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# **Validation and Development of Standard Moist-soil Inventory and Monitoring Procedures**

## **Final Report**

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## Abstract

Rapid assessment of food production and subsequent availability is fundamental to evaluating habitat quality for waterfowl and management practices. Traditional methods of estimating food abundances (i.e., plot and core sampling) require considerable time, expertise, and cost, but rapid assessment models using plant measurements or seed-head area have recently been adapted to predict seed production in moist-soil wetlands. We evaluated existing models of seed production and estimated benthic seed density with data collected during autumn 2011 to improve these models for predicting seed availability for waterfowl. Generally, scanned seed-head area model predictions explained similar variation among published models, new models built from 2011 data, and models built using 2011 data and previously published data ( $R^2 = 0.85\text{--}0.98$ ). Belowground seed and energy densities differed across species relative to typical values in moist-soil wetlands ( $\bar{x} = 0.4\text{--}9.1\%$  of estimates) meaning that production estimates from models should be adjusted on a species-specific basis and the effect of belowground seeds on overall energetic carrying capacity estimates will vary with species composition of wetlands. Generally, the Moist Soil Management Advisor produced recommendations consistent with energy densities and subsequent wetland use by waterfowl; however, we found the software to be problematically outdated and very time consuming to properly parameterize. Waterfowl density in late autumn after wetlands were flooded was positively associated with seed and energy density and supported software recommendations for no active management of these wetlands. Overall, we do not recommend use of the Moist Soil Management Advisor unless significant updates to the software and user interface are completed, but do recommend use of updated moist-soil rapid assessment models to predict waterfowl food availability, predict habitat use, and evaluate management practices.

## Introduction

Waterfowl biologists estimate food resources in wetlands located along migration routes and at wintering sites to calculate energetic carrying capacity and evaluate wetland management practices for waterfowl (Williams et al. 2014). Energetic carrying capacity is often measured using duck-energy days (DEDs; Reinecke and Loesch 1996) which are a measure of the energy available on a per duck basis; that is, one DED is equivalent to the amount of energy required by one average-size duck for one day. U.S. Fish and Wildlife (USFWS) National Wildlife Refuge (NWR) biologists often estimate energetic quality of waterfowl foraging habitats before and after management actions (e.g., mowing and disking) or across large areas to determine energetic carrying capacity (Gray et al. 2013). Traditional methods of estimating seed and tuber densities, which are needed to estimate energetic carrying capacity, include measuring vegetation characteristics to predict seed yield (Laubhan and Fredrickson 1992, Gray et al. 1999a) or taking benthic core samples before waterfowl access wetlands (Kross et al. 2008, Hagy and Kaminski 2012b), but these procedures are time-consuming and costly (Gray et al. 1999; Stafford et al. 2006, 2010). Thus, NWR personnel require rapid assessment methods to evaluate habitat quality for migrating and wintering waterfowl (Laubhan and Fredrickson 1992).

Several methods have been developed to rapidly estimate seed production and availability for waterfowl. Laubhan and Fredrickson (1992) and Gray et al. (1999b) developed

morphological models that accurately predicted seed production of common species in moist-soil wetlands, but measurements were still time consuming. Naylor et al. (2005) developed a much simplified visual foraging habitat quality index for moist-soil wetlands in California, but performance outside of that region was greatly reduced (Stafford et al. 2010) indicating that morphological indices were likely much more accurate and potentially more robust to spatial variation (Anderson 2006). Gray et al. (2009) greatly improved the cost-efficiency of morphological models by streamlining the measurement process using desktop or portable scanners. Seed production prediction models produced by Gray et al. (2009) depended on scanned seed head area instead of time-consuming morphological measurements and retained high predictive power ( $R^2 > 0.91$ ). However, these models predict seed production rather than seed availability, which can be affected by decomposition, granivory, germination, and other factors prior to waterfowl accessing foods (Foster et al. 2009).

In addition to seed production models, NWR biologists have available to them a tool to help guide management practices. The Moist-soil Management Advisor (MSMA) uses inputs of wetland management infrastructure, spatial relationships between management units (i.e., wetlands), hydrology, and annual vegetation taxonomic composition to determine suitable management practices to increase energetic foraging habitat quality for waterfowl (Hamilton and Laubhan 1997, USFWS 2010). While the MSMA software is dated, some wetland managers may use this tool to assist in making management decisions.

## **Objectives**

The project goals and objectives correspond to needs and objectives outlined in the Tennessee NWR Comprehensive Conservation Plan (USFWS 2010). We evaluated standard monitoring protocols used currently on Tennessee NWR, improved rapid food production and availability models, and established a draft protocol for assessing waterfowl habitat quality in moist-soil wetlands. Our results will guide wetland management practices at Tennessee NWR, other refuges in Region 4, and elsewhere. In order to establish standardized models and assist refuge biologists with rapid assessment procedure, we will:

- 1) Evaluate robustness of moist-soil wetland inventory and monitoring procedures used by the USFWS on many NWRs in the southeastern United States (USFWS 2010:78).
- 2) Refine rapid assessment models for predicting energetic carrying capacity of waterfowl (i.e., duck-energy days, DED) in moist soil wetlands (USFWS 2010:93).
- 3) Create and draft protocol including narrative and standard operating procedure (SOP) for Objective #2 following USFWS Inventory & Monitoring Survey Protocol Handbook

## **Methods**

### *Study Area*

Our study was conducted during autumn and winters 2011–2012 and 2012–2013 on

Tennessee National Wildlife Refuge (TNWR) and Cross Creeks National Wildlife Refuge (CCNWR). Since 1970, over 40% of all American black ducks (*Anas rubripes*) observed during mid-winter waterfowl surveys in the Mississippi Flyway have been observed in Tennessee, and the majority of these birds (>75%) occurred on TNWR and CCNWR (Sanders et al. 1995). Tennessee National Wildlife Refuge (20,784 ha) is located along the Tennessee River. The largest contiguous subunit, the Duck River Unit (10,820 ha), is located at the confluence of the Tennessee and Duck Rivers and is managed intensively for waterfowl. Cross Creeks National Wildlife Refuge (3,585 ha) is located along the Cumberland River, approximately 80 km northeast of the Duck River Unit (Sanders et al. 1995). These refuges are managed for migrating and wintering waterfowl, with special attention given to American black ducks. Management consists of water-level control, mechanical manipulations (e.g., disking), herbicide use to control nuisance plants, and agricultural plantings. Primary waterfowl habitats on the refuges are open water, submerged aquatic vegetation (SAV), mudflats, managed and unmanaged moist-soil wetlands, flooded forest and shrubs, and flooded and unflooded agricultural fields.

