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Articles

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Abstract

Moist-soil wetland management is used to precisely control delivery, duration, and timing of water addition to, and removal from, managed wetlands with targeted responses including germination and growth of desirable moist-soil plant species. Similarly, water delivery and removal drives decomposition of moist-soil plants as well as nutrient cycling within these systems, which is a key driver of productivity in such managed wetlands. Through deployment of litter bags, we examined rate of mass loss and decay coefficients of three locally abundant moist-soil annual species that are potentially valuable wintering-waterfowl food sources (nodding smartweed *Persicaria lapathifolia,* red-rooted flatnut sedge *Cyperus erythrorhizos,* and toothcup *Ammannia coccinea*) within man-made moist-soil managed wetlands on the Richland Creek Wildlife Management Area in East-central Texas. All three species lost nearly 100% of their mass during an 11-mo deployment period, where rate of mass lost and decay coefficient rates were driven by time, because all moist-soil managed wetlands used were inundated for the duration of this study. Plant materials exposed to persistent inundation in shallow wetlands exhibited rates of mass loss typical of the first two stages of decomposition, during which a majority of plant material mass was lost. However, during this study, typical inundation and drawdown regimes were not implemented, which may have delayed or prolonged decomposition processes, because litter bags of focal species were inundated for the duration of this study. Both locally and regionally specific moist-soil management hydroperiod manipulation should include both drawdown and inundation, to incorporate temporal transitions between these conditions. Such practices will allow wetland managers to more expeditiously meet plant management and waterfowl food production goals within moist-soil managed wetlands.

Keywords: decomposition; moist-soil managed wetlands; moist-soil plant species; nutrient cycling; Texas

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Introduction

A primary moist-soil managed-wetland management strategy is to strategically maximize plant decomposition by manipulating hydroperiod via precisely timed drawdown and inundation, to promote timely and efficient nutrient release to maintain moist-soil managed-wetland productivity. This management action (i.e., drawdown and inundation) along with others (e.g., disking, mowing, or burning) potentially provides large quantities of food to wintering and migrating waterfowl via increased or enhanced plant growth and subsequent seed production (Fredrickson and Taylor 1982; Haukos and Smith 1993; Gray et al. 1999; Lane and Jensen 1999; Anderson and Smith 2000; Strader and Stinson 2005). Drawdowns solely or in concert with other management practices promote germination and growth of focal plant species (Fredrickson and Taylor 1982; Haukos and Smith 1993; Lane and Jensen 1999; Strader and Stinson 2005) as managed wetland substrates are exposed to aerobic conditions, and large quantities of minerals and nutrients are released from senescent plant material (Klopatek and Stearns 1978; Atkinson and Cairns 2001; Sun et al. 2012). Cycles of water addition and removal, which drive plant decomposition and subsequent nutrient cycling, are important to overall moist-soil managed-wetland function and production (Wrubleski et al. 1997). More specifically, plant decomposition improves seed bank longevity, seed germination response, and wetland function via nutrient cycling in both natural and managed wetlands (van der Valk 1986; Murkin et al. 1989; Haukos and Smith 1993; Anderson and Smith 1999).

Nutrient cycling in wetlands is a function of 1) primary production of annual and perennial plants, and 2) decomposition of this biomass (van der Valk 1986; Bedford et al. 1999), which occurs in three stages (Godshalk and Wetzel 1978; Murkin et al. 1989). During the first stage (0–45 d), organic particles and ions are leached from the litter into the surrounding water, where the greatest biomass reduction occurs within the first few days of inundation (i.e., leaching stage). In the second stage (46–120 d), microbial activity increases and biomass reduction continues to occur gradually, typically over a longer period of time (i.e., decomposer stage). The final stage (>120 d) occurs over an extended period of time (i.e., refractory stage) due to slow degradation of the remaining material, such as lignins that are resistant to decomposition and decay (Ruppel et al. 2004). Therefore, to maximize decomposition, managed wetlands should be inundated long enough to allow completion of the second decomposition stage, which ensures that the majority of the plant matter (excluding lignins) are released into the wetland environment (Murkin et al. 1989; Neckles and Neill 1994; Wrubleski et al. 1997; Anderson and Smith 2002).

Considerable attention has focused on how inundation regimes (e.g., hydroperiods) drive litter decomposition (Brinson et al. 1981; Neckles and Neill 1994; Gingerich et al. 2014), because water directly influences decomposition via leaching and soil moisture, but also indirectly by influencing environmental conditions (e.g., pH, temperature, oxygen levels, and dissolved nutrient availability) that affect microbial activity (Mitch and Gosselink 1993; Kuehn and Suberkropp 1998; Lan et al. 2006). Beyond inundation duration, many studies of wetland plant litter decomposition have focused on herbaceous perennial species (Bell et al. 1978; Neckles and Neill 1994; Wrubleski et al. 1997), rather than on annual species (Anderson and Smith 2002), which tend to have less structural complexity and lignin and shorter decomposition time (Brinson et al. 1981; Ruppel et al. 2004; Poi de Neiff et al. 2006). Consequently, the impact of inundation regimes on decomposition rates is complicated because of variability in conditions other than inundation duration (Brinson et al. 1981; Neckles and Neill 1994; Fuell et al. 2013; Gingerich et al. 2014).

