level, plant responses, plant composition (% cover) and seed production (weight), and wildlife responses. At the end of the season a **brief** narrative should be written summarizing these variables, responses, and recommended management actions. Include alternatives that might improve management of each unit in the future. If possible, a photographic record should also be maintained. All of this information can be mainta ined in a digital format and included in annual habitat management plans. This could be the most valuable source of information a new manager/biologist will have to continue management of moist-soil units as personnel changes occur.

The LMVJV is in the process of developing a database link on their web site (LMVJV.org) for estimating seed production and calculating percent cover by wetland unit. The user will be able to also use that database for archiving management actions.

Conclusions

Moist-soil impoundments are a critical part of waterfowl management on refuges and have an established goal to produce at least 400 pounds of available seed per acre. Because moist-soil management is different in every location, it is not possible to produce a step-by-step listing of what the manager/biologist should do to maximize production on each moist-soil unit. However, it is critical that a plan be developed, plant and animal responses monitored, and records kept in a form usable by whoever is managing the unit, current staff as well as those that might be assuming those duties in the future. Intensive water management, regular soil disturbance, monitoring moist-soil plant responses and associated waterfowl use, controlling nuisance plants, and archiving of data are the keys to successful, consistent moist-soil seed production and waterfowl use of the impoundments. With a scientific approach and adaptive management, moist soil objectives can be consistently met or exceeded. In addition, knowledge and awareness of the habitat needs of other species often allows the moist-soil manager an opportunity to exercise management options that benefit other species groups while minimally affecting moist-soil seed production.

APPENDIX 1: A Waterfowl Food Value Guide for Common Moist-Soil Plants in the Southeast

A Waterfowl Food Value Guide for Common Moist-Soil Plants in the Southeast

Scientific Name	Common Name	Food Value
Acer spp.	maple[1]	Good (wood ducks)
Agrostis spp.	bent grasses	Fair
Alisma subcordatum	water plantain	Fair
Alopecurus carolinianus	foxtail	Fair
Alternanthera philoxeroides	alligatorweed	None
Amaranthus spp.	pigweed	Fair
Ambrosia artemisiifolia	common ragweed	Fair
Ammania latifolia	ammania	Fair
Ammannia coccinea	toothcup	Fair
Amorpha fruticosa	indigo bush	None
Andropogon virginicus	broomsedge	None
Apocynum cannabinum	indian hemp	
Arundiraria gigantea	cane, switch	None
Asclepiadacea currassavica	milkweed, scarlet	None
Asclepias spp.	milkweed	None
Aster spp.	aster, fall	None
Aster spp.	aster	None
Baccharis halimifolia	baccharis	None
Bacopa spp.	water hyssop, bacopa	Good
Bidens cernua	beggar ticks	Good
Bidens laevis	bur marigold	Good
Bidens spp.	beggar ticks	Good
Brasenia shreberii	watershield	Fair
Brunnichia cirrhosa	redvine	None
Calamagrostis cinnoides	reed grass	Good
Campsis radicans	trumpet creeper	None
Cardiospermum halicacabum	balloon-vine	None
Carex spp.	sedge	Good
Centella asiatica	centella	Fair
Cephalanthus occidentalis	buttonbush[1,3]	Fair
Ceratophyllum demersum	coontail	Fair
Chara spp.	muskgrass	Good
Chenopodium album	goosefoot	Good
Clethora alnifolia	sweet pepperbush	Fair
Cyperus erythrorhizos	flatsedge, redroot	Good
Cyperus esculentus	sedge, yellow nut	Good
Cyperus iria	rice flatsedge	Good
Cyperus spp.	flatsedge[3]	Good

Scientific Name	Common Name	Food Value
Decodon verticillatus	water loosestrife	None
Digitaria spp.	crabgrass	Good
Diodia virginiana	buttonweed	Fair
Distichlis spicata	saltgrass	Fair
Echinochloa colonum	jungle rice	Good
Echinochloa crusgalli	barnyardgrass	Good
Echinochloa spp.	millet	Good
Echinochloa walteri	millet, walter's	Good
Echinodorus cordifolius	burhead	None
Eclipta alba	eclipta	None
Elatine spp.	waterwort	Fair
Eleocharis obtusa	spikerush, blunt	Good
Eleocharis palustris	spikerush,common	Fair
Eleocharis parvula	spikerush, dwarf	Good
Eleocharis quadrangulata	foursquare	Good
Eleocharis spp.	spikerush	Good
Eleocharis tenuis	spikerush, slender	Fair
Elodea spp.	waterweed	Fair
Eragrostis spp.	love grass	Good
Erianthus giganteus	beardgrass, wooly	None
Erianthus giganteus	grass, plume	None
Erigeron belliadastrum	fleabane daisy	
Erigeron spp.	horseweed	None
Eupatorium capillifolium	dog fennel	None
Eupatorium serotinum	boneset	None
Fimbristylis spadicea	fimbristylis	Fair
Fraxinus spp.	ash[1]	Fair
Fuirena squarrosa	umbrella-grass	Fair
Gerardia spp.	gerardia	None
Helenium spp.	sneezeweed	None
Heteranthera limosa	mudplantain	None
Hibiscus moscheutos	marsh mallow	None
Hibiscus spp.	rose mallow	None
Hydrochloa spp.	watergrass	Fair
Hydrocotyle umbellata	pennywort, marsh	Fair
Hydrolea ovata	hydrolea	None
Hypericum spp.	st. johns wort	None
Ipomoea purpurea	morning glory	None
Ipomoea spp.	morning glory	None
Iva annua	sumpweed	None
Iva frutescens	marsh elder	None
Juncus effusus	rush, soft	None