### *Vegetation and Core Sampling*

We tested the prediction accuracy of existing models for redroot flatsedge (*Cyperus erythrorhizos*), barnyardgrass (*Echinochloa crus-galli*), Walter's millet (*E. walteri*), red sprangletop (*Leptochloa panicea* subsp. *brachiata*), rice cutgrass (*Leersia oryzoides*), fall panicum (*Panicum dichotomiflorum*), and curlytop knotweed (*Polygonum lapathifolium*) by collecting a random sample of 40 plants per species at each refuge, and comparing actual seed yield with predicted seed yield from the models (Gray et al. 2009). We also collected a 10-cm core sample at each plant location to adjust models for belowground food resources and link production estimates to food available to waterfowl. During September 2011, we located areas of moist-soil vegetation from wetland impoundments and collected seed heads from each species. We were unable to locate rice cutgrass on the DRU and collected samples of that species from Seven Islands Wildlife Refuge in Sevier County, Tennessee.

Following the procedures of Gray et al. (2009), we placed each seed head and associated core sample in separate, appropriately labeled zip-loc bags and transported them to the lab for processing. In the lab, we spread racemes and umbels so that overlapping was minimized and dried heads in a plant press for approximately one month. Following drying and pressing, we scanned seed heads with a desktop scanner, threshed seeds from heads, dried seeds to constant mass in a drying oven at  $\geq 70^{\circ}\text{F}$  for  $\geq 24$ hrs, and weighed seeds to the nearest 0.1 mg. We washed core samples through a large (1.4 mm) and a small sieve (300  $\mu\text{m}$ ) to facilitate processing and removed seed of the target species from the entire large sieve and 25% (by mass) of the small sieve portions to increase processing efficiency (Stafford et al. 2010, Hagy et al. 2011). All seeds and tubers were dried and weighed as previously stated.

We used simple linear regression and cross validation to evaluate models presented by Gray et al. (2009). To cross validate existing models, we inputted scanned seed head area into existing models and regressed the resulting value against threshed seed mass in SAS 9.3 (PROC REG; SAS 2012). Additionally, we built two sets of linear models for each species using 1) data from 2011 and 2) combined data from 2005–2006 and 2011. We examined plots of residual

values to ensure homoscedacity across years. We noted heterogeneous variances across years for combined models of barnyard grass and rice cutgrass and used weighted least squares regression to generate parameters for those species (Gray et al. 2009). Models were evaluated using variance explained ( $R^2$ ,  $R^2_{\text{pred}}$ ).  $R^2_{\text{pred}}$  was calculated by subtracting the quotient of the total sums of squares and the predicted residual sums of squares from 1. If plots indicated heterogeneity of variances among years, we used a Welch option to account for differences. We averaged benthic seed biomass across samples and generated a constant correction factor for each species which can be incorporated into DED estimates. Additionally, we used a one-way analysis of variance to test for an effect of species on seed and energy density from core samples collected adjacent to each plant with Tukey's pair-wise multiple comparisons tests of means when  $P < 0.05$ .

### *MSMA*

In summers 2011 and 2012, Tennessee NWR biologist Clayton Ferrell surveyed approximately 300 1-m<sup>2</sup> plots within 6 moist-soil impoundments at the Duck River Unit. In each subplot, percent species composition of the six most common species was estimated for input into MSMA. We digitized the DRU of TNWR and input appropriate variables into the MSMA (e.g., location of water control structures, hydrology management capabilities, management capabilities, etc.). Following complete parameterization, we ran the MSMA software and recorded the primary management recommendation and evaluated using seed and waterfowl density during late autumn. For instance, if the MSMA recommendation was disking, we would expect waterfowl use and seed density to be relatively low.

Subsequently, as part of an ongoing research project supported by the Black Duck Joint Venture, we collected core samples from foraging locations or experimental management plots within each of those impoundments. We estimated total seed and tuber density and energetic carrying capacity in DEDs in the 6 impoundments where vegetation surveys were conducted by collecting  $\geq 5$  systematically placed core samples in each impoundment during November or December immediately after they were flooded. In two of these impoundments, we did not systematically collect samples, but instead used data from five core samples collected at feeding locations of black ducks. Core samples were processed as previously described. Seeds assumed not to be consumed commonly by waterfowl were discarded (Hagy and Kaminski 2012a). Additionally, we estimated waterfowl abundance once per week within subplots of four impoundments (0.5–3.56 ha) from elevated blinds using binoculars or a spotting scope. We used linear regression in SAS 9.3 to evaluate the relationship between waterfowl densities and 1) seed and tuber densities and 2) duck energy days. We used waterfowl densities recorded within one week of flooding as these were highly correlated ( $r \geq 0.89$ ) with mean densities and peak densities from the first month of surveys and seed and tuber depletion can occur rapidly in moist-soil wetlands (Hagy and Kaminski 2012b).

### **Results**

Models presented in Gray et al. (2009) adequately predicted seed mass from heads collected at TNWR and CCNWR in 2011 ( $F > 347.1$ ,  $P < 0.001$ ), although variance explained was less than across original samples ( $R^2 = 0.82 - 0.96$ ). Barnyardgrass ( $\Delta R^2 = -0.15$ ) and red

sprangletop ( $\Delta R^2 = -0.09$ ) model predictions had notably reduced  $R^2$  values (Table 1). Seed head area for redroot flatsedge (-127%), Walter's millet (-19%), and red sprangletop (-54%) was less and barnyard grass (26%), fall panicum (39%), and curlytop knotweed (43%) was greater in 2011 than samples collected in 2005–2006 (Gray et al. 2009). Regression models built from 2011 samples generally explained similar proportions of variation as did those presented in Gray et al. (2009;  $R^2 = 0.85 - 0.97$ ), but models resultant from combining 2005–2006 and 2011 data had slightly less predictive ability for some species ( $R^2 = 0.82 - 0.97$ ; Table 2).

Mean benthic seed mass from growing season samples differed among plant species ( $F = 6.58$ ,  $P < 0.001$ ) and was greatest in samples collected adjacent to Walter's millet (36.7 kg/ha) and rice cutgrass (45.0 kg/ha; Table 3). Notably, barnyard grass and curlytop knotweed had the lowest benthic seed masses (1.8 and 7.3 kg/ha, respectively), despite being two of the largest of the seven seeds examined. Species-specific correction factors varied widely, ranging from 12.9 DED/ha (redroot flatsedge) to 445.3 DED/ha (rice cutgrass), and are likely to have varying effects on overall energetic carrying capacity estimates.