Inundation duration can be a major determinant of plant community development and stature via inundation rate, depth, duration, and frequency (Davis and van der Valk 1978; Brinson et al. 1981; Neckles and Neill 1994), although drying rate, timing, and predictability of drawdown (Day 1982; Neckles and Neill 1994), and the frequency of transitions between inundated and dry conditions (see Gingerich et al. 2014), can all influence wetland function and community composition. By specifically altering inundation and drawdown timing, frequency, and duration, both decomposition rate and extent, as well as plant establishment (from the seed bank), can be manipulated to meet specific management goals and objectives (Haukos and Smith 1994; Cassanova and Brock 2000; Anderson and Smith 2002).

Decay coefficients and percent mass lost were estimated using litter bag techniques (see Anderson and Smith 2002; Gingerich et al. 2014) for three seasonally and locally common annual moist-soil plant species (i.e., nodding smartweed *Persicaria lapathifolia,* red-rooted flatnut sedge *Cyperus erythrorhizos,* and toothcup *Ammannia coccinea*) occurring in moist-soil managed wetlands at the Richland Creek Wildlife Management Area (RCWMA) in East-central Texas (Collins 2012). These focal species were selected because they were the most frequently occurring hydrophytes during surveys in 2004 (Collins 2012), have value as wintering waterfowl food sources (Fredrickson and Taylor 1982), and are also facultative-wet (nodding smartweed and toothcup) or obligate (red-rooted flatnut sedge) hydrophtyes, indicative of a newly established created moist-soil managed wetlands. Therefore, the primary objective of this research was to more clearly understand how only one management action, inundation duration (i.e., number of days in the inundated wetlands) influenced decomposition of these focal hydrophytes within newly operational moist-soil managed wetlands.

Study Area

The RCWMA is located 40 km southeast of Corsicana, Texas (31°13′N, 96°11′W), along U.S. Highway 287 and FM 488 between Richland-Chambers Reservoir and the Trinity River in Freestone and Navarro counties, Texas (Figure 1). The local climate is subtropical with mild winters and warm, humid summers, with an average

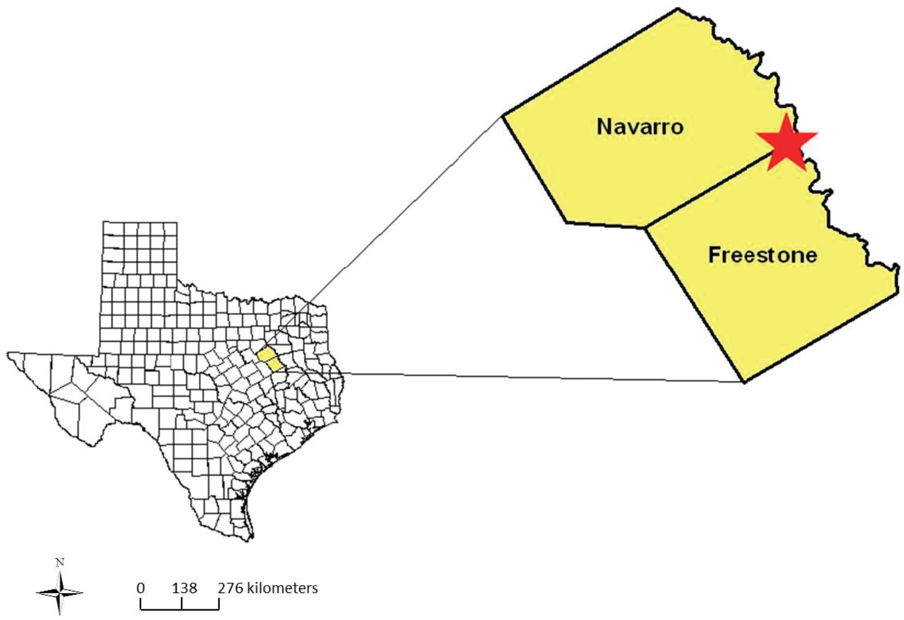

Figure 1. Location of Richland Creek Wildlife Management within Freestone and Navarro counties, East-central Texas, used during plant litter decomposition trials, September 2004–July 2005.

daily summer temperature of 34°C and daily winter temperature of 5°C, an average growing season of 246 d, and average rainfall of 101.6 cm/y (NRCS 2002). Rainfall is typically distributed evenly throughout the year. Soils in the area are predominantly of the Trinity series, which are fine, montmorillonitic, thermic, very haplaquolls, and mollisol soils (NRCS 2002). The RCWMA encompasses 6,271 ha in the ecotone separating the Post Oak Savannah and Blackland Prairie ecological regions (TPWD 2005) and lies primarily within the Trinity River floodplain.