Scientific Name	Common Name	Food Value
Juncus repens	rush, creeping	Fair
Juncus roemerianus	needlerush, black	None
Juncus spp.	rushes	Fair
Lachnanthes caroliniana	redroot	Good
Leersia oryzoides	rice cutgrass	Good
Lemna spp.	duckweed	Good
Leptochloa filiformis	sprangletop	Good
Leptochloa spp.	sprangletop	Good
Lippia lanceolata	frog fruit	None
Ludwigia spp.	seedbox	Fair
Ludwigia spp.	water primrose[2]	Fair
Lysimachia terrestris	loosestrife, swamp	None
Lythrum salicaria	loosestrife, purple[2]	PEST
Melilotus alba	white sweet clover	None
Mikania scandens	hempweed, climbing	None
Myriophyllum spp.	milfoil, water	Fair
Najas guadalupensis	naiad, southern	Good
Najas spp.	naiads	Good
Nelumbo lutea	american lotus	None
Nitella spp.	nitella	Fair
Nuphar luteum	yellow cow-lily	Fair
Nymphaea mexicana	banana water lily	Good
Nymphaea odorata (or tuberosa)	white waterlily	Fair
Obolaria virginica	pennywort	Fair
Oryza sativa	red rice	Good
Panicum dichotomiflorum	fall panicum	Good
Panicum spp.	grasses, panic	Fair to Good
Paspalum disticum	knotgrass	Fair
Paspalum spp.	paspalum	Fair
Paspalum urvillei	vasey grass	None
Peltandra virginica	arrow arum	Fair
Phalaris arundinacea	reed canary grass	
Phragmites communis	common reed	PEST
Plantago lanceolata	english plantain	None
Pluchea camphorata	camphorweed	None
Pluchea pupurascens	fleabane, saltmarsh	None
Polygonum coccineum	water smartweed	Fair
Polygonum hydropiperoides	water pepper	Fair
Polygonum hydropiper	water pepper	Fair
Polygonum lapathifolium	ladysthumb smartweed	Good
Polygonum pensylvanicum	penns. smartweed	Good
Polygonum spp.	smartweed	Fair/Good

Scientific Name	Common Name	Food Value
Polypogon monspeliensis	rabbits-foot grass	Fair
Pontederia cordata	pickerelweed	Fair
Populus spp.	cottonwood	None
Potamogeton pectinatus	pondweed, sago	Good
Potamogeton perfoliatus	redhead grass	Good
Potamogeton spp.	pondweed	Good
Proserpinaca palustris	mermaidweed	Fair
Quercus spp.	oak[1]	None
Ranunculus spp.	buttercup	Fair
Rhynchospora spp.	rush, beaked	Fair
Rotala ramosior	rotala	Fair
Rubus spp.	blackberry	None
Rumex spp.	dock, swamp	Fair
Ruppia maritima	widgeon grass	Good
Sabatia stellaris	marsh pink	None
Sacciolepis striata	gibbons panicgrass	Good
Sagittaria graminea	grassy arrowhead	Good
Sagittaria lancifolia	bulltongue	Fair
Sagittaria latifolia	arrowhead, duck potato	Fair/Good
Sagittaria longiloba	narrow leaf arrowhead	None
Sagittaria montevidensis	giant arrowhead	Good
Sagittaria platyphylla	delta duck potato	Good
Sagittaria spp.	arrowhead	Fair
Salicornia spp.	glasswort	Fair
Salix spp.	willow[1]	None
Saururus cernuus	lizard's tail	None
Scirpus americanus	bulrush, american (olneyi-three	Good
Scirpus confervoides	bulrush, algal	Fair
Scirpus cyperinus	woolgrass	None
Scirpus pungens	sword-grass	Fair
Scirpus robustus	bulrush, saltmarsh	Good
Scirpus spp.	bulrush	Fair
Scirpus spp.	bulrush, slender	None
Scirpus validus	bulrush, softstem[4]	Fair
Sesbania exaltata	sesbania[2]	Fair
Sesbania macrocarpa	sesbania[2]	None
Sesbania spp.	sesbania	None
Setaria spp.	foxtail	Good
Sida spinosa	prickly mallow (ironweed)	None
Solanum spp.	nightshade	None
Solidago spp.	goldenrod	None
Sonchus spp.	sowthistle	

Scientific Name	Common Name	Food Value
Sorghum halepense	johnson grass	
Sorghum vulgare	milo	Good
Sparganium spp.	burreed	Fair
Spartina cynosuroides	big cordgrass	None
Spartina patens	grass, cord (saltmeadow hay)	Fair
Sphenoclea zeylanica	goose weed	None
Spirodella spp.	duckweed, great	Good
Sporobolus spp.	dropseed	Fair
Triglochin striata	arrowgrass	Good
Tripsacum dactyloides	grass, gamma	None
Typha angustifolia	narrow-leaf cattail	None
Typha spp.	cattail	None
Utricularia spp.	bladderwort[5]	Fair
Vallisneria americana	wild celery	Good
Wolffia spp.	water meal	Good
Woodwardia aredata	fern, netted chain	None
Xanthium spp.	cocklebur[2]	None
Xanthium strumarium	cocklebur[2]	None
Xyris spp.	yellow-eyed grass	Fair
Zizania aquatica	southern giant rice	Fair
Zizania aquatica	wild rice, northern	Good
Zizaniopsis miliacea	wild rice, southern, giant cut-	Good

1. Woody plants typically undesirable in moist-soil units.
2. Can be undesirable.
3. When in abundant stands.
4. Tubers only.
5. With invertebrates present.