Waterfowl use of wetland impoundments was positively associated with food and energy density during late autumn and consistent with MSMA management recommendations (Fig. 1). Models of seed mass ( $R^2 = 0.90$ ,  $F = 26.5$ ,  $P = 0.014$ ) and DEDs ( $R^2 = 0.90$ ,  $F = 26.6$ ,  $P = 0.014$ ) explained significant variation in waterfowl density during the first month of fall flooding. Seed mass was lowest in impoundments 3, 5, 6, and 7 in early autumn (range = 208.4–484.6) which is less than typical managed moist-soil wetlands in the Mississippi Alluvial Valley (MAV) according to Kross et al. (2008; 496.3 kg/ha). The MSMA correctly recommended disking during the next growing season as primary management in these impoundments to increase seed production. Impoundments 1 (1,572.8 kg/ha) and 2 (846.3 kg/ha) contained the greatest seed mass and densities were greater than MAV means presented by Kross et al (2008) and managed, robust moist-soil wetland sampled by Hagy and Kaminski (2012b; 750.7 kg/ha) in the MAV. In these impoundments, MSMA recommended only continued fall flooding for target wildlife species and no additional active management (Table 4). Problems with MSMA software prevented generation of alternate management recommendations.

## Discussion

Anderson (2006) and Gray et al. (2009) suggested that scanned seed-head area of moist-soil plants was a good indicator of seed production and our results suggest similar conclusions. Evaluation of models presented in Gray et al. (2009) models with new data support this inference. Intuitively, models generally performed better when used with the data from which they were generated. However, variance explained was only slightly reduced when using models previously presented by Gray et al. (2009) or new models using data from 2005–2006 and 2011 combined. Similarity in performance suggests that regression models predicting seed production are robust to considerable variation in annual differences in seed production in the southeastern United States. Sherfy and Kirkpatrick (1999) and Naylor (2005) cautioned that rapid methods developed for moist-soil plants in one region may lead to error in estimates of seed production in others. However, Anderson (2006) found no difference in predictive capability of models for Walter's millet in different areas, but further validation of model predictions across regions

remains lacking. Temporal variation, however, seemed to have little effect on explanatory power of models in our study area.

Although rapid assessment models are good predictors of seed production, they have not been previously adjusted for benthic seeds which would contribute to seed availability estimates for migrating and wintering waterfowl after these wetlands are flooded. Current production estimates from rapid assessment models may significantly underestimate DEDs available if significant resources exist in the seed bank. We found that relative to overall energetic carrying capacity, biomass and energy density of benthic seeds varied by species and would likely have variable effects on overall carrying capacity estimates depending on species composition of wetlands. For instance relative to total seed and tuber estimates provided by Kross et al. (2008) for managed moist-soil wetlands in the MAV (i.e., 496 kg/ha), benthic seed biomass adjacent to Walter's millet (7.6%), rice cutgrass (9.1%), and red sprangletop (5.4%) plants was found to be much greater than those from redroot flatsedge (0.5%), barnyardgrass (0.4%), fall panicum (1.7%), and curlytop knotweed (1.5%) and could increase energetic carrying capacity estimates considerably (242.6 – 445.3 DED/ha; Table 3). Thus, we recommend incorporating species-specific correction factors for belowground seeds into models to more accurately represent DEDs on the landscape to aid managers in more precise conservation delivery.

While the MSMA is useful for providing management options, the software and interface is outdated and incompatible with computers running Windows versions newer than XP. Moreover, the level of input detail required to properly parameterize the tool requires an intimate understanding of wetland infrastructure, the underlying hydrology, and available management options and their probable outcomes; thus, the background knowledge and expertise required to input data into the program likely require a skilled wetland manager who will be capable of managing moist-soil without the help of the MSMA. Additionally, the MSMA does not predict overall wetland quality or energetic carrying capacity, despite requiring vegetation composition as an input. Despite significant software interface drawbacks and limited usefulness overall, MSMA recommendations were generally supported by waterfowl and energy densities during late autumn. At Tennessee NWR, the MSMA recommended disking in sites with lowest seed and waterfowl densities (Table 4) but did not produce active management recommendations for impoundments 1 (1,572.8 kg/ha) and 2 (846.3 kg/ha), which contained the greatest seed densities. Although reasonable, these recommendations may be unnecessary for experienced biologists. Wetland managers often rely on training and experience to manipulate water levels and vegetation (i.e. disking) to promote germination of desirable moist-soil plants (Fredrickson and Taylor 1982, Gray et al. 1999), and using MSMA software to assist in or support decisions that often can be readily made by the same managers seems inefficient.

Overall, we believe that the MSMA software in current form has limited usefulness to assist moist-soil managers make management decisions. Moreover, the software is dated and must be used on an MS DOS platform which is not available with most modern operating systems. The MSMA requires extensive and time-consuming parameterization, including inputting vegetation survey data, management capabilities and water budgets of each impoundment, "heads-up" digitizing, and knowledge of topography and flora of the area. Thus, data input can be time consuming (i.e., in our case >16 hours) and requires personnel

knowledgeable of specific wetlands and their floral community. Although the initial parameterization effort would not necessarily be required each time the software is used, changes to infrastructure, management capabilities, or hydrology (i.e., flooding) would significantly change input parameters and likely require extensive time and effort. Our opinion is that staff with the level of moist-soil management expertise necessary to properly parameterize the MSMA would likely not benefit from the general recommendations provided by the software package. Thus, we found that the MSMA is probably of little use to moist-soil wetland managers in its present form and managers should instead focus their efforts on other indices of habitat quality, such as moist-soil seed production (Gray et al. 2009, 2013).

Waterfowl densities following initial flooding of moist-soil sites at TNWR were associated positively with seed and energy density. Although previous studies have suggested habitat selection by waterfowl depends on many endogenous and exogenous factors elicited by a combination of proximate and ultimate cues (Pöysä et al. 1998, Gawlick 2002, Arzel and Elmberg 2004), waterfowl use increased with seed and energy density. We should also note that waterfowl use of our impoundments in late autumn may also have been linked with reduced habitat availability at that time before most managed wetlands are flooded. Further research should explore the relationship between visual (Naylor et al. 2005) and rapid quantitative (Gray et al. 2009) seed production and availability indices, estimates of seed availability during late autumn and winter, and concurrent waterfowl use. Additionally, we suggest scientists evaluate seed loss between autumn production estimates and late autumn flooding of wetlands for waterfowl.

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Table 1. Mean scanned seed head area ( $\bar{x}$ , SE), the percent difference between years ( $\Delta\bar{x}$ ), sample size ( $n$ ), and results from a one-way analysis of variance with variance explained ( $R^2$ ) and the difference in variance explained between years ( $\Delta R^2$ ) of seven moist-soil plant species collected at Tennessee and Cross Creeks National Wildlife Refuges and Seven Islands Wildlife Refuge, Tennessee, USA.