We conducted this research on the RCWMA North Unit in four recently created moist-soil managed wetlands (at the time of the study they had become "operational" within the previous 6 mo; Collins 2012). During this study, barnyardgrass *Echinochloa crus-galli*, nodding smartweed, toothcup, red-rooted flatnut sedge, erect burhead *Echinodorus* spp., duck potato *Sagittaria* spp., square-stem spike rush *Eleocharis quadrangulata,* wild millet *Echinochloa walteri,* and water primrose *Ludwigia peploides* were common (Collins 2012). Plant taxonomy follows Diggs et al. (1999).

Each managed wetland occurred within the natural floodplain of the Trinity River, and all were leveed and equipped with water control structures, to provide independent water manipulation (depth and duration) within each moist-soil managed wetland. Water from the Trinity River was delivered to each moist-soil managed wetland from a lift station to a settling pond, after which water movement was gravity-drained, but could be strategically delivered to each managed wetland independently. The dual management objectives for these moist-soil managed wetlands were to provide 1) wetland habitat for wetland dependent species, specifically wintering waterfowl, and 2) clean water from the Trinity River prior to delivery to Richland-Chambers Reservoir, via a cooperative agreement between the Texas Parks and Wildlife Department and the Tarrant Regional Water District.

During this study, the moist-soil managed wetlands were not exposed to typical moist-soil managed-wetland hydroperiods. In 2004, drawdown of all moist-soil managed wetlands began in mid-April, where all four were drying to the point that standing water was limited (July 2004). However, this drawdown was extended temporally due to several large rain events during spring and summer. Water was intentionally returned to desired depths in each managed wetlands by September 2004, and remained inundated for the duration of this study (September 2004–July 2005).

Materials and Methods

Focal plant species

All three focal species were seasonally abundant during compositional surveys performed during the 2004 growing season (Collins 2012). Nodding smartweed is an annual herb attaining heights of 1–2 m and primarily restricted to freshwater sites. The plant grows well on clay mineral soils, but normally proliferates on organic soils that dry in summer and is typically found on slight elevations, on edges of levees, and in road ditches. Nodding smartweed needs an annual late spring–early summer drawdown to promote germination. After germination and plant emergence, nodding smartweed prospers with shallow flooding (Tiner 1993; Stutzenbaker 1999). Toothcup is an annual herb growing to 50 cm and thrives on moist-soils of shallow flooded sites. It is primarily a freshwater plant that requires a spring drawdown for germination, and once established, it prospers with shallow flooding regimes (Stutzenbaker 1999). Finally, red-rooted flatnut sedge is an annual herb

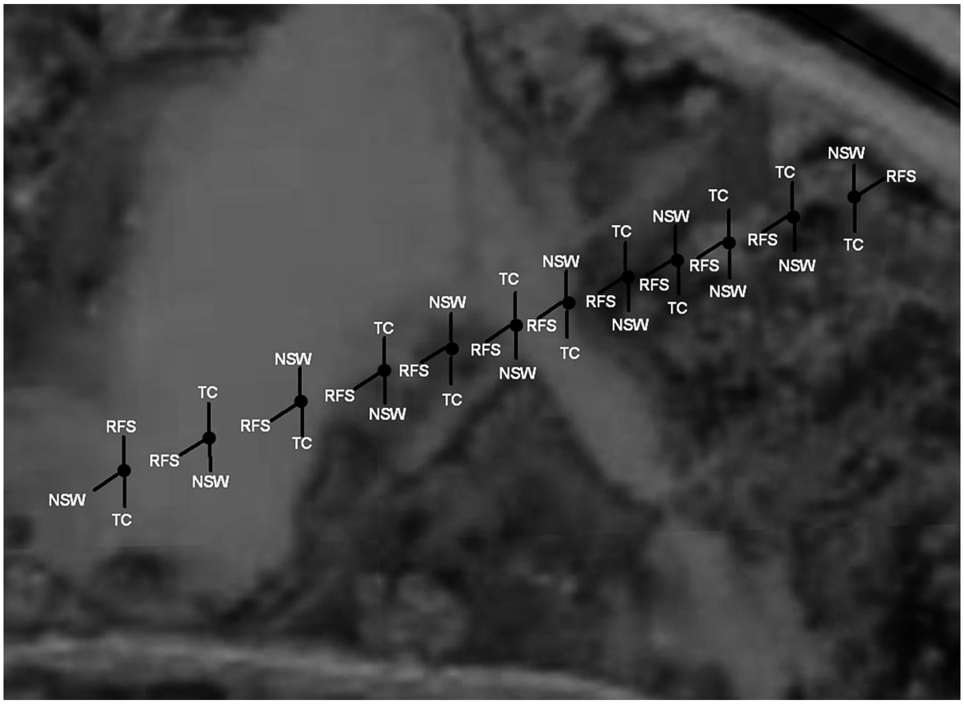

Figure 2. Example of litter bag deployment of three focal moist-soil hydrophytes used to examine decomposition in moist-soil managed wetlands on the Richland Creek Wildlife Management Area, East-central Texas, 23 September 2004–15 July 2005.

