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Stump Sprouting Probabilities for Southern Indiana Oaks

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Importance of Oak Stump Sprouts

Oaks are often a major component of the upland forests of southern Indiana. After stands are harvested for timber, some of the resulting stumps usually produce sprouts. Because of their rapid growth and persistence, oak sprouts often become dominant trees after clearcutting or heavy partial cutting. Moreover, oak regeneration may be largely limited to trees originating from stump sprouts when few large oak seedlings and seedling sprouts are present at the time of timber harvesting (Sander 1971, 1972; Sander and Clark 1971). The replacement of harvested oaks by oak reproduction of seedling and seedling-sprout origin is frequently restricted to the drier sites or to repeatedly burned sites (George and Fischer 1989, 1991; Johnson 1993a, 1993b; Merritt and Pope 1991; Mills *et al.* 1987; Olson 1996; Standiford and Fischer 1980).

Maintaining the presence of oaks in the regional landscape is nevertheless important because of their timber value, the importance of acorns to wildlife, and the associated role of oaks in maintaining biodiversity. Because the regeneration of oaks in southern Indiana is often largely limited to sprouts originating from stumps, this source of reproduction assumes great importance in maintaining the presence of oaks in many of the region's upland forests.

Therefore, predicting the frequency of occurrence of oak stump sprouting before stands are harvested may be useful in managing southern Indiana oak forests. Fortunately, the likelihood that a tree will produce a stump sprout after cutting is predictable from tree characteristics before cutting. In the Missouri Ozarks, oak stump sprouting was related to tree age and diameter and to site quality expressed as site index (Johnson 1977). Similarly, we report here the sprouting probabilities for five species of upland oaks in southern Indiana. The five species studied were northern red oak (*Quercus rubra* L.), black oak (*Q. velutina* Lam.), scarlet oak (*Q. coccinea* Muenchh.), white oak (*Q. alba* L.), and chestnut oak (*Q. prinus* L.).

Application

Based on observations in clearcut stands, 1 year after cutting the parent tree, the occurrence of sprouts varied with tree age and diameter (d.b.h.) and with site index at an index age of 50 years (fig. 1). For all five species, the probability of sprouting decreased with increasing age and d.b.h. of the parent tree, and increased with increasing site index. For a given d.b.h., age, and site index, sprouting probabilities were highest for chestnut oak. Although probabilities for white oak were relatively high for small, young trees, probabilities declined more rapidly with increasing diameter and age than in the other species. The sprouting trends for all species generally parallel sprouting probabilities for white oak and black oak in the Missouri Ozarks (Johnson 1977). Because probabilities for scarlet and northern red oaks did not differ significantly ($\alpha = 0.05$), a single set of curves expresses their sprouting response.

The curves presented in figure 1 facilitate visual assessment of sprouting relations and quick estimation of sprouting probabilities for each species. The equations on which they are based also are presented (table 1). The latter may be useful in computer applications and in regeneration modeling. In the practical application of sprouting curves or equations, an inventory of the d.b.h., age,