Species	2005–2006		2011		$\Delta\bar{x}$	$n$	$F$	$P$	$R^2$	$\Delta R^2$
	$\bar{x}$	SE	$\bar{x}$	SE						
<i>Cyperus erythrorhizos</i>	186.6A	9.3	82.2B	4.4	-127%	79	915.3	<0.001	0.92	-0.05
<i>Echinochloa crus-galli</i>	48.1A	1.9	65.2B	3.2	26%	78	352.2	<0.001	0.82	-0.15
<i>Echinochloa walteri</i>	111.4A	4.5	93.5B	5.3	-19%	40	743.7	<0.001	0.95	-0.02
<i>Leptochloa panicea</i>	66.4A	2.6	43.0B	3.1	-54%	75	512.3	<0.001	0.87	-0.09
<i>Leersia oryzoides</i>	18.6A	0.7	17.3A	0.6	-8%	38	402.3	<0.001	0.92	-0.07
<i>Panicum dichotomiflorum</i>	24.2A	1.7	39.8B	3.9	39%	73	347.1	<0.001	0.83	-0.07
<i>Polygonum lapathifolium</i>	31.5A	2.6	54.8B	4.1	43%	77	1,879.6	<0.001	0.96	-0.01

Table 2. Models for predicting seed production of seven common moist-soil plants collected at Tennessee and Cross Creeks National Wildlife Refuges and Seven Islands Wildlife Refuge, Tennessee, USA during September 2005–2006 and 2011 using scanned seed head area (AREA, cm<sup>2</sup>), sample size (*n*), and results from a one-way analysis of variance with variance explained (*R*<sup>2</sup>).

Species	Class	<i>n</i>	Model	F	<i>R</i> <sup>2</sup>	<i>R</i> <sup>2</sup> <sub>pred</sub>
<i>Cyperus erythrorhizos</i>	2005–2006	59	$Y = (0.018 \times \text{AREA}) + 0.209$	1070.1	0.97	0.97
	2011	78	$Y = (0.022 \times \text{AREA}) - 0.001$	689.2	0.95	0.94
	Combined	136	$Y = (0.019 \times \text{AREA}) - 0.001$	2036.3	0.97	0.97
<i>Echinochloa crus-galli</i>	2005–2006	60	$Y = (0.026 \times \text{AREA}) - 0.023$	982.2	0.97	0.97
	2011	76	$Y = (0.013 \times \text{AREA}) + 0.002$	268.7	0.88	0.85
	Combined	136	$Y = (0.015 \times \text{AREA}) + 0.001$	473.7	0.88	0.85
<i>Echinochloa walteri</i>	2005–2006	60	$Y = (0.010 \times \text{AREA}) + 0.256$	1178.2	0.98	0.97
	2011	37	$Y = (0.019 \times \text{AREA}) - 0.001$	579.2	0.97	0.97
	Combined	95	$Y = (0.012 \times \text{AREA}) + 0.001$	572.2	0.92	0.91
<i>Leptochloa panicea</i>	2005–2006	59	$Y = (0.008 \times \text{AREA}) + 0.301$	682.2	0.96	0.96
	2011	74	$Y = (0.009 \times \text{AREA}) + 0.001$	355.9	0.91	0.89
	Combined	133	$Y = (0.012 \times \text{AREA}) - 0.001$	719.2	0.92	0.91
<i>Leersia oryzoides</i>	2005–2006	59	$Y = (0.009 \times \text{AREA}) + 0.009$	2664.8	0.99	0.99
	2011	36	$Y = (0.007 \times \text{AREA}) + 0.001$	386.8	0.96	0.95
	Combined	95	$Y = (0.007 \times \text{AREA}) + 0.001$	1297.4	0.97	0.96
<i>Panicum dichotomiflorum</i>	2005–2006	58	$Y = (0.023 \times \text{AREA}) - 0.281$	326.2	0.92	0.90
	2011	73	$Y = (0.010 \times \text{AREA}) + 0.001$	528.9	0.94	0.93
	Combined	130	$Y = (0.009 \times \text{AREA}) + 0.001$	375.3	0.85	0.82
<i>Polygonum lapathifolium</i>	2005–2006	62	$Y = (0.045 \times \text{AREA}) - 0.059$	1067.5	0.97	0.97
	2011	74	$Y = (0.044 \times \text{AREA}) - 0.001$	1262.8	0.97	0.97
	Combined	136	$Y = (0.044 \times \text{AREA}) - 0.001$	2066.1	0.97	0.97

Table 3. Mean ( $\bar{x}$ , SE) belowground seed density (kg/ha[dry]) of each seed species, number of core samples processed ( $n$ ), and duck energy days (DED) from core samples adjacent to seven moist-soil plant species collected at Tennessee and Cross Creeks National Wildlife Refuges and Seven Islands Wildlife Refuge, Tennessee, USA during September 2011.

Species	$n$	kg/ha <sup>a</sup>		DED <sup>a</sup>	
		$\bar{x}$	SE	$\bar{x}$	SE
<i>Cyperus erythrorhizos</i>	11	2.3 A	1.0	12.9 A	5.9
<i>Echinochloa crus-galli</i>	10	1.8 A	0.8	16.0 A	6.8
<i>Echinochloa walteri</i>	26	36.7 B	8.6	326.7 B	76.6
<i>Leersia oryzoides</i>	10	45.0 B	16.1	445.3 B	159.2
<i>Leptochloa panicea</i>	13	27.1 B	6.1	242.6 B	54.7
<i>Panicum dichotomiflorum</i>	33	8.8 A	2.6	73.3 A	21.7
<i>Polygonum lapathifolium</i>	27	7.3 A	2.6	30.0 A	10.8

<sup>a</sup> Means within columns followed by unlike letters are different by analysis of variance and Tukey-Kramer HSD test.

