Rodent Damage to Direct Seeded Willow Oak in Louisiana

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Abstract: Direct-seeding is no longer commonly used for reforesting bottomland hardwood habitat because of low seedling survival due in part to predation of seeds by animals. We investigated the impact of seed predation by rodents on direct seeded willow oak (*Quercus phellos*). Acorns of willow oak were planted at a rate of 5,982 seeds/ha on low-lying farmland in the Ouachita Wildlife Management Area, Louisiana. A 200 live-trap grid and randomly placed seedling survival plots were used to study the relationship between density and activity of rodents, and predation rate of seeds and seedling survival. Rice (*Oryzomys palustris*) and cotton (*Sigmodon hispidus*) rats were the most likely acorn predators. Average survival rate of seedlings was negatively correlated with rodent activity. The phenological maturity of vegetation and the amount of vegetative cover was positively correlated with rodent activity. By seeding at rates 62% higher than normal (5,982 seeds/ha), successful seedling establishment was achieved despite moderate densities of rodent seed predators. Management guidelines are suggested to maximize the efficacy of direct-seeding on cleared bottomland sites.

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Approximately 36,891 ha of marginal cropland in Louisiana was replanted to bottomland hardwood forest by various governmental agencies in the last 10 years (D. Feducia, La. For. Comm.; D. Lawrence, Nat. Resour. Conserv. Serv.; S. Mott, U.S. Fish and Wildl. Serv.; K. Ribbeck, La. Dep. Wildl. and Fish.; and J. Webber, U.S. Corps. Eng., pers. commun.). Nearly one-quarter of this total is the result of the Louisiana Department of Wildlife and Fisheries (LDWF) effort to enlarge and connect existing state owned wildlife management areas. The work began in 1967 and relies on 2 methods of establishing hardwood seedlings: planting of 1-year nursery seedlings and direct seeding of acorns.

Based on LDWF experience, direct seeding has proven to be economical and allows an expanded planting season, especially where heavy-clay soils discourage mechanized seedling planting. Fall and winter direct seeding also eliminates the need for seed storage. Despite these advantages, several agencies have abandoned direct seeding as a method of choice because of extensive failures during the late-1980s (Allen 1990). Suspected causes of low seedling survival after direct seeding include residual herbicide contamination, drought, animal predation, flooding, poor seeding technique, low seed quality, off-site planting, and weed competition (Kennedy 1990).

We had success direct seeding approximately 30% of the 1,619-ha reforestation project completed on Ouachita Wildlife Management Area (WMA) in 1993. Excellent seedling establishment was produced by direct planting of the large seeds of nuttall oak (*Quercus nuttallii*), even under drought conditions; however, planting smaller-sized seeds such as water (*Q. nigra*), cherrybark (*Q. falcata pagodoefolia*), laurel (*Q. laurifolia*), and willow oak produced variable results. In June 1992, 115 ha of direct seeded willow oak appeared to have significant animal damage to germinating seedlings. Because rodent damage is suspected as a serious problem in direct seeding but is not well documented (S. Meadows, pers. commun.), we conducted this study to identify the seed predators and measure the extent of damage to germinating seedlings.

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Methods

Ouachita WMA is a 3,539-ha tract owned and managed by LDWF in Ouachita Parish, Louisiana. Bottomland hardwood forest covers 36% of the area. The remaining 64% was deforested in the mid-1960s and farmed 20 years for rice and soybean production. This portion of the WMA has been undergoing an intensive wetland restoration process since its purchase in 1984. Ouachita WMA lies completely within the Bayou Lafourche floodplain. Perry clay is heavy alluvial clay soil that occupies 90% of this site and is subject to a frequency of flooding of 1 to 5 years in late-winter and spring. Historically, this soil supported mixed stands of overcup oak (*Q. lyrata*), bitter pecan (*Carya aquatica*), green ash (*Fraxinus pennsylvanica*), nuttall oak, sugarberry (*Celtis laevigata*), honey locust (*Gleditsia triacanthos*), persimmon (*Diospyros virginiana*), American elm (*Ulmus americana*), drummond red maple (*Acer drummondii*), and swamp privet (*Forestiera acuminata*). Soils deposited as natural levees by the Arkansas River occupy the remaining 10%. These narrow silt-loam ridges are composites of Hebert, Portland, and Rilla soils that are subject to inundation once every 5 to 50 years. Willow oak, cedar elm (*U. crassifolia*), and delta post oak

(*Q. stellata mississippiensis*) were prominent overstory species. DePoe and Pritchett (1986) described the soils and vegetation of the area in detail.