This guide was originally prepared by the Biologists' Group of the Roanoke-Tar-Neuse-Cape Fear Ecosystem of the U.S. Fish and Wildlife Service in September 2000. It was developed to assist them in standardizing waterfowl food values rankings for freshwater marsh/swamp vegetation. The original area the guide covered is northeastern North Carolina and southeastern Virginia. Several of the National Wildlife Refuges in this area complete annual vegetation transects in moist-soil impoundments and summarize these data to monitor vegetation response to various management actions. The ranking classifications were chosen arbitrarily as None, Fair, and Good. In an attempt to broaden the scope of the RTNCF Ecosystem efforts to the entire southeast, particularly the MAV, the Jackson Migratory Bird Field Office, with comments from biologists from the MAV, added numerous species and rankings to their list. Various published plants guides were consulted and professional judgment was used to assign the rankings. **This guide is considered a**

working guide and as new information becomes available, will be updated and redistributed. Please send comments and additions to Bob Strader, Migratory Bird Field Office, Jackson, MS 39213, 601-965-4903 x12 or e-mail: bob_strader@fws.gov.

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APPENDIX 2: A Technique for Estimating Seed Production of Common Moist-Soil Plants

13.4.5. A Technique for Estimating Seed Production of Common Moist-soil Plants

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Seeds of native herbaceous vegetation adapted to germination in hydric soils (i.e., moist-soil plants) provide waterfowl with nutritional resources including essential amino acids, vitamins, and minerals that occur only in small amounts or are absent in other foods. These elements are essential for waterfowl to successfully complete aspects of the annual cycle such as molt and reproduction. Moist-soil vegetation also has the advantages of consistent production of foods across years with varying water availability, low management costs, high tolerance to diverse environmental conditions, and low deterioration rates of seeds after flooding.

The amount of seed produced differs among plant species and varies annually depending on environmental conditions and management practices. Further, many moist-soil impoundments contain diverse vegetation, and seed production by a particular plant species usually is not uniform across an entire unit. Consequently, estimating total seed production within an impoundment is extremely difficult.

The chemical composition of seeds also varies among plant species. For example, beggartick seeds contain high amounts of protein but only an intermediate amount of minerals. In contrast, barnyardgrass is a good source of minerals but is low in protein. Because of these differences, it is necessary to know the amount of seed produced by each plant species if the nutritional resources provided in an impoundment are to be estimated.

The following technique for estimating seed production takes into account the variation resulting from different environmental conditions and management practices as well as differences in the amount of seed produced by various plant species. The technique was developed to provide resource managers with the ability to make quick and reliable estimates of seed production. Although on-site information must be collected, the amount of field time required is small (i.e., about 1 min per sample); sampling normally is accomplished on an area within a few days. Estimates of seed production derived with this technique are used, in combination with other available information, to determine the potential number of waterfowl use-days available and to evaluate the effects of various management strategies on a particular site.

Technique for Estimating Seed Production

To estimate seed production reliably, the method must account for variation in the average amount of seed produced by different moist-soil species. For example, the amount of seed produced by a single barnyardgrass plant outweighs the seed produced by an average panic grass plant. Such differences prevent the use of a generic method to determine seed production because many species normally occur in a sampling unit.

My technique consists of a series of regression equations designed specifically for single plant species or groups of two plant species closely related with regard to seed head structure and plant height (Table 1). Each equation was developed from data collected on wetland areas in the Upper Mississippi alluvial and Rio Grande valleys. The regression equations should be applicable throughout the range of each species because the physical growth form of each species (i.e., seed head geometry) remains constant. As a result, differences in seed production occur because of changes in plant density, seed head size, and plant height, but not because of the general shape of the seed head. This argument is supported by the fact that the weight of seed samples collected in the Rio Grande and Upper Mississippi valleys could be estimated with the same equation.

Estimating seed production requires collecting the appropriate information for each plant species and applying the correct equations. The equations provide estimates in units of grams per 0.0625 m^2; however, estimates can readily be converted to pounds per acre by using a conversion factor of 142.74 (i.e., grams per 0.0625-$m^2 \times 142.74$ = pounds per acre). Computer software developed for this technique also converts grams per square meter to pounds per acre.

Collection of Field Data

Measurements Required

Plant species
Seed heads (number)
Average seed head height (cm)
Average seed head diameter (cm)
Average plant height (m)

Equipment Required

Meter stick
Square sampling frame (Fig. 1)
Clipboard with paper and pencil (or field computer)

Method of Sampling

1. Place sampling frame in position. Include only those plants that are rooted within the sampling frame.

Table 1. *Regression equations for estimating seed production of eleven common moist-soil plants.*