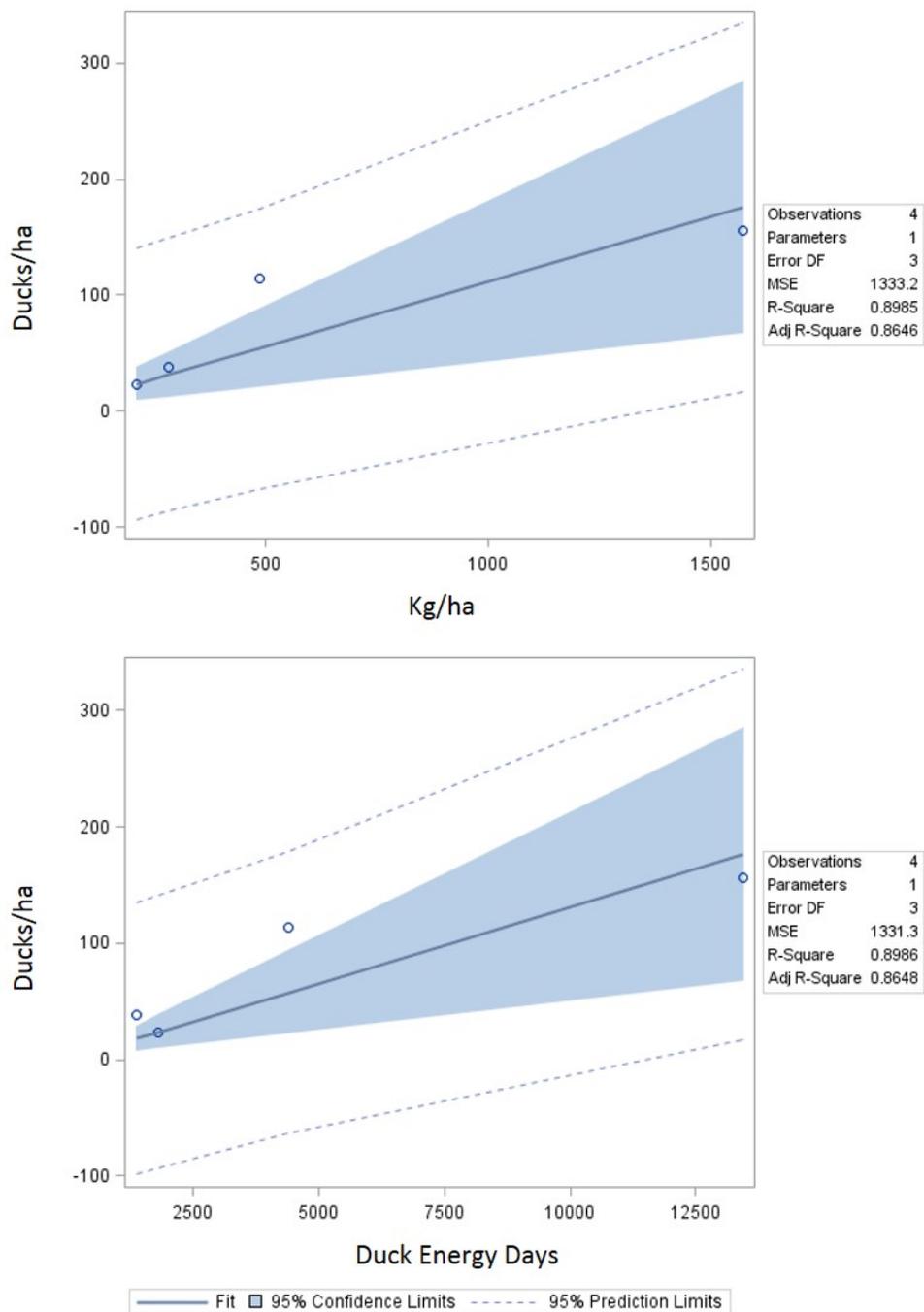
Table 4. Seed and tuber density assumed to provide nutritional value to waterfowl (kg/ha[dry]), duck energy days (DED), waterfowl densities within one week of flooding and food sampling (ducks/ha/survey), and Moist Soil Management Advisor (MSMA) -generated management recommendations from vegetation surveys at Tennessee National Wildlife Refuge, Tennessee, USA during autumn 2011.

Impoundment	kg/ha	DED	Waterfowl Density	MSMA Recommendation
1	1,572.8	13,446.8	156.2	Begin Flood Late Fall
2	846.3	5,659.3	–	Begin Flood Late Fall
2 <sup>a</sup>	281.3 <sup>a</sup>	1,358.4 <sup>a</sup>	38.4 <sup>a</sup>	Begin Flood Late Fall
3	484.6	4,394.6	113.9	Disk
5	237.3	2,744.3	<sup>b</sup>	Disk
6	208.4	1,805.3	23.4	Disk
7	454.5	5,022.0	<sup>b</sup>	Disk

<sup>a</sup> Waterfowl observations began one month later than other impoundments. Seed mass and DED estimates collected just prior to observations were used for regression with waterfowl density.

<sup>b</sup> DED estimates taken from foraging sites of American black ducks. Waterfowl density was not recorded.

Figure 1. Regression of peak duck densities and seed and tuber densities (kg/ha) and energy density (duck energy days) obtained from 4 managed moist-soil wetlands at Tennessee National Wildlife Refuge, Tennessee, USA during late autumn 2011.



Submitted by:

A handwritten signature in black ink, reading "Heath Hagy". The signature is written in a cursive style with a large initial "H" and a stylized "Hagy".

Heath M. Hagy, Ph.D., AWB  
Director, Forbes Biological Station  
Illinois Natural History Survey

Date: 22 August 2014

Appendix A.

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# Rapid Assessment of Moist-soil Wetland Foraging Habitat Quality for Dabbling Ducks

*Region IV, Protocol Framework (Draft Ver1)*

Survey ID Number: XXXXXXXXXXX-000

Southeast Regional Protocol Framework for the Inventory and Monitoring of Moist-soil Wetland Quality



*Moist-soil Wetland in Pool 1 at the Duck River Unit of Tennessee NWR  
Photograph by: Joshua Osborn*

<b>Protocol Title:</b> Rapid Assessment of Moist-soil Wetland Foraging Habitat Quality for Dabbling Ducks				
<b>Version<sup>1</sup> :</b> Draft1				
<b>Station Name:</b> Tennessee NWR		<b>Authors and Affiliations</b> Osborn, J.M. and H.M. Hagy, Illinois Natural History Survey M.D. McClanahan and M.J. Gray, University of Tennessee-Knoxville		
<b>Approvals</b>				
<b>Action</b>		<b>Appropriate Signature/Name</b>		
<b>Survey Coordinator<sup>2</sup></b>				
<b>Submitted by:</b>				
<b>Zone I&amp;M<sup>3</sup> or equivalent Approval:</b>				<b>Date</b>
<b>Regional I&amp;M<sup>4</sup> Approval:</b>				
<b>National I&amp;M<sup>5</sup> Approval:</b>				
<b>Version<sup>1</sup></b>	<b>Date</b>			
		<b>Author</b>	<b>Change Made</b>	<b>Reason for Change</b>

<sup>1</sup> Version is a decimal number with the number left of decimal place indicating the number of times this protocol has been approved (e.g., first approved version is 1.0.; prior to first approval all versions are 0.x; after first approval, all minor changes are indicated as version 1. x until the second approval and signature, which establishes version 2.0, and so on).

