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Abstract

Methods to sample the abundance of moist-soil seeds efficiently and accurately are critical for evaluating management practices and determining food availability. We adapted a portable, gasoline-powered vacuum to estimate abundance of seeds on the surface of a moist-soil wetland in east-central Mississippi and evaluated the sampler by simulating conditions that researchers and managers may experience when sampling moist-soil areas for seeds. We measured the percent recovery of known masses of seeds by the vacuum sampler in relation to 4 experimentally controlled factors (i.e., seed-size class, sample mass, soil moisture class, and vacuum time) with 2–4 levels per factor. We also measured processing time of samples in the laboratory. Across all experimental factors, seed recovery averaged 88.4% and varied little (CV = 0.68%, n = 474). Overall, mean time to process a sample was 30.3 ± 2.5 min (SE, n = 417). Our estimate of seed recovery rate (88%) may be used to adjust estimates for incomplete seed recovery, or project–specific correction factors may be developed by investigators. Our device was effective for estimating surface abundance of moist-soil plant seeds after dehiscence and before habitats were flooded. (WILDLIFE SOCIETY BULLETIN 34(1):186–190; 2006)

Key words

Mississippi, moist-soil management, moist-soil plants, sampling methods, seed abundance, wetlands.

Moist-soil management entails manipulation of vegetation, soil, seed banks, and hydrology to stimulate production of herbaceous vegetation and propagules (e.g., seeds, tubers) as food for waterfowl and other wetland wildlife (Low and Bellrose 1944, Fredrickson and Taylor 1982). Managers typically apply this technique on seasonally flooded wetlands in regions important to migrating and wintering waterfowl (Smith et al. 1989).

Researchers and managers have used many techniques to estimate abundance of seeds and tubers used by waterfowl and other wildlife (Higgins et al. 1996). Many studies estimated seed yield of moist-soil plants by clipping plants and threshing seeds from inflorescences (Low and Bellrose 1944, Haukos and Smith 1993, Taylor and Smith 2003). Seed traps have been used to estimate seed production in uplands (Davison et al. 1955) and wetlands (Olinde et al. 1985, Moser et al. 1990, Penny 2003). Measurements of seed-head morphology have been used to develop predictive models to estimate seed production (Laubhan and Fredrickson 1992; Gray et al. 1999*a*,*b*; Sherfy and Kirkpatrick 1999). Soil cores have been used to estimate seed availability of legumes (Ripley and Perkins 1965), waste rice (Manley et al. 2004, Stafford et al. 2005), and wetland seeds and tubers (van der Valk and Rosburg 1997, Naylor 2002, Penny 2003). Generator-powered vacuums have been used to estimate waste-rice abundance but not natural seed abundance in wetlands (Miller et al. 1989).

Harper and Guynn (1998) collected terrestrial invertebrates with a backpack-mounted vacuum sampler and suggested vacuums could be used to estimate seed production and availability for wildlife. Our objectives were to evaluate accuracy of a portable, gasoline-powered blower-vacuum to estimate abundance of seeds on the surface of moist-soil habitats in autumn after seed fall, as an alternative to available techniques, and to quantify processing time of samples obtained with this device.

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Study Area

We conducted our evaluation in moist-soil habitat in a privately owned and managed wetland impoundment (6 ha) 20 km south of Starkville, Mississippi, adjacent to Noxubee National Wildlife Refuge (33.3° N, 88.1° W). This area represented moist-soil habitat typical of the Mississippi Alluvial Valley (MAV; Reinecke et al. 1989). Management practices in the complex involved autumn–early winter natural flooding, followed by drawdown during April–May, and annual or alternate-year mowing or disking in June–July to promote growth of grasses and sedges (Fredrickson and Taylor 1982, Gray et al. 1999*c*).

Methods

Vacuum Sampler

We used a Stihl™ model BG 85 blower-vac (Stihl Incorporated, 536 Viking Drive, Virginia Beach, Virginia) equipped with a Stihl BG 85 vacuum kit (No. 4229–007-1000). We selected the Stihl BG 85 because it was lightweight (4.2 kg) and the most powerful hand-held blower-vacuum commercially available. Air speed in the collection head was >82 m/sec, which Southwood (1978) indicated was sufficient to collect terrestrial invertebrates and seeds.