Hardwood regeneration methods followed recommendation of USDA Hardwood Research Station Stoneville, Mississippi (Johnson 1984, Kennedy 1990). In August 1991, 115 ha of silt-loam ridge soil was site prepared for fall planting by double discing. This acreage was distributed over 7 different fields ranging in size from 5 ha to 34 ha. Locally collected acorns of willow oak were removed from 5 months of cold storage and direct seeded at a spacing of 0.5 × 3.7 m on 28 April and 5 May 1992. A prestorage viability test indicated 96% seed soundness. A John Deere 7300 Maximerge planter equipped with a laser seed drop indicator was used to plant approximately 5,982 seeds/ha to an average soil depth of 5 cm. This seeding rate was 62% above our normal rate of 3,707/ha, to compensate for expected reduced survival because of the late planting date and the harsh nature of the silt-loam ridge site. Soils on the site were droughty and depleted by 20 years of intensive farming. Hardwood restoration projects in other areas of the lower Mississippi River valley experienced difficulties on similar sites (Allen 1990).

Normal LDWF procedure for assessing direct seeding results is to establish seedling survival plots representing a 2% sample. Survival plots were established on every third row at the time of planting. A 15.2-m length of the row was marked with 5, 1-m stake wire flags placed directly in the planter furrow. Plots were aligned across the field to represent variations in soil type and elevation. Regeneration is considered successfully established in a field if an average of ≥3 live seedlings/plot (i.e., ≥539 seedlings/ha) is present in the fall, 1 growing season after planting.

Seedling survival is normally determined in November; however, because of animal damage noted early in 1992, 2 additional evaluations of survival plots were made. Seedling survival in June, August, and November, and seedspot (i.e., location of 1 planted acorn) damage in August were determined by close visual inspection of a narrow 5- to 10 cm-wide area delineated by a string pulled between wire flags marking each survival plot. This method gave a fairly precise reconstruction of the original planter furrow. Seedspots were considered damaged if characteristic rodent digging (digs) was observed near the string. Digs were small excavations with soil piled in one direction. Digs were recorded in 2 ways, those with direct evidence of damage to seed or seedling and digs without evidence of damage. Percent damage was determined by dividing the number of digs/15.2-m plot by the estimated planting rate of 33 seeds/plot. During the August evaluation, 2 characteristics of the vegetation at each survival plot were recorded. The average height was measured with a calibrated range pole to the nearest 0.1 m. Percent ground cover was determined by ocular estimation from above.

Sherman folding live traps (8 × 9 × 23 cm) baited with rolled oats were used to capture rodents. Rodents were collected in 2 fields with 100 traps spaced in 10 × 10 m grids and in 3 fields with grids having 2 traps aligned at opposite ends of seedling survival plots at 15.2 × 14.6 m.

A small-scale enclosure/exclosure study was conducted to help identify potential seed predators and demonstrate the capability of identified rodents to locate and unearth planted seeds. Three enclosure/excluder cages 0.6 × 0.6 × 2.4 m in size were constructed of 13 mm mesh hardware cloth to eliminate rodent access, and 25 mm poultry wire to eliminate rabbit and raccoon access but admit rodents. In the last week of July 1992 a simulated direct seeding was established in heavy clay soil in a field that had evidence of rodent damage. Willow oak acorns were hand planted 5 cm deep in 5 treatments of 12 seeds beneath cages. Treatments were seeds enclosed with a female hispid cotton rat, seeds enclosed with a male marsh rice rat, seeds excluded from large mammals but exposed to rodents, and seeds excluded from all animals. A fifth treatment of 20 seeds was planted adjacent to cages as a standard of comparison (control).

For population studies, animals were captured for 10 consecutive days (28 July to 6 August) in a grid of 200 traps spaced at 15 × 15 m. Animals were marked in each ear with numbered Monel 1005-1 small animal ear tags (Natl. Band and Tag Co., Newport, Ky.) and released. Trap days totaled 2,000. The Triple Catch method (Begon 1979, Donnelly and Guyer 1994) was used to calculate abundance of cotton and rice rats on the first, fifth, and ninth days of trapping. Ninety-five percent (95%) confidence intervals were derived for fifth day population estimates. The Triple Catch method makes few assumptions and can be used in situations where populations are open to gains and losses. Rat densities were calculated by dividing the abundance of each species at the mid-point of the trapping period (day 5) by the area of the trapping grid.