<sup>2</sup> Signature of station representative designated lead in development of a site-specific survey protocol.

<sup>3</sup> Signature signifies approval of a site-specific survey protocol.

<sup>4</sup> Signature by Regional I&M Coordinator signifies approval of a protocol framework to be used at multiple stations within a Region.

<sup>5</sup> Signature by National I&M Coordinator signifies approval of a protocol used at multiple stations from two or more Regions.

DRAFT

## **Survey Protocol Summary**

*Rapid assessment of food production and subsequent availability is fundamental to evaluating habitat quality for waterfowl and wetland management practices. Traditional methods of estimating food abundances (i.e., plot and core sampling) require considerable time, expertise, and cost. Reliable and rapid assessment of food production is dependent upon identifying predictor variables that correlate with the seed mass and have low variation over time and space. This protocol provides the guidance necessary for refuge personnel with limited biological training to quickly and cost-effectively estimate seed and energy density which serves as an indicator of waterfowl habitat quality on refuges throughout the southeast using collected seed heads and plant density estimates from wetland plots. Seed heads from common moist-soil plant species that produce seeds consumed by waterfowl should be collected and species densities estimated in randomly-placed 1-m<sup>2</sup> plots throughout an individual wetland or refuge. Seed heads should then be pressed, dried, and scanned (i.e., with a portable or desktop scanner) according to specific protocols. Scanned seed head areas and plant stem densities can then be used to predict seed production and subsequent availability in managed moist-soil wetlands. The University of Tennessee (UT) Wetlands Program offers a drying, scanning, and analysis service if suitable equipment or expertise is not available to refuge personnel. Field sample collection procedures require little time commitment (i.e., approximately 40 person-hours during late summer or early autumn) and minimal expense for supplies (i.e., \$100). Processing procedures require a moderate time commitment (i.e., approximately 5 min/plot/species) or a moderate cost (\$20/plot or \$200/impoundment for contracting with UT).*

### **Suggested citation:**

Osborn, J.M., H.M. Hagy, M.D. McClanahan, and M.J. Gray. 2014. Rapid assessment of moist-soil wetland foraging habitat quality for dabbling ducks. Tennessee NWR, Region IV. USFWS Southeast Region Atlanta, GA.

This protocol is available from ServCat [ *URL TBD* ]

## **Acknowledgments**

We wish to acknowledge the Black Duck Joint Venture, U.S. Fish and Wildlife Service, Ducks Unlimited, Illinois Natural History Survey, and the University of Tennessee Institute of Agriculture for funding and in-kind support. Further we acknowledge previous researchers who have worked to further conservation efforts geared towards the efficient and accurate estimation of food resources for migrating and wintering waterfowl. Refinement of rapid assessment models would not have been possible without the support of field and lab technicians R. Corlew, S. Veum, J. Droke, and J. Gaddis. Additionally, field collections could not have been accomplished with the guidance of C. Ferrell and cooperation from B. Crawford, T. Littrell, D. Zabriski, R. Wheat, and R. Hine of Tennessee and Cross Creeks NWR.

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# Narrative

## Introduction

### **Background**

Waterfowl biologists estimate food resources in wetlands located along migration routes and at wintering sites to calculate energetic carrying capacity and evaluate wetland management practices for waterfowl (Williams et al. 2014). Energetic carrying capacity is often measured using duck-energy days (DEDs; Reinecke and Loesch 1996) which are a measure of the energy available on a per duck basis; that is, one DED is equivalent to the amount of energy required by one duck for one day. U.S. Fish and Wildlife (USFWS) National Wildlife Refuge (NWR) biologists often estimate energetic quality of waterfowl foraging habitats before and after management actions (e.g., mowing and disking) or across large areas to determine energetic carrying capacity (Gray et al. 2013). Traditional methods of estimating seed and tuber densities, which are needed to estimate carrying capacity, include measuring vegetation characteristics to predict seed yield (Laubhan and Fredrickson 1992, Gray et al. 1999a,b) or taking benthic core samples before waterfowl access wetlands (Kross et al. 2008, Hagy and Kaminski 2012b), but these procedures are time-consuming and costly (Gray et al. 1999a,b; Stafford et al. 2006, 2010). Thus, NWR personnel require rapid assessment methods to evaluate habitat quality for migrating and wintering waterfowl (Laubhan and Fredrickson 1992).

Several methods have been developed to rapidly estimate seed production and availability for waterfowl. Laubhan and Fredrickson (1992) and Gray et al. (1999) developed morphological models that accurately predicted seed production of common species in moist-soil wetlands, but measurements were still time consuming. Naylor et al. (2005) developed a much simplified visual foraging habitat quality index for moist-soil wetlands in California, but performance outside of that region was greatly reduced (Stafford et al. 2010) indicating that morphological indices were likely much more accurate and potentially more robust to spatial variation (Anderson 2006, Osborn et al. 2014). Gray et al. (2009) greatly improved the cost-efficiency of morphological models by streamlining the measurement process using desktop or portable scanners. Seed production prediction models produced Gray et al. (2009) depended on scanned seed head area, instead of time-consuming morphological measurements and retained high predictive power ( $R^2 \geq 0.84$ ).

Osborn and Hagy (2014) tested and improved predictive models of Gray et al. (2009) and estimated benthic seed density which can be used to adjust production estimates for actual seed availability. Moreover, they showed a positive relationship between estimates of seed availability and waterfowl use suggesting that seed availability indices may be useful in predicting waterfowl use of wetlands. Herein, we

outline standard methods for rapidly and efficiently evaluating moist-soil seed availability and foraging habitat quality for dabbling ducks (Anatini).

### **Objectives**

1. Evaluate foraging habitat quality for dabbling ducks and other wetland wildlife in moist-soil wetlands during autumn.
2. Estimate seed production and potential availability for dabbling ducks in moist-soil wetlands during late autumn.
3. Estimate energy density for dabbling ducks in moist-soil wetlands during late autumn.
4. Predict wetland use by dabbling ducks during late autumn and early winter.
5. Evaluate the effects of wetland management practices and changing conditions on foraging habitat quality of dabbling ducks in moist-soil wetlands during autumn.