The blower-vacuum was equipped with a black plastic tube (11.4-cm inside diameter, 80-cm length) mounted to the engine housing (Fig. 1). We reinforced the tube's attachment to the motor with duct tape. The tube was similar in diameter to conventional core samplers used to collect invertebrates and moist-soil plant seeds (Murkin et al. 1996, Penny 2003, Manley et al. 2004). We cut the angled distal end of the tube straight and cemented a PVC coupler (12.7-cm inside diameter, 9.5-cm

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Figure 1. A blower-vacuum sampler (Stihl BG-85) used to estimate abundance of moist-soil plant seed mass.

Figure 3. A sampling frame used in moist-soil habitat to prevent collection of seeds outside the sampling area during vacuum sampling.

length) to this end (Fig. 2). We inserted a second PVC coupler (11.4-cm inside diameter, 9-cm length) into the first coupler to fabricate a removable attachment (Fig. 2). Before field sampling, we inserted a nylon stocking (10-cm length) inside the removable coupler to collect seeds and prevent vacuumed material from reaching the engine fan (Fig. 2). Separate from the vacuum, we used a circular section of plastic coupling (12.7 cm in diameter, 4 cm in height) as a sampling frame to prevent the vacuum from collecting seeds outside the enclosed sample area (Fig. 3).

Experimental Design

We conducted field evaluations 25 April and 9 May 2002. We chose spring to minimize collection and mixing of naturally occurring seeds with those deposited for the experiment. We measured recovery of moist-soil seeds by the vacuum sampler in relation to 4 factors with 2–4 levels per effect: 1) seed size (very small, small, intermediate, or large), 2) sample mass (low, intermediate, or high), 3) surface soil-moisture (moist or dry), and 4) vacuum time (10 or 20 sec). We simulated conditions researchers and managers may experience when sampling, replicated each treatment combination 10 times, and collected 480 samples.

Figure 2. PVC couplers attached to the Stihl BG-85 hand-held blower vacuum, showing inserted nylon stocking that collected seeds and debris during vacuum sampling.

To represent variation in seed sizes, we selected seeds of common moist-soil and agronomic plants consumed by waterfowl and found in wetlands (Reinecke et al. 1989). We used 1) sprangletop (*Leptochloa fusca*) to represent very small seeds, 2) common barnyard grass (*Echinochloa crusgalli*) as small seeds, 3) Japanese millet (*E. frumentacea*) as intermediate seeds, and 4) rice (*Oryza sativa*) to mimic large natural seeds (e.g., horned beak rush, *Rhynchospora corniculata*). We obtained Japanese millet from a local vendor and other seeds from Mississippi State University Delta Research and Extension Center (DREC) in Stoneville, Mississippi.

Because moist-soil seed abundance varies spatially and temporally (Gray et al. 1999*c*, Penny 2003), we tested the effect of varying sample mass on recovery rate. We selected treatment levels for this effect as a function of a published estimate of high seed abundance in intensively managed moist-soil impoundments (1,629 kg/ha [dry mass]; Fredrickson and Taylor 1982). We selected 3 percentiles of this estimate to represent increasing seed mass within each seed-size class: 1) low mass, 10% of 1,629 kg/ha; 2) intermediate, 50%; and 3) high, 90%. We converted each percentile category to mass per 113 cm^2 (i.e., our circular sampling area).

We stained experimental seeds with a liquid red vegetable dye to mark and differentiate seeds used in our evaluation from naturally occurring seeds, soil, and plant litter recovered by the vacuum. We weighed air-dried samples to the nearest 0.001 g and allocated seeds to the 3 experimental mass categories.

We evaluated the vacuum sampler under dry and moist soil conditions. We deemed soil dry when topsoil exhibited no surface water and felt dry to the touch. We deemed soil moist following a rainfall event of approximately 1 cm when soil was wet but no surface water was present. We selected vacuuming times of 10 and 20 seconds to test if seed recovery varied with vacuuming time and deemed 10 and 20 sec reasonable field sampling periods.