restricted to freshwater wetlands, reaching approximately 1 m. Spring drawdown is required for germination, and once emerged and established, it will tolerate shallow flooding (Stutzenbaker 1999).

Material collection and sample deployment

We collected mature standing nodding smartweed, toothcup, and redroot flatnut sedge leaves, seeds, and stems (up to 1.2 kg/species/moist-soil managed wetland) during late August and early September 2004. Using hand clippers, we collected all plant materials prior to senescence, from monotypic stands of each species in each moist-soil managed wetland. We placed all samples in labeled plastic garbage bags and stored them on ice in the field. For the field deployment portion of this study, we returned all plant materials to the moist-soil managed wetland from which they were collected (see below).

We constructed fiberglass litter bags using two pieces of 1-mm-aperture window screen secured with aluminum staples. We prepared individual, monospecific samples of each focal species by clipping 15–20-cm stem lengths and placing whole seeds or seed heads and leaves into each litter bag, which we uniquely labeled. We secured a composite 20-g sample (equal biomass of stems, leaves, and seeds) of a focal species in each litter bag, following Anderson and Smith (2002). We air-dried all litter bags with premeasured 20-g wet-mass plant materials, and then deployed them in the field experiment. All moist-soil managed wetlands had standing water in them when litter bags were deployed (see above for hydroperiod description), and all moist-soil managed wetlands remained inundated throughout the duration of the study (September 2004–July 2005).

On 15 September 2004, we distributed 13 litter bags/species into each moist-soil managed wetland. We deployed 39 litter bags (13 bags/species) in each moist-soil managed wetland, for 156 total litter bags used in this study. We established one transect in each moist-soil managed wetland, where we placed a uniquely marked pole every 10 m (13 posts in each moist-soil managed wetland; see Figure 2). We randomly attached three bags (one of each species) to each pole using 20 cm of monofilament and laid them on the wetland floor. Starting on 23 September 2004, we randomly retrieved three litter bags (1 bag/species) in each moist-soil managed wetland every 8 d. All litter bags were retrieved by 17 July 2005.

At the time of litter bag removal, we measured the following water quality metrics at each collection point: water depth (cm), water temperature (°C), dissolved oxygen (mg/L), conductivity (μS/cm^3), and pH using YSI model 85 and YSI 200 pH meter(s). We removed litter bags and placed them in a 500-μm sieve to capture any plant matter lost from the litter bag during retrieval in the field. We then placed each litter bag into a labeled plastic bag and stored it on ice. We removed plant material from each sample bag and gently washed it to remove silt and other debris (Wrubleski et al. 1997). We then oven-dried the remaining matter to a constant mass at 60°C for 48–92 h and weighed the matter to the nearest 0.01 g.

Data analyses

We calculated monthly mean decay rates and mass loss over time (i.e., months) from the initial time of