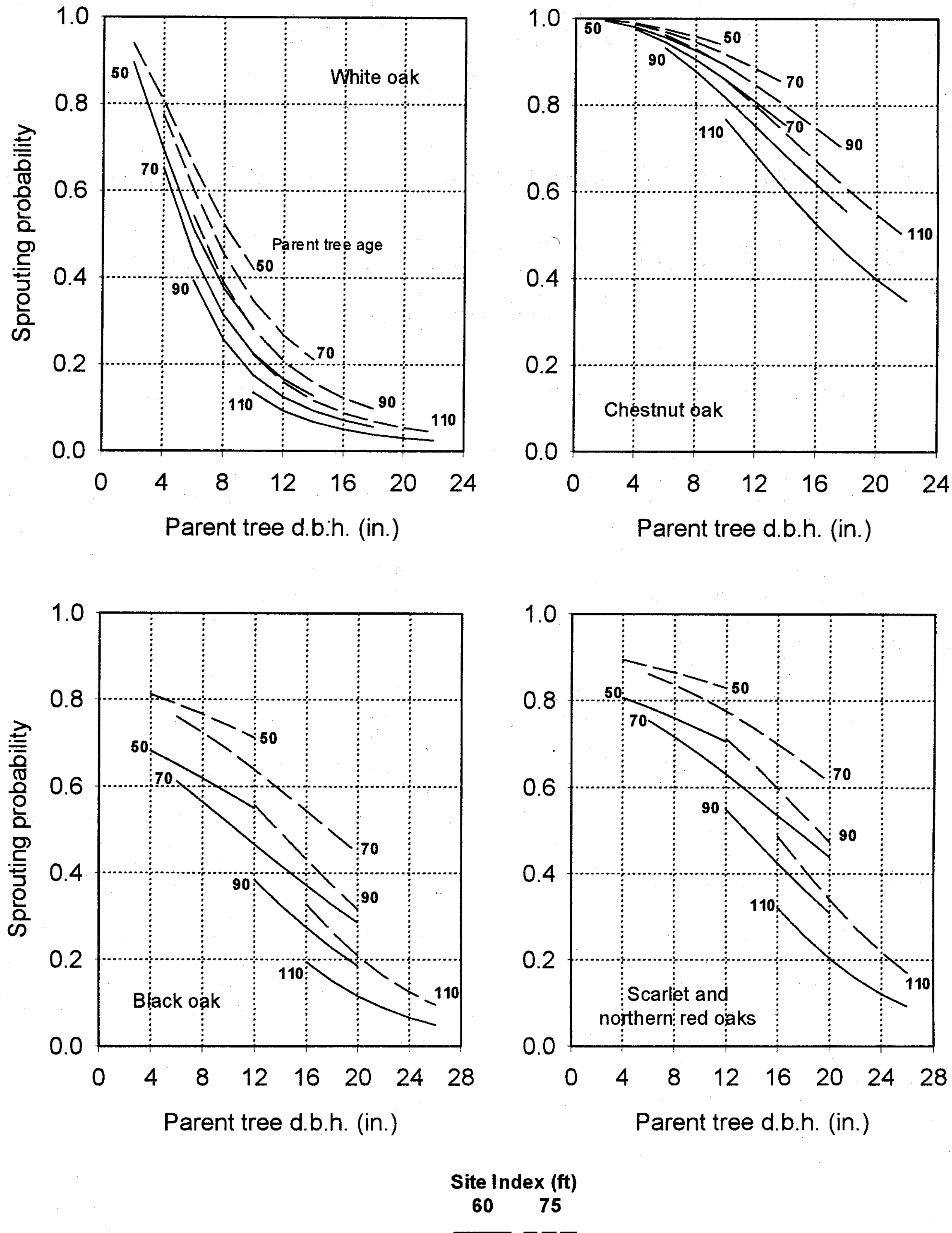

Figure 1.—*The estimated probability that an oak stump will have at least one living sprout 1 year after the parent tree is cut, by species, parent tree age and d.b.h., and black oak site index.*

Table 1.—*Logistic regression models for estimating the probability that an oak stump will have at least one living sprout 1 year after the parent tree is cut*

Species	Parameter estimates*						p**	N***
	b_0	b_1	b_2	b_3	b_4	b_5		
White oak	-7.6179	-1.5760	2.7069	-0.00667			0.080	1,547
Chestnut oak	-4.5719	-1.5760	2.7069	-0.00667				
Black oak	-1.7718				-0.0014	0.0469	0.091	637
Red and scarlet oaks	-1.1012				-0.0014	0.0469		

*Regression models are of the form $P = \{1 + \exp[-(b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5)]\}^{-1}$, where P is the estimated probability that a cut tree will produce a stump sprout; X_1 is the natural log of parent tree diameter (d.b.h.) in inches; X_2 is the natural log of black oak site index (where site index is derived from Carmean *et al.* 1989); $X_3 = (X_1 \cdot \text{tree age})$ where age is in years at stump height; X_4 is (d.b.h.•age); and X_5 is black oak site index. All parameter estimates differ significantly from zero at $\alpha = 0.05$.

**The probability (p) that estimated sprouting probabilities differ from the observed based on the Hosmer-Lemeshow chi-square test (Hosmer and Lemeshow 1989).

***White and chestnut oaks were combined into one analysis; differences between species were significant ($\alpha = 0.05$). Similarly, black, northern red, and scarlet oaks were combined into one analysis; differences between black oak and the scarlet oak-northern red oak group were significant. Northern red oak and scarlet oak did not differ significantly.

and site index of overstory trees (i.e., trees $\geq$2 inches d.b.h.) is required before stands are harvested. Numbers of trees by d.b.h. classes then can be estimated from the inventory. We recommend estimating the average age of each oak species present from a sample of tree ages obtained from increment cores. In doing so, it is important to obtain age samples across the range of diameters present to determine if a species' population is even-aged or multi-aged. We suggest that a population be deemed even-aged if all of the sample trees are within $\pm$10 percent of the estimated mean population age. In that case, the mean age of the trees can be assigned to all population sample trees regardless of their d.b.h. If a population is not even-aged, and small trees tend to be of a younger age class, we recommend that sprouting estimates be based on assigning an average age to the smaller trees (representing a designated d.b.h. range), and another average age to larger trees (representing a second designated d.b.h. range). More than two age classes accordingly can be defined if the intensity of age sampling and objectives justify such refinement.