Table 1. Mean percent recovery of known-mass samples of moist-soil seeds by seed size (plant species), soil-moisture class (dry, moist), and vacuuming time (10, 20 sec) for an experimental vacuum sampler, Mississippi, 2002.

Seed size	Soil moisture[a]	Vacuuming duration[a]	% recovery		
			$\bar{x}$	SE	n
Very small (*Leptochloa fusca*)			74.5	1.3	119
Small (*Echinochloa crusgalli*)			95.9	0.5	117
Intermediate (*E. frumentacea*)	Moist	10	92.5	1.8	30
		20	87.8	1.8	30
	Dry	10	97.1	1.7	30
		20	92.0	1.7	30
Large (*Oryza sativa*)			90.8	0.8	118
		Mean	88.4	0.4	474

[a] Statistics for soil moisture and vacuum time were included only when these were significant ($P < 0.05$) effects in analysis of variance.

Field and Laboratory Procedures

We placed the circular sampling frame at randomly selected points in the moist-soil habitat and scattered a sample of randomly selected seed size and mass within the frame. While the machine was idling, we placed the vacuum sampler tube in contact with the ground. We engaged the throttle and vacuumed at full speed for 10 or 20 sec. After vacuuming, we removed the nylon stocking containing the recovered material.

We processed samples by manually separating marked seeds from soil and debris with a series of sieves and forceps (Nos. 16, 18, 50 meshes [1.00-mm, 1.16-mm, and 300-μm apertures]). We used a 5× Magni-Focuser™ (Edroy Products Company, Incorporated, Nyack, New York) to recover marked seeds. To assess sample processing efficiency, we recorded minutes required to remove marked seeds from each sample. We weighed recovered air-dried seeds to the nearest 0.001 g with a digital scale.

Statistical Analyses

Our experimental unit for analysis of seed-recovery data was the individual sample of known seed mass. We expressed seed recovery rate as the percentage of known seed mass placed in the sample plot. Initially, we used analysis of covariance (ANCOVA, PROC MIXED; SAS Institute 1999), with known mass of seeds placed at each site as a categorical covariate (i.e., 1 = low, 2 = medium, 3 = high), to model the effects of experimental treatments on percent seed mass recovered. However, the covariate had minimal influence on mean percentages of seed mass recovered among treatment combinations (i.e., difference was <1%). Therefore, we deleted the covariate from our models and tested treatment effects using analysis of variance (PROC MIXED; SAS 1999). We designated soil-moisture class and vacuuming time as fixed effects. Although we did not designate any random effects, we used PROC MIXED because it enables analysis of data with equal or unequal variance structures (Littell et al. 1996). Akaike's Information Criterion provided by PROC MIXED indicated a model with unequal variances was best supported by our data. We performed analyses within seed-size classes because earlier field observations during autumn 2001 indicated our 12.7-cm-diameter sample frame typically contained only seeds from one dominant plant species at each sample site (Penny 2003). We omitted 6 samples from analyses because of inaccurate measurements or loss of samples.

We defined sample processing time as minutes expended removing marked seeds from a sample. We predicted processing time would increase with mass of recovered seed; therefore, we included recovered seed mass as a continuous covariate in ANCOVA. We designated soil-moisture class (i.e., moist or dry) as a fixed effect. We performed ANCOVA within seed-size classes and did not designate any random effects in PROC MIXED consistent with our analyses of seed recovery data. We omitted the 20-sec vacuuming period as an effect in ANCOVA of processing time because recovery rate for 3 of 4 seed-size classes did not differ ($P > 0.05$) between vacuuming periods and was lower for intermediate-sized seeds when vacuuming time was 20 sec (see Results).

Results

Seed Recovery

Recovered percentages of very small-, small-, and large-sized seeds did not vary with soil moisture or vacuuming time ($0.096 \leq P \leq 0.931$). Mean recovery was lowest (74.5%) for very small seeds, intermediate (90.8%) for large seeds, and greatest (95.9%) for small seeds (Table 1). Soil moisture ($F_{1, 111} = 6.61$, $P = 0.012$) and vacuuming time ($F_{1, 111} = 7.93$, $P = 0.006$) independently influenced recovery of intermediate-sized seeds. Mean recovery of intermediate-sized seeds was greater for samples vacuumed from dry soil for 10 sec (97%) than 20 sec (92%) and greater for 10 sec (93%) than 20 sec (88%) from moist soil (Table 1). Across seed-size classes, soil-moisture categories, and vacuuming times, overall seed recovery averaged 88.4% and varied little (CV = 0.45%, $n = 474$; Table 1).