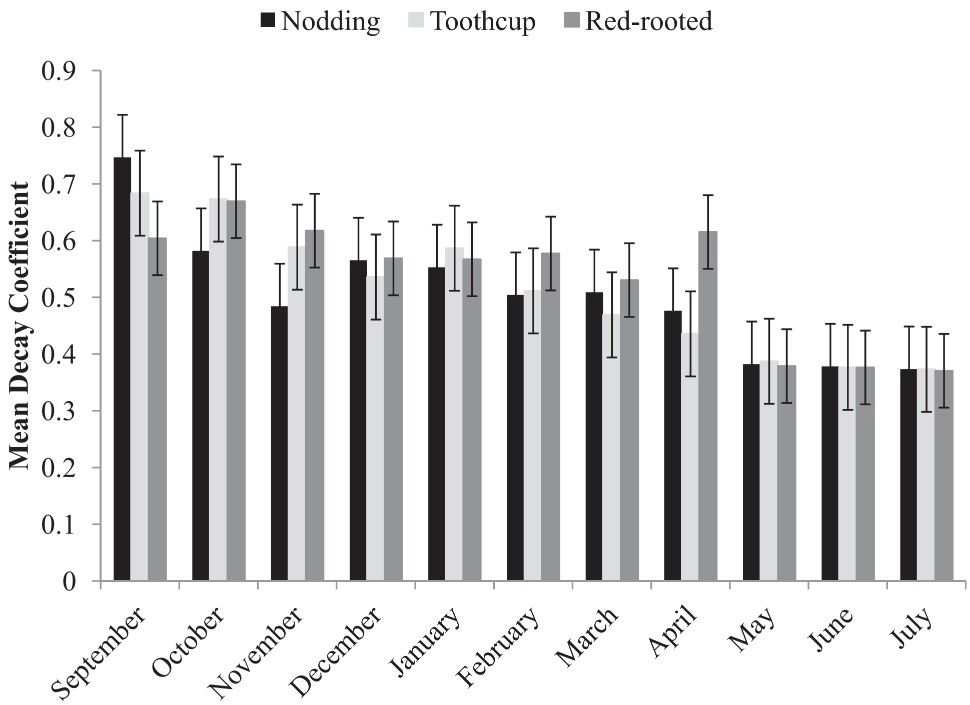

Figure 3. Mean decay coefficients rates of nodding smartweed *Persicaria lapathifolia*, toothcup *Ammannia coccinea,* and red-rooted flatnut sedge *Cyperus erythrorhizos* samples over time in moist-soil managed wetlands on Richland Creek Wildlife Management Area, East-central Texas, 23 September 2004–15 July 2005.

deployment as related to the entire study period, as well as the three stages of decomposition (i.e., leaching stage, decomposer stage, and refractory stage). We estimated decay coefficients for each species 1) among all moist-soil managed wetlands; and 2) within each moist-soil managed wetland using the single exponential decay model created by Taylor and Parkinson (1988). We fit data to the model as follows:

$$W_t/W_o = ln(-kt)$$

where t was time (days), W_o was the original mass (g), W_t was mass remaining at time t, and k was instantaneous mass loss rate per week. We calculated exposure days as the total number of days from day of deployment to day of retrieval. We used a factorial analysis of covariance to examine differences in biomass loss and decay coefficients within each species, among moist-soil managed wetlands, and among time periods. For these analyses, individual moist-soil managed wetlands were of interest as potential site-specific influences on biomass loss and decay coefficients (Data S1 and S2, *Supplemental Material*). Also, we used time periods as categorical decomposition stages (i.e., leaching stage: 0–45 d; decomposer stage: 46–120 d; and refractory stage: >120 d). We used the following (i.e., depth, temperature, conductivity, pH, and dissolved oxygen) as covariates in these analyses to examine whether characteristics of the extended inundation influenced biomass loss and decay coefficients. No drawdown occurred during this study; therefore, we did not examine the effect of hydroperiod transitions (see Gingerich et al. 2014).

Results

Mean monthly decay coefficient rates for all three species ranged from 0.60 to 0.74 $\pm$ 0.06 in September to 0.37 $\pm$ 0.005 in July (Figure 3). Collectively, decay rates during the first leaching stage (i.e., 0–45 d) of decomposition were 0.60 (nodding smartweed), 0.67 (toothcup), and 0.65 (red-rooted flatnut sedge). Approximately 50–75% of all decomposition for all three species occurred during this leaching stage (Figure 4). During the second (decomposer) stage (i.e., 46–120 d), decay rates were 0.53 (nodding smartweed), 0.55 (toothcup), and 0.59 (red-rooted flatnut sedge), indicating that an additional 15–20% mass loss occurred for nodding smartweed and toothcup, but only an additional 4% was lost for red-rooted flatnut sedge (Figure 4). During the final (refractory) stage (i.e., >120 d), decay rates were 0.44 (nodding smartweed and toothcup) and 0.48 (red-rooted flatnut sedge). An additional 10–15% additional mass was lost for each species during this final stage (Figure 4). All species lost nearly 100% of initial mass during the 11-mo deployment period. Both nodding smartweed and toothcup approached 100% mass lost by May (i.e., 228–257 d), whereas red-rooted flatnut sedge neared 100% mass lost by the end of May (i.e., 197–227 d; Figure 5).

Individual moist-soil managed wetland did not influence ($P > 0.05$) biomass loss or decay rate for any of the focal species, nor did any of the water-related covariates (i.e., depth, temperature, conductivity, pH, and dissolved oxygen; $P > 0.05$). As such, subsequent analyses focused upon time (i.e., days of exposure). For