## **Sampling Design**

### **Sample design**

Sample plots should be allocated by random or systematic-random processes across each moist-soil wetland or contiguous areas of moist-soil vegetation about which inference is to be made. At least ten 1-m<sup>2</sup> plots should be placed within each discrete area of moist-soil vegetation and a minimum of 40 plots per area of inference should be sampled, but the number of plots may vary according to the overall size of the survey area. Often, time and available resources will dictate the number of plots that can be sampled. Although assigning random plot locations using a program such as ArcMap is preferable, an easier and acceptable sample plot allocation design is systematic-random placement of plots. For systematic-random sampling, a transect can be placed at a random starting point and direction along one side of a wetland and plots sampled at a regular interval along the transect. For this approach, we suggest establishing the first plot at a random distance within the expected between-plot interval and then keeping the interval consistent for the remainder of the transect.

### **Sampling units, sample frame, and target universe**

Sampling at each location targets 7 species of wetland plants known to be consumed by waterfowl: redroot flatsedge (*Cyperus erythrorhizos*), Walter's millet (*Echinochloa walteri*), red sprangletop (*Leptochloa panicea*), rice cutgrass (*Leersia oryzoides*), fall panicum (*Panicum dichotomiflorum*), and curlytop knotweed (*Polygonum lapathifolium*). Plots (1 m<sup>2</sup>) should be systematically or randomly placed throughout the inference area and one individual of each species collected at each plot until  $n = 40$  for each species.

### **Sample Selection and Size**

Sample plots should be a standard and known size. We suggest 1-m<sup>2</sup> plots because this is reasonable for two personnel to assess in a short amount of time.

### **Survey timing and schedule**

Sampling should occur when the majority of plants have produced seed heads but prior to seed dislodging from heads (i.e., typically in late August – early October in the southeastern U.S.).

### **Sources of Error**

Potential for sampling bias exists if samples are not randomly selected or representative of the survey area. Protocol suggests one sample of each species be collected from multiple 1-m<sup>2</sup> plots until the desired sample size ( $n = 40$ ) for each species is reached. If resources are available, adding sample plots or transects may be necessary until target sample sizes are reached.

## **Field Methods and Sample Processing**

### **Pre-survey logistics and preparation**

Field work for seed collection should be conducted towards the end of the growing season (September) to permit collection of fully mature plants. Data collection will take (2) personnel approximately 40 person-hours, provided personnel have knowledge of moist-soil plant identification. Moist-soil plant species often reach maturity as early as July, and by mid-September the majority of seeds have matured. Accordingly, two collection periods may be necessary to capture all species in full production. A list of necessary supplies for field sampling is provided below:

- (up to 280) One-gallon Ziploc bags for seed heads
- (2) large coolers or plastic tubs for temporary storage and transport of seed-head samples
- (2-4) Plant press for pressing and drying of seed heads
- (2) Scissors
- (1) Box of permanent markers to write on Ziploc bags
- (1) GPS with accuracy ( $\pm 20$ m) (*optional*)

Training required:

- Moist-soil plant identification. We suggest the moist-soil field guide, “*A Guide to Common Moist-soil Wetland Plants of the Mississippi Alluvial Valley*”
- Motorboat Operator’s Certification (*optional*)
- All-Terrain Vehicle Operating Certification (*optional*)

If technicians or field interns are used, a dedicated vehicle and ATV may be needed for the duration of the field work in addition to the needs of refuge personnel. On or near-site housing will be necessary throughout the week for temporary staff.

All precautions for safe operation of vehicles, boats, and ATVs should be followed while using USFWS property. Heat-exhaustion and heat-stroke can occur during summer in the Southeast U.S. Personnel should ensure to take appropriate precautions to prevent heat-related injuries (e.g., increased hydration, avoiding certain times of the day for sampling). Personnel should be prepared for mosquitos and other biting insects.

Each day, personnel should discuss a work plan including schedule and location with the refuge manager or other supervisor. Further, personnel should have a mode of communication (e.g., cell phone with reception, two-way radio, etc.) in case of emergency. If interns or volunteers conduct field work, volunteer service agreements (150FW 1, FWS 2003) should be discussed and signed by each individual.

### ***Establishment of sampling units***

Each refuge or area should be sampled by random or systematic-random allocation of plots. Personnel should have a detailed map of the area for navigation and to mark locations of potential collecting sites. Plots may be established on the day of sampling and require no seasonal or permanent boundaries. Waypoints can be collected at each sample location in North American Datum 83 (NAD83) format and uploaded to ArcMap or other mapping software for visual display and record keeping.

### ***Data collection procedures (field, lab)***

Within each sample plot, personnel should identify and count the stems of 7 moist-soil plant species if present in the plot: redroot flatsedge (*Cyperus erythrorhizos*), barnyardgrass (*Echinochloa crus-galli*), Walter's millet (*E. walteri*), red sprangletop (*Leptochloa panicea* subsp. *brachiata*), rice cutgrass (*Leersia oryzoides*), fall panicum (*Panicum dichotomiflorum*), and curlytop knotweed (*Polygonum lapathifolium*). Following stem enumeration, personnel should collect one visibly mature and intact seed head for each of the 7 species listed above, if present. Seed heads should be placed in individual Ziploc bags, labeled with a unique identifier and number, and placed flat in a container. In plots where a species does not occur, collect target species that are present and continue to the next plot. After all plots have been sampled, plants should be pressed and dried as soon as possible. If plant pressing cannot be completed immediately, bags should be stored in a refrigerator or similar cold place for <48 hours until processing can be completed. If plants are going to be shipped or transported to the University of Tennessee Wetlands Program for processing, all air should be removed from Ziploc bags, bags should be placed flat and stacked inside a

hard-sided shipping container, and the container should be shipped immediately with a shipping time of  $\leq 3$  days.

### ***Processing of collected materials***

*\*The following procedures can be completed by refuge personnel or by contract with the University of Tennessee Wetlands Program.*

- 1) After all plots have been sampled, separate and place plants in a plant press with pedicels spread apart to avoid overlapping seeds. Store plants in plant press at room temperature for  $>7$  days to facilitate drying of seed heads. Ensure that each seed head remains associated with a plot label.
- 2) Remove each seed head individually from the plant press and place on desktop scanner. If a seed head is too large for the scanner; cut, scan separately, and sum estimates of area across parts.
- 3) Record the scanned area and the plot information.

### ***End-of-season procedures***

Following laboratory processing, Ziploc bags and plant press materials can be discarded or saved for future uses.

## **Data Management and Analysis**

*\*The following procedures can be completed by refuge personnel or by contract with the University of Tennessee Wetlands Program.*

### ***Data entry, verification, and editing***

Enter all data into a Microsoft Excel, Access, or spreadsheet available through another software provider. Include the following column headings in the first row:

- A) Species
- B) Sample plot identification
- C) Scanned seed-head area
- D) Number of stems
- E) Average scanned seed head area
- F) Average number of stems

### ***Metadata***

Metadata should include sampling date, observer identity, wetland or impoundment identifier, GPS locations, and other pertinent information. Other data can be collected at each plot, such as number of invasive or undesirable species or threatened or endangered species. Observers could also conduct other rapid vegetation quality indices, such as described by Naylor et al. (2005).