We used SAS PROC MEANS to calculate standard errors for field values (SAS Inst. 1985) PROC GLM was used to test for differences in seedling abundance during each sampling period and total damage due to rodents during the summer (SAS Inst. 1985). The Waller-Duncan K-ratio option was used to determine groupings of variable means.

Results

Preliminary seedling counts among fields in June varied (F = 19.6, 6 df, P < 0.0001). Mean live willow oak seedlings/plot (LWOS) ranged from 1.3 to 10.5 (Table 1). LWOS varied among fields in 20 July to 8 August (F = 34.97, 6 df, P < 0.0001), ranging from 1.0 to 12.5. Differences were also detected in November (F = 20.29, 6 df, P < 0.0001).

Seedspot disturbance was variable (F = 13.29, 6 df, P < 0.0001), ranging from 1.4 to 13.8 digs/plot. Digs typically occurred in old planter scars at regular intervals indicating association with seedspots, and were often accompanied by an exposed acorn, partially eaten seed, empty pericarp, and damaged seedling. Both old (i.e., weathered) and new digs were present during sampling indicating that June and July were periods of rodent damage. Field 19 had the highest disturbance rate for a single plot with 32 of 33 potential seedspots disturbed. Seed predation by rodents, as evidenced by their characteristic diggings, was correlated (R_s = −0.85, N = 7, P = 0.038) with the number of seedlings surviving in each plot at the end of the germination period (Table 1). Five fields with the highest dig rates had a reduction or no gain in seedling germination between June and August. Over all fields, 9.9% to 22.9% of the

Table 1. Seedling survival rates and rodent damage on Ouachita Wildlife Management Area, Louisiana, 1992.

	Willow oak seedlings/15.2-m plot									Rodent digs/15.2-m plot		
	Jun			Jul/Aug			Nov			Jul/Aug		
Field	*N*	$\bar{x}$	SE	*N*	$\bar{x}$	SE	*N*	$\bar{x}$	SE	*N*	$\bar{x}$	SE
24	28	10.5A[a]	1.0	27	12.5A	1.1	27	14.6A	1.2	27	1.4E	0.5
19	28	5.0B	1.2	28	2.8B	0.9	28	8.9B	1.4	28	7.6CD	0.9
21	68	4.0BC	0.5	68	5.4BC	0.6	55	7.4B	0.7	68	6.2D	0.9
22	90	3.3CD	0.4	90	2.4CD	0.4	90	4.4C	0.4	90	7.1CD	0.5
17	17	1.3E	0.6	17	1.0E	0.4	17	4.0C	0.9	17	13.8A	1.3
18	42	2.2DE	0.4	39	1.9DE	0.4	42	3.8C	0.6	39	10.9B	0.7
31	52	1.4 E	0.3	52	1.3E	0.3	52	3.6C	0.7	52	9.5BC	0.9

[a]Means within columns with the same letter are not different ($P > 0.05$).

seedspots were damaged by rodents, with only 18.4% of the seeds producing year-old seedlings (Table 2). Typical germination and survival rate for direct seeded acorns is 35% (Kennedy 1990). Field 17 suffered the highest damage rates of 17% to 42% and had only 12% of the seeds produce live seedlings. In contrast, with only 1.8% to 4.1% damage rate, field 24 had successful establishment of 42.7% of the planted seeds. A final seedling survival assessment in November revealed that the LDWF target of 3.0 LWOS/plot for successful establishment was exceeded in all fields. The range of survival rates was 3.6 to 14.6 LWOS/plot.

The amount and structure of vegetation affected the amount of rodent activity. Plots with greater vegetation height ($R_s = 0.20, N = 327, P = 0.0009$) and more ground cover ($R_s = 0.29, N = 327, P = 0.0001$) had more rodent digs. The lowest damage rate occurred in a dry ridge-top field (24) with sparse vegetation. We suspect that rodent activity was supressed because cotton rats are known to avoid sparsely vegetated (<

Table 2. Estimated rodent damage to seeds and seedlings and seedling survival on Ouachita Wildlife Management Area, Louisiana, 1992.