Processing Time

Soil moisture and recovered mass of seeds interacted to influence processing time of very small seeds ($F_{1, 56} = 4.43$, $P = 0.039$). Mean processing time for samples with very small seeds decreased 37% between dry- (118.7 ± 5.2 min [SE]) and moist-soil (74.4 ± 5.2 min) samples at the mean recovered mass over all experimental combinations (0.610 g; Table 2). Only recovered seed mass influenced processing time (16.1 ± 0.8 min; Table 2) of small seeds ($F_{1, 58} = 14.21$, $P = 0.004$). Recovered mass ($F_{1, 55} = 110.67$, $P = 0.001$) and soil moisture ($F_{1, 55} = 4.11$, $P = 0.047$) independently influenced processing time of intermediate-sized seeds. Nonetheless, mean processing time of these seeds differed only by 2 minutes between soil-moisture categories (9.1 ± 0.6 min, dry soil; vs. 7.2 ± 0.7 min, moist soil; Table 2). Only recovered seed mass influenced processing time of large seeds ($F_{1, 58} = 24.16$, $P = 0.001$). As anticipated, mean processing time was least

Table 2. Least-squares mean processing time (min) of samples estimated at the overall mean for recovered moist-soil plant seed mass (0.610 g) by seed-size (plant species) and soil-moisture classes (dry, moist), Mississippi, 2002.

		Processing time		
Seed size	**Soil moisture[a]**	$\bar{x}$	**SE**	**n**
Very small (*Leptochloa fusca*)	Dry	118.7	5.2	60
	Moist	74.4	5.2	59
Small (*Echinochloa crusgalli*)		16.1	0.8	60
Intermediate (*E. frumentacea*)	Dry	9.1	0.6	60
	Moist	7.2	0.7	60
Large (*Oryza sativa*)		1.5	0.1	118
	Mean	30.3	2.5	417

[a] Statistics were presented for soil moisture when it was a significant ($P < 0.05$) effect in analysis of covariance.

for large seeds (1.5 ± 0.1 min; Table 2). Across all seed sizes and soil-moisture categories, mean processing time was 30.3 ± 2.5 min for the 10-sec vacuuming time (Table 2).

Discussion

Seed Recovery

Neither soil moisture nor vacuuming time affected seed recovery rates for very small, small, and large seeds. Seed recovery was greater for small seeds than very small and large seeds. Because optical equipment readily enabled detection of recovered marked seeds, we speculate decreased recovery of very small seeds may have resulted from the vacuum sampler dispersing some very small seeds outside the sampling frame immediately before vacuuming. Samples of large seeds were composed of fewer seeds of greater individual mass; hence, failure to recover one large seed had a greater influence on the percentage of seed mass recovered than missing ≥1 small seeds. Mean recovery of intermediate-sized seeds was greatest from dry soil after vacuuming for 10 sec. Moist soil may have caused some seeds to adhere to the substrate and reduce recovery. We cannot explain increased recovery of intermediate-sized seeds after vacuuming for 10 instead of 20 sec.

Processing Time

As predicted, recovered seed mass increased processing time for all seed-size classes (Penny 2003). Additionally, the interaction of recovered seed mass and soil-moisture class was important in explaining variation in processing times of samples containing very small seeds. Some randomly selected plots where very small seeds were placed were especially moist, and soil seemed less compacted at these plots. Very small seeds were more difficult for laboratory personnel to separate from moist loose soil than dry soil because optical equipment was necessary. Additionally, samples that exceeded 0.610 g (i.e., overall mean recovered seed mass) contained more seeds and required additional processing time.