Measurement[a] group	Plant species	Regression equation[bc] (weight in grams per 0.0625 m^2)	Coefficient of determination (R^2)
Grass			
	Barnyardgrass[d]	(HT × 3.67855) + (0.000696 × VOL)[e]	0.89
	Crabgrass	(0.02798 × HEADS)	0.88
	Foxtail[f]	(0.03289 × VOL)[g]	0.93
	Fall panicum	(0.36369 × HT) + (0.01107 × HEADS)	0.93
	Rice cutgrass	(0.2814 × HEADS)	0.92
	Sprangletop	(1.4432 × HT) + (0.00027 × VOL)[e]	0.92
Sedge			
	Annual sedge	(2.00187 × HT) + (0.01456 × HEADS)	0.79
	Chufa	(0.00208 × VOL)[h]	0.86
	Redroot flatsedge	(3.08247 × HEADS) + (2.38866 × HD) – (3.40976 × HL)	0.89
Smartweed			
	Ladysthumb/water smartweed	(0.10673 × HEADS)	0.96
	Water pepper	(0.484328 × HT) + (0.0033 × VOL)[g]	0.96

[a] Refer to Fig. 3 for directions on measuring seed heads.
[b] HT = plant height (m); HEADS = number of seed heads in sample frame; HL = height of representative seed head (cm); HD = diameter of representative seed head (cm); VOL = volume (cm^3).
[c] Conversion factor to pounds per acre is: grams per 0.0625 $m^2 \times 142.74$.
[d] *Echinochloa crusgalli* and *E. muricata*.
[e] VOL (based on geometry of cone) calculated as: (HEADS) × ($\pi r^2 h/3$); $\pi = 3.1416$, r = HD/2, h = HL.
[f] *Setaria* spp.
[g] VOL (based on geometry of cylinder) calculated as: (HEADS) × ($\pi r^2 h$); $\pi = 3.1416$, r = HD/2, h = HL.
[h] VOL (based on geometry of half sphere) calculated as: (HEADS) × ($1.33\pi r^3/2$); $\pi = 3.1416$, r = HD/2.

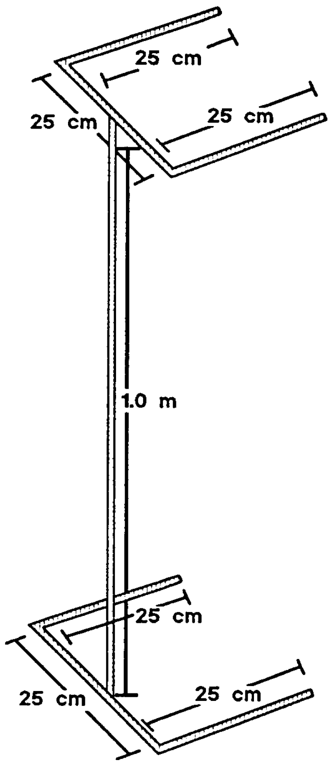

Fig. 1. Sampling frame design.

2. Record plant species present within sample frame on data form (Fig. 2).
3. For each plant species, record the number of seed heads within the sample frame. All seed heads occurring within an imaginary column formed by the sample frame should be counted.
4. For each plant species, select a single representative plant and measure
   a. the straightened height of the entire plant (from the ground to the top of the tallest plant structure) in meters,
   b. the number of seed heads within the sample frame,
   c. the height of the seed head in centimeters (measure along the rachis [i.e., main stem of flower] from the lowest rachilla [i.e., secondary stem of flower] to the top of the straightened seed head [Fig. 3].), and
   d. the diameter (a horizontal plane) of the seed head in centimeters (measure along the lowest seed-producing rachilla [Fig 3].).

Although average values calculated by measuring every plant within the sample frame would be more accurate, the time required to collect a sample would increase greatly. In contrast, obtaining measurements from a single representative plant allows a larger number of samples to be collected per unit time. This method also permits sampling across a greater portion of the unit, which provides results that are more representative of seed production in an entire unit.

Suggested Sampling Schemes

There are two basic approaches to estimating seed production within an impoundment. Both methods should supply similar results in most instances. The choice of method will depend largely on physical attributes of the impoundment and management strategies that determine the diversity and distribution of vegetation.

First approach: Sample across entire unit. The most direct procedure of estimating seed production is to collect samples across an entire unit using the centric systematic area sample design (Fig. 4). This method is recommended when vegetation types are distributed randomly across the entire impoundment (e.g., rice cutgrass and smartweed occur together across the entire

Plot Number	Plant species	Height (m)	Seed heads (no.)	Seed head height (cm)	Seed head diameter (cm)
1					
2					
3					
4					
5					
6					

Fig. 2. Sample data form for collecting information necessary to estimate seed production.

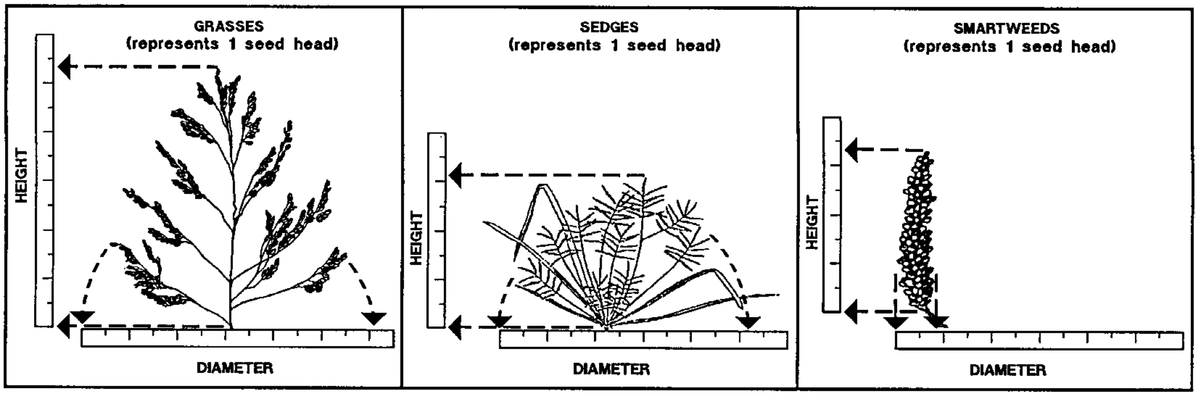

Fig. 3. Method of measuring dimensions of three seed head types.