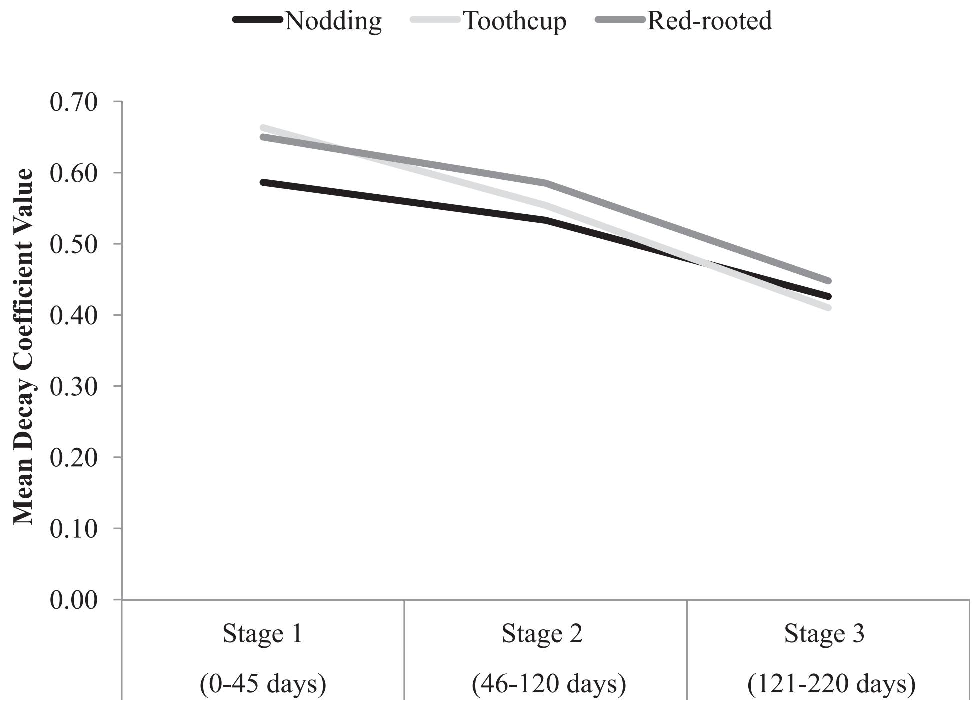

Figure 4. Mean decay coefficient rates of nodding smartweed *Persicaria lapathifolia*, toothcup *Ammannia coccinea*, and red-rooted flatnut sedge *Cyperus erythrorhizos* along three stages of decomposition from moist-soil managed wetlands on Richland Creek Wildlife Management Area, East-central Texas, 23 September 2004–15 July 2005.

nodding smartweed, time (F = 7.87, df = 1,51; P = 0.007) strongly influenced rate of mass loss, but not decay rate (F = 0.03, df = 1,51; P = 0.852). Stage of decomposition, rather than any individual moist-soil managed wetland or water covariate, was most influencing rate of mass loss, where most mass lost occurred during the first stage (see Figure 5). For toothcup, time (F = 40.92, df = 1,51; $P <$ 0.001) drove mass loss and decay rate (F = 4.21, df = 1,51; P = 0.045), where, as with nodding smartweed, most mass lost occurred during the first stage of decomposition (Figure 5). Finally, for red-rooted flatnut sedge, decay rates were driven by time (F = 7.14, df = 1,51; P = 0.010), but mass loss was not (F = 1.51, df = 1,51; P = 0.225). For all three focal species, time (i.e., stage of decomposition) was the driver of decomposition (i.e., mass loss and decay rate), rather than any water-related covariate or individual moist-soil managed wetland.

Discussion

Plant matter typically decomposes through fast, intermediate, and slow stages of leaching, decomposer, and refractory stages, respectively, according to the processes dominating mass loss during the three stages of decomposition (Bell et al. 1978; Valiela et al. 1985). The mass loss of the three seasonally abundant species followed this typical three-stage pattern, where nodding smartweed, toothcup, and red-rooted flatnut sedge lost approximately one-third of their biomass during the first stage of decomposition. Over the second stage of decomposition, all three species lost between 50% and 80%, while during the third stage, mass loss for all three species was nearly complete. Similarly, there was no direct influence of water quality nor individual moist-soil managed wetland on focal species decomposition, which was clearly driven solely by time since inundation. Spieles and Mora (2007) found that wetland hydrology (i.e., mean water depth and exposure duration) was significantly correlated and concluded that site conditions explain decomposition rates. However, previous studies have suggested decomposition rate is influenced by a wide range of factors that include litter nutrients and quality (Poi de Neiff et al. 2006; Crawford et al. 2007; Gingerich and Anderson 2011), invertebrates (Conner and Day 1991; Langhans and Tocker 2006; Poi de Neiff et al. 2009), microbes (Kuehn and Suberkropp 1998), site conditions such as hydrology (Atkinson and Cairns 2001; Anderson and Smith 2002; Poi de Neiff et al. 2006), transitions between wet and dry conditions (Gingerich et al. 2014), and water quality (Conner and Day 1991; Verhoeven and Arts 1992). Clearly, a wide variety of environmental influences drive decomposition in wetland systems, and influences likely include interactive suites of environmental factors.