			Jul/Aug		Nov
Field	*N* plots	Total seeds in all plots[a]	Digs with damage (%)[b]	Total *N* digs[c]	Live seedlings
17	17	561	98 (17.0%)	235 (42.0%)	68 (12.0%)
18	42	1,386	260 (18.8%)	432 (31.2%)	159 (11.5%)
31	52	1,716	131 (7.6%)	494 (28.8%)	186 (10.8%)
22	90	2,970	275 (9.3%)	639 (21.5%)	399 (13.4%)
19	28	924	108 (11.7%)	193 (20.9%)	248 (26.8%)
21	68	2,244	172 (7.7%)	421 (18.8%)	517 (23.0%)
24	28	924	17 (1.8%)	38 (4.1%)	395 (42.7%)
Total	325	10,725	1,061 (9.9%)	2,452 (22.9%)	1,972 (18.4%)

[a]Based on an estimated seeding rate of 33 acorns/15.2-m plot.
[b]Digs with direct evidence of rodent damage to a seedspot.
[c]Rodent dig = 1 seedspot damaged by a rodent.

20 cm high) areas such as these (Goertz 1964). In the cages, both the cotton and rice rat proved to be capable and efficient predators of acorns. The male rice rat consumed 11 of 12 seeds (92%) before dying on the 7th day. The female cotton rat, after giving birth to a litter of young on the first day, dug and consumed all 12 seeds (100%) in 4 days. Digs produced by these animals were identical to those observed during field evaluation of seedling damage. During the 8-day trial, 75% of the seeds were removed in the large mammal excluder and 40% in the control. No seed in the cage excluding all mammals was disturbed.

Trap days totalled 3,688 for animal identification and population studies. Three species of rodents were trapped, including the rice rat, cotton rat, and house mouse (*Mus musculus*). House mice were present in very low numbers ($N = 7$), were rarely recaptured (<50%), and then never more than once per animal. Rice rats were present on the trap grid in very low numbers at the beginning of the study (approx. 6 individuals), increased to 19.8 ± 2.4 individuals by the fifth day of trapping, and reached 68 individuals by the ninth day of trapping. The density of rice rats at the midpoint of the study averaged 4.4 rats/ha.

Cotton rats exhibited a population increase during the course of the study and were present in greater numbers than rice rats. Approximately 54 cotton rats were present initially on the trap grid and by the fifth day of trapping the population expanded to 84 ± 17 individuals. On the ninth day of trapping 133 cotton rats were thought to occupy the grid area. The average density of cotton rats at the midpoint of the trapping period was 18.7 rats/ha.

Discussion

Seed predation by rodents can have an adverse impact on efforts to restore forested sites by direct planting of acorns. This is particularly true if rodent populations flourish due to suitable climatic and herbaceous conditions at the site. Two critical elements of cotton rat habitat are the height and density of ground level vegetation (Goertz 1964, Dancak 1984, Fleet and Dickson 1984). Approximately 1,776 ha of early-successional (1–6 year) vegetation on the wetland restoration site at Ouachita WMA provided stable habitat conditions for rice rats and cotton rats. Dense vegetation and the lack of perches hindered aerial predators, 1 of the primary limiting factors for fall and winter cotton rat populations in the southeast (Schnell 1968). There appears to be a site-dependent threshold level of vegetative cover necessary for rodent populations to cycle (Elmer et al. 1976). Once the vegetation is above this threshold, the quality of the habitat may determine the amplitude and duration between cycle peaks.

Several factors led to the vegetative cover on our site being suitable for rodent population growth. The 7 plantations of willow oak were located along narrow ridge sites interspersed with large areas of tall herbaceous vegetation. Fields were double-disced in August 1991 for fall planting but soil conditions prevented seeding until April 1992. Site preparation completed too far in advance of planting allowed rapid revegetation in the spring of 1992, facilitating the immigration of rodents from surrounding habitat in June.

The growing populations of rice and cotton rats at our study site had negative impact on acorn survival, but can by no means be considered unusually large. The summer population estimate of 4.4 rice rats/ha was relatively low compared to densities for other habitat types (Negus et al. 1961, Smith and Vrieze 1979, Forys and Dueser 1993). Similarly the densities of cotton rats are not particularly high in comparison to the literature. Maximum fall cotton rat densities ranging from 14/ha in Texas to 69/ha in Georgia were reported (Cameron and Spencer 1981). Cotton rat densities, however, typically increase during the summer and peak in autumn if abundant food and cover ensures the survival of young (Eugene et al. 1972, Bigler et al. 1977). Population estimates indicate that both rice and cotton rat populations were increasing in early-August. Our evidence shows that rodent damage occurred well before peak densities were reached.