impoundment; Fig. 5a). Divide an entire unit into blocks of equal dimension and establish a 0.0625-m^2 sample frame at the center of each block. In the field, this is accomplished by walking down the center of a row of such blocks and sampling at the measured interval. The precise number of samples necessary to provide a reliable estimate depends on the uniformity of each plant species within the impoundment and the desired accuracy of the estimate. The dimensions of the blocks are adjustable, but collect a minimum of one sample for every 2 acres of habitat. For example, a block size of 2 acres (i.e., 295 feet per side) results in 25 samples collected in a 50-acre moist-soil unit.

At each sampling station, measure and record each plant species of interest and the associated variables (i.e., plant height, number of seed heads, seed head height, and seed head diameter)

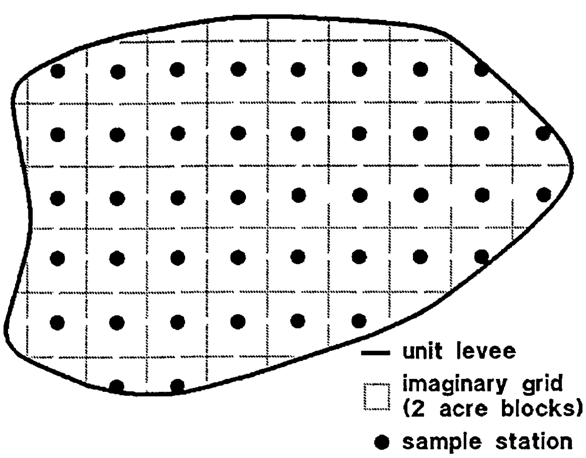

Fig. 4. Centric area sample method (unit = 84 acres)

necessary for estimating seed production of that species. If the same plant species occurs at two distinct heights (e.g., 0.4 m and 1.2 m), determine a seed estimate for plants at each height. If a plant species for which an estimate is desired does not occur within the sample frame, the plant species should still be recorded and variables assigned a value of zero. For example, if barnyardgrass seed production is to be estimated and the sample frame is randomly placed in an area where no barnyardgrass occurs, record a zero for plant height, number of seed heads, seed head height, and seed head diameter. This represents a valid sample and must be included in calculating the average seed production of barnyardgrass in the unit.

Collect samples across the entire unit to ensure that a reliable estimate is calculated. Exercise care to sample only those areas that are capable of producing moist-soil vegetation. Borrow areas or areas of high elevation that do not produce moist-soil vegetation should not be sampled.

Estimate the weight of seed produced by each plant species in a sample with the appropriate regression equation (Table 1), or with the software developed for this purpose. Determine the average seed produced by each species in an impoundment by calculating the mean seed weight of all samples collected (if the species is absent from a sample, a zero is recorded and used in the computation of the mean) and multiplying the mean seed weight (grams per 0.0625m^2) by the total area of the unit. Determine total seed production by summing the average seed produced by each plant species sampled. Following collection of at least five samples, the accuracy of the estimate also can be

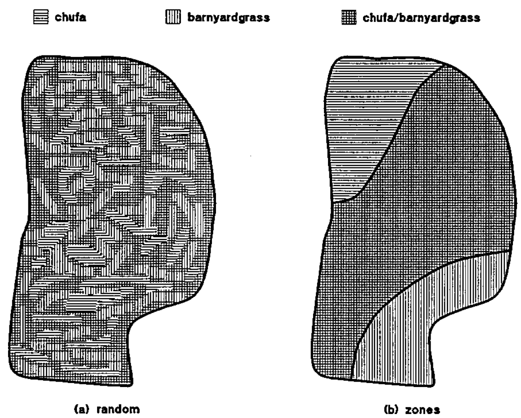

Fig. 5. Two general types of vegetation distribution.

determined. If higher accuracy is desired, collect additional samples by reducing the block size the appropriate amount or by randomly collecting additional samples.

Second approach: Sample within vegetation zones of a unit. This method is recommended for use in impoundments when species or groups of plants occur in distinct and nonoverlapping zones within a unit (e.g., smartweeds only occur at low elevations and barnyardgrass only occurs at higher elevations within the same unit; Fig. 5b). The same general methodology previously outlined for sampling an entire unit applies to this sampling scheme, except that

1. the centric area sampling method is applied separately to each vegetation zone within an impoundment,
2. seed production of an individual plant species over the entire unit is determined by multiplying the average seed production (based only on the samples collected within that zone) by the acreage of the zone sampled,
3. total seed production within a zone is calculated by summing the seed production estimates of each plant species occurring within that zone, and
4. total seed production across the entire impoundment is calculated by summing the seed production estimates of all zones composing the unit. If this sampling scheme is used, a cover map delineating vegetation zones is useful for calculating the acreage of zones sampled.