Across all seed-size classes, processing time was greatest when samples were vacuumed from dry soil (Penny 2003). We suggest the increased volume of material recovered when sampling dry soil increased processing time, although we did not weigh debris recovered in samples. Conversely, adhesiveness of moist soil at some sites may have reduced collection of debris and thereby reduced processing time. Overall, mean processing time varied greatly and ranged from 1.5 min for samples containing large seeds to 118.7 min for small seeds.

Management Implications

Researchers and managers require accurate and efficient methods to estimate moist-soil plant seed mass (Laubhan and Fredrickson 1992, Gray et al. 1999*a*). Our modified vacuum sampler provided an effective and efficient alternative method to estimate relative abundance of moist-soil seeds on the soil surface in autumn. We recommend other researchers and managers evaluate the vacuum sampler after seed fall in autumn to determine general applicability of the technique in moist-soil habitats. Generally, seed recovery was greater when samples were vacuumed from dry than moist soils. Therefore, we recommend users vacuum under dry soil conditions for 10 sec to increase seed recovery rates, although processing time also may increase under these conditions. Because seed recovery was incomplete (88%) with vacuum sampling, we recommend users increase recovered mass of seeds by a factor of 1.14 (1.00/0.88) or develop their own correction factor.

Sample processing time varied relative to seed size, soil moisture, and debris in samples, but processing time of vacuum samples was only half that of soil cores (Penny 2003). For planning purposes we recommend users of the vacuum sampler anticipate an average laboratory processing time of approximately 30 min per sample.

In a related study, we collected soil cores in the MAV in October–mid-November 2002 after seed fall but before managed areas were flooded (Penny 2003). Under these conditions, investigators can use the vacuum sampler to estimate seed mass on the soil surface of moist-soil habitats. Our sampler was not designed to recover seeds or tubers from beneath the soil surface. We recommend core sampling if above- and below-ground estimates of seeds and tubers are needed (e.g., Penny 2003, Manley et al. 2004, Stafford et al. 2005).

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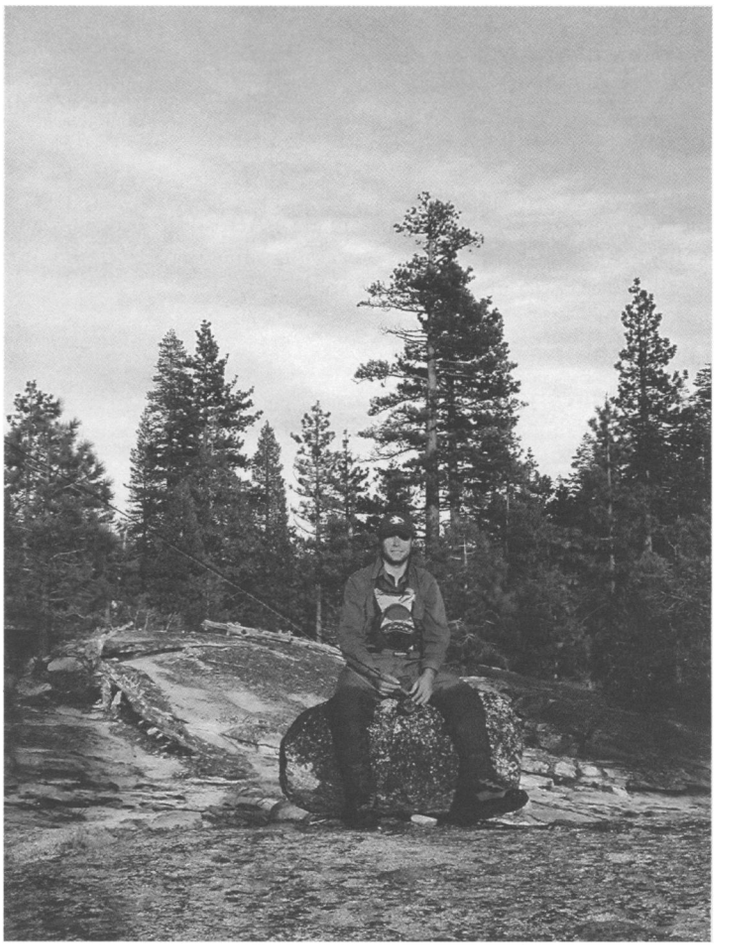

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