Populations of the relatively shade intolerant red oaks (i.e., northern red, scarlet, and black oaks) often make up a single age class, whereas the more shade tolerant white oaks often make up two or more age classes. Where oaks form uneven-aged populations, d.b.h. and age may be poorly correlated (Loewenstein 1996). In such stands, accurate estimation of stump sprouting may require intensive sampling of tree ages. Although the most accurate estimates can be obtained by directly determining the age of each sample tree, such determinations will seldom be practical or necessary. In application, assigning an average age to a d.b.h. class may provide sufficient accuracy for estimating sprouting probabilities.

Sampling of tree ages can be combined with site index determinations from dominant and codominant black oaks based on black oak site index curves for the Central States (Carmean *et al.* 1989). Ten or more increment cores should be obtained for that purpose alone (McQuilkin and Rogers 1978). Larger numbers of age determinations will be required to obtain reliable site index estimates in stands that vary greatly in site quality. If trees suitable for site index determination are not present, oak site index alternatively can be estimated from soil and topographic factors (Hannah 1968).

The sprouting probabilities presented are based on data from clearcuts. Therefore, their application to partial cuts or small group openings may produce results that differ appreciably from the predictions presented. Although the stumps of some hardwoods are inhibited by overstory shading (Church 1960), similar responses in oaks have not been reported but are possible. For some species of oaks, there is evidence that stumps sprout more frequently when trees are cut or killed during the dormant season than during the growing season (Clark and Liming 1953, Kays *et al.* 1988). However, the present study did not evaluate such possible effects. Trees in the present study were cut primarily during the growing season.

Information on the growth, survival, quality, and silviculture of oak stump sprouts is reported elsewhere (e.g., Groninger *et al.* 1998; Johnson and Godman 1983; Johnson and Rogers 1984; Lamson 1988a, 1988b; McGee 1978; Roth and Hepting 1969; Stroempl 1983). Entry of decay organisms into stump sprouts via parent stumps or other pathways is sometimes cited as problematic in oak sprouts. However, this problem can be largely eliminated by cutting low stumps (e.g., within 6 inches of the ground) (Roth and Hepting 1969). Stumps that sprout typically produce multiple-stemmed clumps. Black oak and white oak clumps usually self-thin to one or two stems by age 20, whereas stems in scarlet and northern red oak clumps are more persistent. Twenty-year-old clumps of northern red oak averaged four stems per clump (Johnson 1975).

How the Study was Conducted

Data for the sprouting probabilities were obtained from oaks in nine stands in southern Indiana. Before the stands were harvested, we located, tagged, and measured the d.b.h. of 2,184 white, chestnut, black, scarlet, and northern red oaks $\geq$ 2 inches d.b.h. Sample size ranged from 108 northern red oaks to 1,367 white oaks. Black oak site index in the nine study areas ranged from 60 to 80 feet at an index age of 50 years based on the site index curves of Carmean *et al.* (1989). After harvest, the tree stumps were relocated and aged. For each species, the stumps selected for study represented a wide range of diameter and age classes (table 2). One year after harvest the presence of living sprouts was recorded for each stump.

Logistic regression analysis was used to estimate the probability that a stump will have at least one living sprout 1 year after the parent tree is cut. Preliminary analyses tested for differences between species. To do this, white oak and chestnut oak (the white oak group) were combined into one analysis as were black oak, scarlet oak, and northern red oak (the red oak group). Results indicated that probabilities for the two white oaks differed, and that black oak differed from the combined scarlet oak and northern red oak datasets. For the white oak group, d.b.h., site index, and the d.b.h. x age interaction were significant predictors (table 1). For the red oak group, site index and the d.b.h. x age interaction were significant predictors.

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Table 2.—*Number of stumps observed by species, age class, and d.b.h. class*

Age class (years)	D.b.h. class (in.)	Species				
		White oak	Chestnut oak	Black oak	Northern red oak	Scarlet oak
50	4	212	3	35	11	3
	8	87	5	40	11	10
	12	21	--	18	4	5
	16	1	--	8	--	--
	20	1	--	3	--	1
	All	322	8	104	26	19
70	4	54	1	2	1	--
	8	164	8	37	15	16
	12	57	6	50	13	34
	16	26	2	29	7	22
	20	6	2	16	--	7
	24	1	1	4	1	--
	28	--	--	2	--	1
	All	308	20	140	37	80
90	4	4	1	--	--	--
	8	86	14	2	1	1
	12	151	44	24	12	6
	16	109	22	35	9	11
	20	24	6	11	3	3
	24	2	1	2	1	2
	28	--	--	2	--	--
	All	376	88	76	26	23
110	4	1	--	--	--	--
	8	17	--	--	--	--
	12	110	11	6	4	1
	16	156	35	29	6	4
	20	68	14	26	5	1
	24	9	4	11	4	1
	28	--	--	6	--	2
	All	361	64	78	19	9
	Species total	1,367	180	398	108	131

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