When to Collect Field Data

Samples must be collected when vegetation has matured and seed heads are fully formed because the regression equation for each plant species is based on seed head dimensions and plant height. Timing of sampling varies across latitudes because of differences in growing season length and maturation times of plant species. Information can be collected before the after-ripening of seeds (i.e., seed heads completely formed but seeds not mature) because seed head dimensions will not change appreciably. Information also can be collected following seed drop because seed head dimensions can be determined based on the geometry of the remaining flower parts (i.e., rachis and rachilla). This allows a greater time span for collecting information. If timed correctly, estimates for most moist-soil plants can be determined during the same sampling period.

Under certain conditions, two crops of moist-soil seeds can be produced within the same unit in a single year. Often, the second crop will be composed of plant species different from those composing the first crop. If this occurs, estimating total seed production requires sampling both first- and second-crop vegetation, even if the species composition of the second seed crop is similar to the first crop. Estimates based on the first crop cannot be applied to the second crop because seed head dimensions will be different.

Determining Required Sample Size

The number of samples necessary to estimate seed production will depend on the level of accuracy desired. Although as few as three samples will provide a mean value of seed production and an estimate of the variability within the unit, this type of estimate normally is unreliable. The most important factors influencing accuracy include the degree of uniformity in plant distribution and the species of plant sampled.

Plant distribution affects accuracy if the density of a plant species varies widely within the area sampled. Potential factors influencing changes in plant density include differential hydrology, use of spot mechanical treatments, and changes in soil type. Often, these factors can be controlled by selecting the appropriate sampling scheme. In addition, seed production by perennials that propagate by tubers tends to be more variable and, therefore, a larger number of samples may be required.

Following collection of at least five samples in a unit, the standard deviation (SD) can be calculated with the equation SD = $(s^2)^{1/2}$. The sample variance (s^2) is estimated with the formula $s^2 = (\sum_{i=1}^{n} x_i - \bar{x})^2 / n-1$, where x_i = seed estimate of sample i, $\bar{x}$ = average seed weight of all samples, and n = number of samples collected. The standard deviation indicates the degree of variation in seed weight and is, therefore, a measure of precision (see example)—the larger the SD, the lower the precision of the estimate.

The number of samples necessary to achieve a specified level of precision (95% confidence interval) can be calculated with the formula $n = 4s^2/L^2$, where s^2 = sample variance and L = allowable error (± pounds per acre). The sample variance (s^2) can be estimated from previous experience or calculated based on preliminary sampling. Because seed production varies among plant species and units, sample variance should be determined independently for individual plant species and units. Numerous environmental factors influence seed production on a particular site. Therefore, sample variance should be calculated annually for each site. A subjective decision must be made concerning how large an error (L) can be tolerated. This decision should be based on how the seed production estimate is to be used. For example, an L of ± 100 pounds per acre would be acceptable for determining the number of waterfowl use-days available. In other cases, a larger error might be acceptable. As the allowable error increases, the number of samples required decreases.

Estimating Seed Production

Although the technique is simple to use, several important factors must be considered to obtain accurate estimates of seed weight. The following example illustrates the process of making these decisions. In addition, the process of computing estimates using the regression equations demonstrates the correct manner of using field data to arrive at valid estimates.

1. *Unit considerations*—unit size is 10 acres. Vegetation consists of barnyardgrass distributed uniformly across the entire unit.
2. *Sampling strategy*—use a centric area sampling method with a maximum recommended block size of 2 acres to establish the location of five sample areas uniformly across the unit.
3. *Data collection*—at each plot, select a representative barnyardgrass plant within the sample frame and record the necessary information (Table 2).
4. *Estimate seed production*—for each sample, use the appropriate equation to determine the estimated seed weight. In this example, only the barnyardgrass equation is required (Table 3).
5. *Maximum allowable error*—in this example, an L of ± 100 pounds per acre is used for barnyardgrass. The standard deviation is then calculated to determine the precision of the estimate. If the standard deviation is less than the allowable error, no additional samples must be collected. However, if the standard deviation is greater than the allowable error, the estimated number of additional samples that must be collected is calculated.

- Allowable error = L = ± 100 pounds per acre
- Number of samples collected = n = 5
- Weight of individual samples (pounds per acre) = x_i = 982; 1,119; 871; 1,124; 1,237
- Average weight of samples (pounds per acre) = $\bar{x}$

  = 982 + 1,119 + 871 + 1,124 + 1,237 / 5
  = 5,333 / 5
  = 1,066.6 or 1,067
- Variance = $s^2 = \Sigma(x_i - \bar{x})^2/n-1$

  $= (982 - 1{,}067)^2 + (1{,}119 - 1{,}067)^2 + (871 - 1{,}067)^2$
  $+ (1{,}124 - 1{,}067)^2 + (1{,}237 - 1{,}067)^2 / 5 - 1$
  $= (-85)^2 + (52)^2 + (-196)^2 + (57)^2 + (170)^2 / 4$
  = 7,225 + 2,704 + 38,416 + 3,249 + 28,900 / 4
  = 80,494 / 4
  = 20,123.5 or 20,124 pounds per acre
- Standard deviation = $s = (s^2)^{1/2}$

  $= 20{,}124^{1/2}$
  = 141.8 or 142 pounds per acre

Based on these computations, an estimated average weight of 1,067 ± 142 pounds per acre (i.e., 925–1,209 pounds per acre) of barnyardgrass seed was produced. However, the standard deviation (142 pounds per acre) is greater than the allowable error (100 pounds per acre), indicating that additional samples must be collected to obtain an average seed weight value that is within the acceptable limits of error.