Rodent damage was prevalent when discovered in June, and active damage continued through early August. Typically this is the period of active germination in direct-seeded red oaks (Johnson and Kinard 1987). Typical damage involved rats consuming acorns prior to germination or severing the cotyledon from the radicle and stem of the seedling at various stages of germination. Adams (1982) found that removal of the seed during initial seedling emergence by birds was fatal to water oak seedlings. Damage after the 2-leaf stage produced a smaller less vigorous seedling. We observed little resprouting (1%) of seedlings in old rodent digs in August. No seedling was produced from the 40 disturbed seedspots in our simulated planting. All evidence of animal disturbance to seedspots was gone by November, apparently erased by rainfall and soil activity. As a consequence, we suspect that rodent damage could easily be overlooked by checking seedling survival only once in the fall.

It might be expected that catastrophic events, such as flood, may effectively control rodent populations and provide an opportune time for seeding; however, small mammal populations adapted to floodplain sites apparently cope well with flooding (Ruffer 1961, Blem and Blem 1975, Batzli 1977, Brown and Arnold 1983). In 1991, a 50-year event flood inundated 100% of Ouachita WMA. With the exception of trees and a few elevated spoil areas, the nearest dry upland was 0.67 km west of planted fields. Rice rats are strong swimmers that have the ability to colonize and recolonize barrier islands (Forys and Dueser 1993). Cotton rats are similarly flexible in their mobility. Cotton rats can readily shift from disturbed areas to surrounding cover and return when habitat conditions permit (Briese and Smith 1974). At our restoration site, rice and cotton rats recolonized the Bayou LaFourche floodplain in only 2 growing seasons after a flood that featured extreme depth and duration.

Cotton and rice rats coexist in several moist habitats in Louisiana (Goertz and Long 1973, Lowery 1974, Hebert 1977). These sympatric rodents apparently occupy different microhabitats with rice rats typically utilizing wet areas with herbaceous annuals (dicot species), while cotton rats segregate into more productive sites that support dense stands of grasses (Goertz 1964, Kincaid et al. 1983). Also, rice rats have semiaquatic adaptions that allow them to reside in wetter habitats than cotton rats (Esher et al. 1978). In a marshy pasture in Florida, for example, rice rats dominated during wet periods and cotton rats rapidly invaded the site under dry conditions (Birkenholtz 1963). Because of their wide distribution and frequent association, any bottomland hardwood restoration project in the lower Mississippi River valley may have a problem with 1 or both of these seed predators when direct seeding.

Our 12-year effort to establish hardwood seedlings on Ouachita WMA has met with some failures, regardless of planting method. An unexplained failure of 55 ha of direct seeded willow oak occurred in 1986. A severe early-summer drought in 1988 caused a failure of 216 ha of predominantly hand-planted seedlings of nuttall oak. A 50-year event flood in June 1991 killed 81 ha of well established 3- to 6-year-old cherrybark, cow (*Q. michauxii*), shumard (*Q. shumardii*), and water oak seedlings that are not adapted to extreme flooding as are willow oaks. In our experience, 3 factors severely reduce hardwood seedling establishment: growing season drought, off-site planting, and rodent damage to seeds. In the following section we present management suggestions for minimizing the negative effect of these factors on reforestation efforts.

Management Implications

Although direct seeding has in some cases resulted in failures under extreme environmental conditions, we demonstrated that it can be a reliable method of establishing bottomland hardwood regeneration when proper technique is used. We suggest the following protocol for direct seeding with small-seeded species that have a tendency to germinate later and are subject to increased vulnerability to seed predators due to shallow planting depth.

1) Always site prepare by double-discing *just prior* to planting to eliminate rodent habitat, reduce weed competition, and decrease the potential for cracking in heavy clay soils during dry periods. Eliminate vegetation on adjacent areas if possible.

2) Avoid no-till direct-seeding in herbaceous vegetation.

3) Increase the seeding rate from the standard recommended rates of 2,471 to 3,707 ha (Kennedy 1990), if potential causes of low survival are known to occur at the site.

4) Plant in the fall soon after seeds are collected. Acorns develop a strong odor after long-term storage making them more attractive to animals in spring planting (Johnson 1981, 1984). Fall planting may also increase germination rates (Johnson 1984).

5) Utilize high quality (viable), locally collected seeds.

6) Match species to the proper soil and flooding conditions; restore historical occupants when uncertain.

Reforestation of marginal cropland is a means to restore Louisiana's bottomland hardwoods and is important for recreating and connecting fragmented wildlife habitat. Careful use of the direct seeding method can be an effective and cost-efficient way of restoring hardwood forests even on sites with a known history of damage by rodents.

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