Persistent inundation clearly will influence plant decomposition in shallow freshwater wetlands via stage 1 (leaching) and stage 2 (decomposer) decomposition (Neckles and Neill 1994). However, the most rapid decomposition will occur during aerobic conditions (Brinson et al. 1981; Anderson and Smith 2002), and transitions between wet and dry conditions will not only influence decomposition, but may accelerate (or even be a better predictor of) decomposition rate (Gingerich et al. 2014). Neither condition was observed in the current

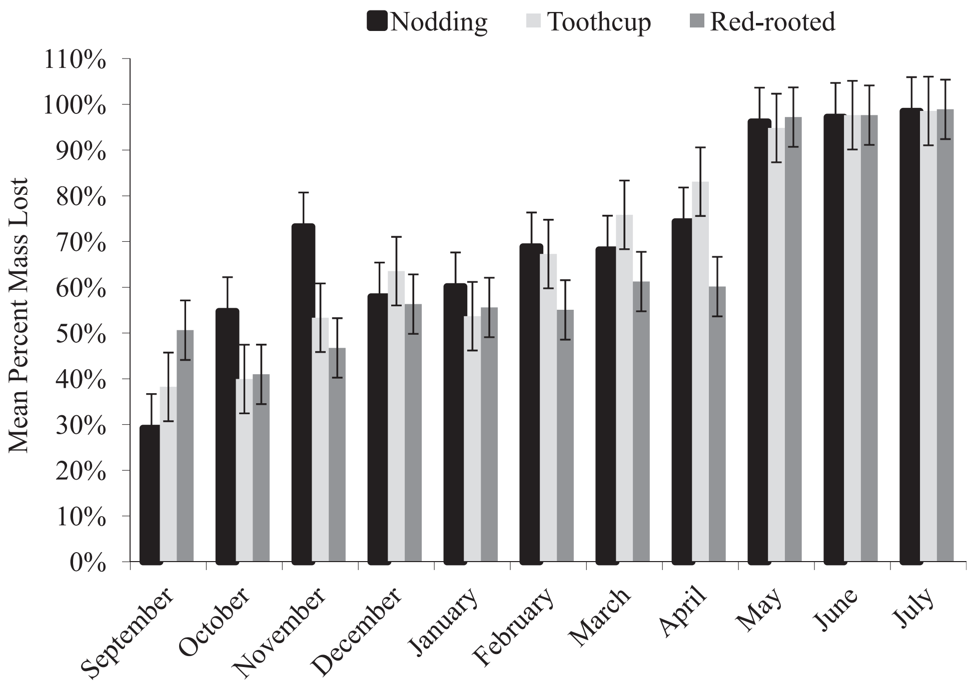

Figure 5. Mean percent mass lost over time (i.e., months) of nodding smartweed *Persicaria lapathifolia*, toothcup *Ammannia coccinea*, and red-rooted flatnut sedge *Cyperus erythrorhizos* on Richland Creek Wildlife Management Area, East-central Texas, 23 September 2004–15 July 2005.

study. For example, plant materials exposed to persistent inundation were entering stage 3 (refractory) decomposition phase by the end of the first growing season. However, plant materials exposed to intermediate inundation did not reach the refractory stage until the middle of the second growing season (Neckles and Neill 1994), suggesting relationships to inundation depth that were not apparent in this study. Depending on wetland type, mass loss can increase with frequency of inundation from intermittently flooded to flooded twice daily, but may not be influenced by daily and permanent flooding (Odum and Heywood 1978). In other wetland types, inundation duration has little effect on mass loss as long as litter is flooded for a portion of the growing season (Day 1982; Sharma and Gopal 1982; Neckles and Neill 1994). In short, inundation duration potentially impacts the timing and/or arrival of all decomposition stages for plant materials in the moist-soil managed wetlands used in this study.

Although the moist-soil managed wetlands at RCWMA did not go through a typical drawdown (i.e., drying) cycle, dry conditions tend to result in less leaching, as well as to inhibit microbial and invertebrate colonization and community development, resulting in loss of soluble plant material and slowing decomposition of readily decomposable fractions (Wrubleski et al. 1997; Weltzin et al. 2005). However, dry conditions do provide temporal windows in which decomposition accelerates, particularly if portions of plants of interest are less structurally complex (see Anderson and Smith 2002). The physical structure of these three wetland plant species might allow for rapid decomposition, although none of the other measured environmental conditions (i.e., water temperature and depth, conductivity, pH, and dissolved oxygen) influenced decomposition. Ruppel et al. (2004) stated that pH and dissolved oxygen appeared to be the most significant factors affecting decomposition rates, followed closely by aquatic invertebrate density. However, their work was conducted during a relatively short temporal window, whereby decomposition rates could have been much greater if their study was continued longer and during summer, where water quality variables may more directly impact decay rates. Murkin et al. (1989) suggested that to remove the most litter an area should be flooded long enough to allow the species to complete the second phase of decomposition.