Table 2. *Sample data sheet for estimating seed production.*

Plot	Plant species	Height (m)	Seed heads (number)	Seed head height (cm)	Seed head diameter (cm)
			Initial samples		
1	Barnyardgrass	1.1	12	16	9
2	Barnyardgrass	1.1	13	16	10
3	Barnyardgrass	1.1	11	16	8
4	Barnyardgrass	1.1	14	15	10
5	Barnyardgrass	1.2	9	18	12
			Additional samples		
6	Barnyardgrass	1.1	12	16	10
7	Barnyardgrass	0.9	15	17	9
8	Barnyardgrass	0.9	14	17	10

Table 3. *Estimating seed weight of individual samples.*

Plant species	Regression equation[a]	Plot	Estimated weight (grams per 0.0625-m^2)	Estimated weight (pounds per acre)
		Initial samples		
Barnyardgrass	(HT × 3.67855)	1	6.88[b]	982 [c]
	+ (0.000696 × VOL)	2	7.84	1,119
		3	6.10	871
		4	7.88	1,124
		5	8.67	1,237
		Additional samples		
		6	7.55	1,077
		7	7.08	1,010
		8	7.65	1,092

[a] HT = plant height (m); HEADS = number of seed heads in sample frame; HL = height of representative seed head (cm); HD = diameter of representative seed head (cm); VOL = volume (based on geometry of cone) calculated as: (HEADS) × (πr^2h/3); π = 3.1416, r = HD/2, h = HL.
[b] Weight (grams per 0.0625-m^2) = (HT × 3.67855) + (0.000696 × VOL) = (1.1 × 3.67855) + (0.000696 × 4081.6) = 4.0464 + 2.8408 = 6.88 VOL = (HEADS) × (πr^2h/3); π = 3.1416, r = 9/2 = 4.5, r^2 = 20.3, h = 16 = (12) × (3.1416 × 20.3 × 16/3) = (12) × (340.131) = 4081.6
[c] Conversion from grams per 0.0625-m^2 to pounds per acre: 6.88 × 142.74 = 982.

Total number of samples required = $4s^2/L^2$
= (4 × 20,124) / (100)^2
= 80,496 / 10,000
= 8
Additional samples required = total samples required – samples collected
= 8 – 5
= 3

Based on these calculations, three additional samples must be collected.

6. *Additional samples*—collect additional samples at random locations (Tables 3 and 4). Following collection of data, the average seed weight and standard deviation of samples must be recalculated using the equations in Step 5. If the accompanying software is used, these calculations are performed automatically. In this example, the revised estimate of average seed weight ($\bar{x}$) is 1,064 pounds per acre, and the standard deviation (s) is 110 pounds per acre.
7. *Estimating total seed production*—after collecting a sufficient number of samples of each species to obtain an average seed estimate with a standard deviation less than the maximum allowable error, estimate total seed production. An estimate of seed produced by each species is determined by computing the average seed weight of that species in all samples collected and multiplying this value by the area sampled. Total seed production is estimated by summing seed produced by each species. In this example only barnyardgrass was sampled. Therefore, total seed produced is equivalent to barnyardgrass seed produced.

Barnyardgrass seed produced = average seed weight × area sampled
= 1,064 (± 110) pounds per acre × 10 acres
= 10,640 ± 1,100 pounds in unit.

Computer Software

Computer software is available for performing the mathematical computations necessary to estimate seed weight. The program is written in Turbo Pascal and can be operated on computers with a minimum of 256K memory. The program computes the estimated seed weight of individual plant species collected at each sample location and displays this information following entry of each sample. In addition, a summary screen displays estimates of average and total seed produced in an impoundment as well as the standard deviation of the estimate. This information is automatically stored in a file that can be printed or saved on a disk. A copy of the program is available upon request. Instructions pertaining to the use of the program are obtained by accessing the README file on the program diskette.

Suggested Reading

Fredrickson, L. H., and T. S. Taylor. 1982. Management of seasonally flooded impoundments for wildlife. U.S. Fish and Wildlife Service Resource Publication 148, Washington, D.C. 29 pp.

Reinecke, K. J., R. M. Kaminski, D. J. Moorehead, J. D. Hodges, and J. R. Nassar. 1989. Mississippi alluvial valley. Pages 203–247 *in* L. M. Smith, R. L. Pederson, and R. M. Kaminski, editors. Habitat management for migrating and wintering waterfowl in North America. Texas Tech University Press, Lubbock.

Appendix. Common and Scientific Names of Plants Named in Text.

Annual sedge	*Cyperus iria*
Barnyardgrass	*Echinochloa crusgalli*
Barnyardgrass	*Echinochloa muricata*
Beggarticks	*Bidens* spp.
Chufa	*Cyperus esculentus*
Crabgrass	*Digitaria* spp.
Fall panicum	*Panicum dichotomiflorum*
Foxtail	*Setaria* spp.
Ladysthumb smartweed	*Polygonum lapathifolium*
Redroot flatsedge	*Cyperus erythrorhizos*
Rice cutgrass	*Leersia oryzoides*
Sprangletop	*Leptochloa filiformis*
Water pepper	*Polygonum hydropiper*
Water smartweed	*Polygonum coccineum*

Note: Use of trade names does not imply U.S. Government endorsement of commercial products.

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FISH AND WILDLIFE SERVICE
***Fish and Wildlife Leaflet* 13**
Washington, D.C. • 1992

APPENDIX 3: Herbicides and Application Uses on Moist-Soil Units in the Southeast

Some herbicides and application uses on moist-soil units in the Southeast Region.