### **Data security and archiving**

Refuge personnel should manage and archive data locally or according to established protocols.

### **Analysis methods**

In Microsoft excel, average scanned seed head area and average number of stems across all plots within each impoundment or independent area of inference. Use regression models (Osborn and Hagy 2014) to predict seed for each plant species. A downloadable worksheet is available ([http://fwf.ag.utk.edu/mgray/DED/Excel\\_v1\\_1.xls](http://fwf.ag.utk.edu/mgray/DED/Excel_v1_1.xls)) to make this process simple. If a plant species other than the 7 target species defined previously was collected, it may be possible to use a model from a similar plant species with a similar seed-head shape to predict yield (e.g., common barnyard grass for Japanese millet); however, we do not advocate this practice.

### **Software**

We suggest using Microsoft Excel for data entry and analysis.

## **Reporting**

### **Report Content and Recommendations**

*\*The following procedures can be completed by refuge personnel or by contract with the University of Tennessee Wetlands Program.*

The downloadable Excel file produces four outputs which can be used or summarized according to the individual objectives of managers:

- 1) Kg of seed (dry mass) produced per hectare: Calculated using prediction equations in Table 1 in Osborn and Hagy (2014). Seed mass (g) predictions per plant from the equation is multiplied by plant density and converted to kg seed per hectare by multiplying by 10 (i.e., simultaneously converts g to kg and m<sup>2</sup> to ha). **NOTE:** Commonly, 50 kg/ha is subtracted from the above DED estimate to account for the “giving-up” density of food resources, which is when waterfowl abandon foraging sites because it is no longer energetically profitable (Greer et al. 2009). The Excel file does not perform this calculation; however, users can account for this threshold if desired by subtracting 50 kg/ha from the total seed produced/ha or by subtracting 423 DED/ha from the total DED/ha (i.e., summation values in the YELLOW cells of the Excel spreadsheet).

- 2) Duck energy days (DED) per hectare: DEDs are calculated using true metabolizable energy (TME) of seed for each plant species from Kaminski et al. (2003). If a value was not available for a plant species, 2470 kcal/kg was used, which is the standard TME used for moist-soil seed. Daily energy requirements for a suite of dabbling duck species common to moist-soil wetlands in the Southeast (294 kcal/day) was used (Gray et al. 2013)
- 3) Total kg of seed produced: Estimates in #1 are multiplied by area (ha) of the moist-soil wetland. **NOTE:** Calculations should be performed separately for each moist-soil wetland on an area to account for spatial variation in seed production.
- 4) Total DED: Estimates in #2 are multiplied by area (ha) of the moist-soil wetlands. **NOTE:** To incorporate the giving-up threshold for the entire wetland, multiply 50 kg/ha or 423 DED/ha by total wetland acreage (ha) and subtract this value from the corresponding totals given in the Excel sheet (see TAN cells).

#### *Implications and application*

Wetland monitoring techniques are used at various NWRs; however, the robustness of their predictions of wetland quality has not been evaluated thoroughly. Validating these procedures is fundamental to making science-based adaptive management decisions. This work will increase the capacity for adaptive management on Tennessee NWR as well as other refuges in the southeast. Regional application of monitoring techniques via standardized protocols will strengthen capacity of the Inventory & Monitoring Program to assess wetland condition for waterfowl, a primary focus of the National Wildlife Refuge System.

#### *Objectives and Methods*

See objectives and methods for “*Southeast Regional Protocol Framework for the Inventory and Monitoring of Moist-soil Wetland Quality.*”

#### *Summary of Results*

Managers can summarize results from the Excel file according to their objectives.

#### *Important Findings*

Results from our study refines a tool developed by the University of Tennessee that efficiently predicts DEDs in moist-soil wetlands. Models may be used at NWRs across Region IV for adaptive management. Further, this protocol will make this technique

readily accessible for consistent data collection across multiple refuges promoting region-wide conservation delivery.

### ***Reporting schedule***

Managers should distribute their findings prior to the subsequent growing season so management plans can incorporate monitoring information.

### ***Reporting distribution***

Managers should distribute their finding according to their objectives.

## **Personnel Requirements and Training**

### ***Roles and responsibilities***

Refuge personnel should design appropriate sampling protocols for their desired sample area(s) and conduct plant collections. Refuge biologists are responsible for ensuring that personnel conducting vegetation survey have sufficient skills to identify plants and collect accurate data.

### ***Qualifications***

Knowledge of wetland plant identification is necessary but his can be aided by supplying field personnel with “*A Guide to Moist-soil Wetland Plants of the Mississippi Alluvial Valley.*” Personnel may also require ATV certification and motorboat operator certification, dependent upon the topography and conditions of the collection site.

### ***Training***

Wetland plant identification  
ATV operator certification (*optional*)  
Motorboat operator certification course (*optional*)

## **Operational Requirements**

### ***Budget***

The budget should include startup costs, supplies, equipment, and salaries of personnel conducting field work and subsequent analysis. If work will be contracted to the University of Tennessee Wetlands Program, updated fees and facilities and Administration charges should be considered.

Costs:

- Supplies: \$200.00 (up front) or \$100.00 (recurring); (2) Scissors, ( $\geq 280$ ) Ziploc bags, (2) coolers, (2-4) plant press, (1) GPS (*optional*)
- Desktop scanner: LI-COR Inc., Lincoln, NE; US\$9,000 in 2008. Alternatively, the University of Tennessee Wetland Program will scan seed heads, enter and analyze data, and generate a report for \$200/wetland.
- Shipping costs: These will vary with distance from the Refuge to the University of Tennessee and vendor rate.

### **Staff Time**

Approximately 40 person-hours will be required to collect vegetation samples, press and scan samples, and analyze data from 40–50 plots in one large moist-soil wetland. If the University of Tennessee will be contracted for pressing, scanning, and analyzing data, approximately 20 person-hours would be needed to collect and ship samples.

### **Schedule**

Plant Collection: Late August-Early September (USFWS)

### **Coordination**

Refuge should continue normal operating procedures. USFWS law enforcement should be informed of personnel using areas of the refuge that may not be open to the public. Collectors should coordinate with refuge biologists to ensure they collect fully mature plants prior to senescence. Coordination will also be necessary for the use of refuge equipment (ATV, vehicles, or boats).

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