Anderson and Smith (2002) and Wrubleski et al. (1997) concluded that pink smartweed *Polygonum pensylvanicum* and other annuals have plant parts that decompose at different rates. Pink smartweed followed the three stages of decomposition (Valiela et al. 1985; Murkin et al. 1989), but the rate of mass loss varied according to plant part and hydrological regime in natural playa wetlands (Anderson and Smith 2002). Although the current study focused on aboveground biomass (i.e., leaves, stems, and seeds), Murkin et al. (1989) reported that litter was quite persistent in northern prairie marshes, where 70% of shoot litter and 50% of root litter was still present after 1 y in the field. In that instance, shoot and root parts did not decompose rapidly, but created litter mats on the wetland floor. Such litter can reduce germination during drawdowns or inundation by physically changing environmental conditions such as light or temperature regimes, burying seedlings, and potentially releasing chemicals that inhibit seed germination or development (i.e., through allelopathy; van der Valk 1986). In contrast, in more southerly latitudes in playas with variable inundation duration, Anderson and Smith (2002) reported that decomposition was more rapid and more complete in playas that were flooded <50% of the time. These diverse responses to flooding, and specific plant-part response to flooding, have hindered generalizations regarding the effects of flooding on decomposition in wetland ecosystems. In the present study, despite permanent inundation throughout the study, nearly complete mass loss occurred, although future work should focus upon experimentally manipulating water depth and inundation duration in moist-soil managed wetlands to examine their influence on decomposition of different plant parts as well.

Neckles and Neill (1994) also found that water depth and inundation duration played a major role in mass loss over time with ≥50% lost by the time plants entered into the third (refractory) stage of decomposition. Similarly, Anderson and Smith (2002) observed rapid (within 7 d) mass loss of pink smartweed (seeds, stems, and leaves) in inundated playas. In this study, each focal species had lost ≥40% of their mass in 45 d, whereas nodding smartweed lost 55% by this time. As moist-soil managed wetlands age, they may shift from a detritus-poor to a detritus-rich system where organic matter may accumulate, although natural wetland substrates typically contain greater organic content (Craft et al. 1999, 2002; Nair et al. 2001; Campbell et al. 2002; except for playas, which historically have low organic soil components). Consequently, rates of detritus decomposition and accumulation increase with age in created wetlands (Atkinson and Cairns 2001; Spieles and Mora 2007). As such, if traditional moist-soil management (i.e., properly timed inundation and drawdowns) is conducted on RCWMA, these moist-soil managed wetlands will eventually experience more efficient decomposition rates and nutrient cycling over time.

Management Implications

Plant matter decomposition is key for both short-term and long-term productivity of moist-soil managed wetlands, and should be foci of hydroperiod manipulation regimes. In this study, nearly 100% of plant matter decomposed after 11 mo of inundation, although transitions between inundated and dry conditions (see Gingerich et al. 2014) would likely expedite decomposition of annuals used in this study. Therefore we recommend hydroperiod manipulation on RCWMA specifically, and for moist-soil managed wetlands regionally, to consistently mirror typical drawdown and inundation regimes used in traditional moist-soil managed wetlands. Coupled with other acceptable habitat manipulations, traditional hydroperiod manipulation will promote efficient nutrient cycling and litter decomposition to promote germination, growth, and maturation of desired moist-soil plant species.

Supplemental Material

Please note: The *Journal of Fish and Wildlife Management* is not responsible for the content or functionality of any supplemental material. Queries should be directed to the corresponding author for the article.

Data S1. Data used for analyses of all three moist-soil plant species in which decomposition rates were examined in 2004–2005, in moist-soil managed wetlands in East-central Texas, are contained in the XLS source file under the overall tab with column abbreviations explained in the TXT source file.

Found at DOI: http://dx.doi.org/10.3996/072013-JFWM-050.S1 (128 KB XLS).

Data S2. Column abbreviations for Data S1.

Found at DOI: http://dx.doi.org/10.3996/072013-JFWM-050.S2 (1 KB TXT).

Reference S1. Collins DP. 2012. Moist-soil managed wetlands and their associated vegetative, aquatic invertebrate, and waterfowl communities in East-central Texas. Doctoral dissertation. Nacogdoches, Texas: Stephen F. Austin State University.

Found at DOI: http://dx.doi.org/10.3996/072013-JFWM-050.S3 (6689 KB PDF).

Reference S2. Fredrickson LH, Taylor TS. 1982. Management of seasonally flooded impoundments for wildlife. Washington, D.C.: U.S. Fish and Wildlife Service, Resource Publication 148.

Found at DOI: http://dx.doi.org/10.3996/072013-JFWM-050.S4 (2536 KB PDF).

Reference S3. Lane JJ, Jensen KC. 1999. Moist-soil impoundments for wetland wildlife. U.S. Army Corps of Engineers. Technical Report EL-99-11.

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