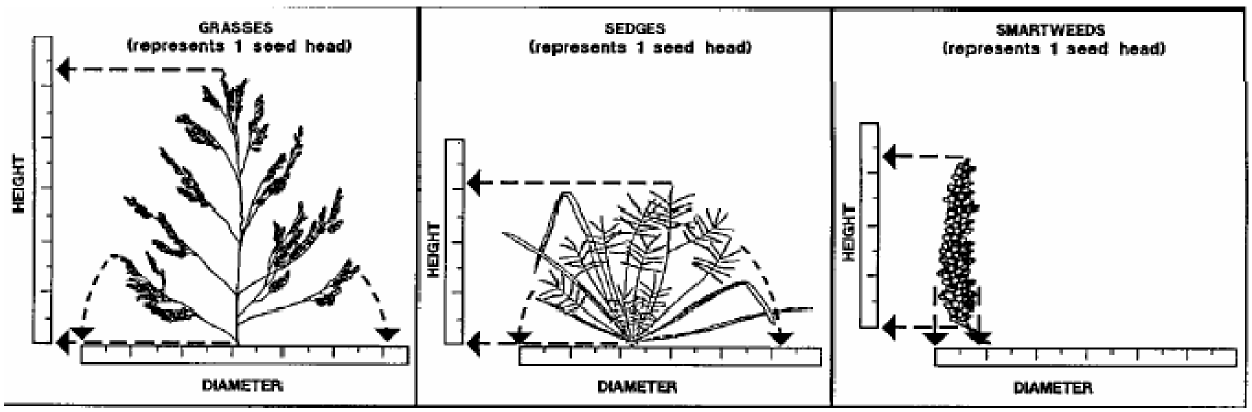
Trade name	**Common name**	**Aquatic label**	**Application uses**
Round-up, several others	glysophosate	No	Highly effective, broad spectrum herbicide.
Rodeo, several others	glysophosate	Yes	Highly effective, broad spectrum herbicide approved for aquatic applications.
Various	2,4-D	Yes	Highly effective, inexpensive broadleaf herbicide (includes sedges) used to release grasses. Effective on hard to control weeds like alligatorweed. Extreme caution is recommended for use in cotton growing areas, check for applicable restrictions
Aim	Carfentrazone	Yes	Broadleaf herbicide used in rice culture when weeds are small. Can be used a lowest recommended rates to treat coffeebean. Will also eliminate desirable broadleaves such as pigweed.
Blazer, others	Acifluorfen	No	Broadleaf herbicide, particularly effective on coffeebean.
Basagran	Bentazon	No	Broadleaf herbicide, particularly effective on cocklebur.
Banvil, others	Dicamba	No	Broadleaf herbicide for controlling small broadleaf weeds, including morning glory, smartweed, redvine (a.k.a., ladies-eardrop), etc.
Habitat	Imazapyr	Yes	Highly effective broad spectrum herbicide, including emergent, floating, or spreading aquatics (maidencane), and woody vegetation (willows and Chinese tallow). Not approved for use on crops or irrigation water.

Notes: 1.) Except AIM, all of the above-listed herbicides are on the refuge manager's approval list.
2.) Refuge managers must require all applicators to abide by all label guidelines and/or restrictions
3.) In selecting an herbicide, applicators must be familiar with the potential desired and undesired affects.
4.) Much of the information presented here and a good source for additional information is the LSU Extension Service's Weed Control Guide for 2005 (www.lsuagcenter.com/Subjects/guides/weedguide/01weeds.htm). Another good source of information can be found at the Greenbook web site (www.greenbook.net).

APPENDIX 4: Seed Production Estimator "Cheat" Sheet and Sample Data Form

Seed Production Cheat Sheet

1. Place sampling frame in position.
2. Record species present that are also on the list below.
3. For each species, record the number of seed heads in the frame.
4. For each species, select **ONE** representative plant and measure:
    a. Straightened height of the entire plant (from ground to tip) in meters
    b. Height of seed head in cm.
    c. Diameter of seed head in cm.



Seed estimates can only be performed on the following species:

Barnyardgrass[a] . . . . *Echinochloa crusgalli*
Barnyardgrass[a] . . . . *Echinochloa muricata*
Crabgrass . . . . *Digitaria* spp.
Foxtail . . . .*Setaria* spp.
Fall panicum . . . . *Panicum dichotomiflorum*
Rice cutgrass . . . .*Leersia oryzoides*
Sprangletop . . . .*Leptochloa filiformis*
Annual sedge . . . .*Cyperus iria*
Chufa . . . . *Cyperus esculentus*
Redroot flatsedge . . . . *Cyperus erythrorhizos*
Ladysthumb smartweed[b] . . . . *Polygonum lapathifolium*
Water pepper[b] . . . .*Polygonum hydropiper*
Water smartweed . . . . *Polygonum coccineum*

[a] Considered as one for the estimate.
[b] Considered as one for the estimate. We also lumped Pennsylvania smartweed, *P. pennsylvanicum* with these.

Moist-Soil Plants (m^2)/Seed Production (1/4 m^2) Data Sheet

Refuge:____________ Impoundment:_______________ Observer(s):_____________ Date:_________

Plot # (UTM)	Species (Top 5 for % cover)	# Seed Heads	Plant Height (m) (% Cover)	Head Diam (cm)	Head Height (cm)