

Bottomland Forests in the Lower Mississippi Alluvial Valley Associated with the Endangered *Lindera melissifolia*

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ABSTRACT Forest canopy and subcanopy data were collected from and compared among five disjunct bottomland hardwood forests in the Lower Mississippi Alluvial Valley, each with known occurrence of a population of the federally endangered shrub *Lindera melissifolia*. All study sites are cut-over forests, underlain by hydric soils, and have a seasonal high water table. Canopy and subcanopy species are similar among sites, but species differ in relative importance, and flood tolerant tree species exceed that of flood intolerant species. Distribution of *L. melissifolia* colonies within each study site was not associated with mean tree density or d.b.h. Forest composition and structure at each study site reflect hydrologic regime, topography, historical disturbance, and an absence of recent disturbance. Results of this study provide a quantitative description of bottomland forests that currently sustain *L. melissifolia* populations. This information may be utilized for development of forest management plans aimed at ensuring continued sustainability of existing *L. melissifolia* populations and assessing other bottomland hardwood forests for potential reintroduction of this endangered species.

INTRODUCTION *Lindera melissifolia* (Walt.) Blume is an aromatic, dioecious shrub endemic to the southeastern United States. In 1986, this species was listed under the Federal Endangered Species Act of 1973 (U.S. Fish and Wildlife Service 1986). In response, U.S. Fish and Wildlife Service generated a recovery plan, whereby down-listing the species requires permanent protection of 15 self-sustaining *L. melissifolia* populations. The requirement for delisting is permanent protection of 25 self-sustaining populations (U.S. Fish and Wildlife Service 1993). The Recovery Plan for Pondberry (U.S. Fish and Wildlife Service 1993) emphasizes searching for new populations and studying the species and its habitat as actions needed to meet down-listing or delisting criteria. Cur-

rently, relatively small disjunct *L. melissifolia* populations are found in Alabama, Arkansas, Georgia, Mississippi, Missouri, North Carolina, and South Carolina. Of these, the most numerous and perhaps the largest populations, are found in the Lower Mississippi Alluvial Valley (LMAV). *Lindera melissifolia* populations are composed of unisexual colonies, and populations tend to be male-biased, with male to female colony ratios ranging from 7:1 (Wright 1994) to 19:1 (Hawkins et al. 2007).

Although Wright (1989, 1990) and Priest and Wright (1991) have described some edaphic and hydrologic factors associated with *L. melissifolia* in Arkansas, little is known about the ecology of this species. In the LMAV, its habitat has been qualitatively described as closed canopy bottomland hardwood forests (Klomps 1980, Priest and Wright 1991, Smith 2003, Wright 1989) and in Arkansas and Missouri it is found growing on the edges of depressions associated with forested swales between old dunes formed from glacial outwash (Saucier 1978). Similarly, descriptions of arborescent species

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associated with *L. melissifolia* are limited to qualitative observations (Devall et al. 2001, Morris 1987). Klomps (1980) provided basal area of tree species in Missouri growing in association with a small *L. melissifolia* population; however, this information was based only on two, small variable diameter plots.

Given the lack of information about the ecology of *L. melissifolia*, and in keeping with actions needed as described in the Recovery Plan for Pondberry (U.S. Fish and Wildlife Service 1993), the objective of our research was to provide a quantitative assessment of bottomland forest composition and structure associated with the presence of *L. melissifolia* in the LMAV. Characterizing bottomland forests in which *L. melissifolia* currently occurs will provide much needed information for targeting additional bottomland forests with high probability for discovery of additional *L. melissifolia* populations, as well as assessing sites for reintroduction of this species and developing management strategies that ensure sustainability of existing populations.

STUDY SITES The Delta National Forest (DNF) and Bolivar County (BC) study sites are located in Sharkey and Bolivar counties, Mississippi, respectively (Figure 1). The former is a 25 ha section of Delta National Forest that has been under management by the U.S. Forest Service since 1938 (Devall and Ramp 1992). The BC study site is a privately owned, 30 ha forest fragment surrounded by agricultural fields. Both sites experience a flood duration of two to three months in late winter and early spring (Hawkins, unpubl. data). The soil association is Dowling (very fine, smectitic, nonacid, thermic Vertic Endoaquepts)-Alligator (very-fine, smectitic, thermic Chromic Dystraquepts)-Sharkey (very-fine, smectitic, thermic Chromic Epiaquepts), an association characterized by poorly drained, fine-textured clayey surface soils and subsoils formed from Mississippi River alluvium (Rogers 1958). Mean annual temperature for DNF and BC is approximately 18.0°C, and total annual precipitation ranges from 1,228 mm to 1,319 mm (Rogers 1958, Scott and Carter 1962).

The St. Francis Sunken Lands (SFS) site (Figure 1) is located in the St. Francis Floodway in Craighead County, Arkansas and is part of St. Francis Sunken Lands Wildlife Management Area. The St. Francis Floodway

encompasses all land inside the main levees of the St. Francis River, which is a tributary of the Mississippi River. This 50 ha section of the Sunken Lands was commercially logged (diameter limit cut) in the late 1970's (Robert Zachary, Arkansas Game and Fish Commission, pers. comm.) and has a seasonal high water table in late winter and early spring. The soil association is Sharkey (Ferguson 1979). Mean annual temperature for Craighead County is 16.1°C and mean annual total precipitation is 1,223 mm (Ferguson 1979).

Clay County (CC) and Sand Pond (SP) sites are located in Clay County, Arkansas and Ripley County, Missouri, respectively (Figure 1). The CC site is an 8 ha section of forest, protected and managed by the Arkansas Natural Heritage Commission. SP is a 13 ha section of forest protected and managed by the Missouri Department of Conservation. Soil association for CC is Wardell (fine-loamy, mixed, superactive, thermic, Mollic Epiaqualfs)-Foley (fine-silty, mixed, thermic Albic Glosic Natraqualfs), a poorly drained, moderate to strongly acid, loamy soil found on broad flats and in depressions on natural levees and old floodplains (Fielder et al. 1978). At SP, soil association is Tuckerman (fine-loamy, mixed active Typic Endoaqualfs)-Bosket (fine-loamy, mixed, acid, thermic Mollic Hapludalfs), an association typified by low, convex, sand ridges and mounds of Bosket surrounded by lower lying Tuckerman soil that is subject to occasional flooding (Graves 1983). Both sites are seasonally flooded in late winter and early spring (Hawkins, pers. obs.). Mean annual temperature for Clay and Ripley counties is 15.3°C and mean annual total precipitation is 1,180 mm (Fielder et al. 1978, Graves 1983).

METHODS

Data Collection

Canopy and subcanopy data were collected using a nested center-plot method. At DNF, BC, CC, and SP, 0.04 ha circular plots were sampled at 30 m intervals along parallel transects placed 50 m apart. Placement of circular plots at SFS was also at 30 m intervals; however, transects were placed 100 m apart. Within each 0.04 ha plot, woody stems with a diameter at breast height (d.b.h.) ≥ 10.16 cm (canopy) were measured

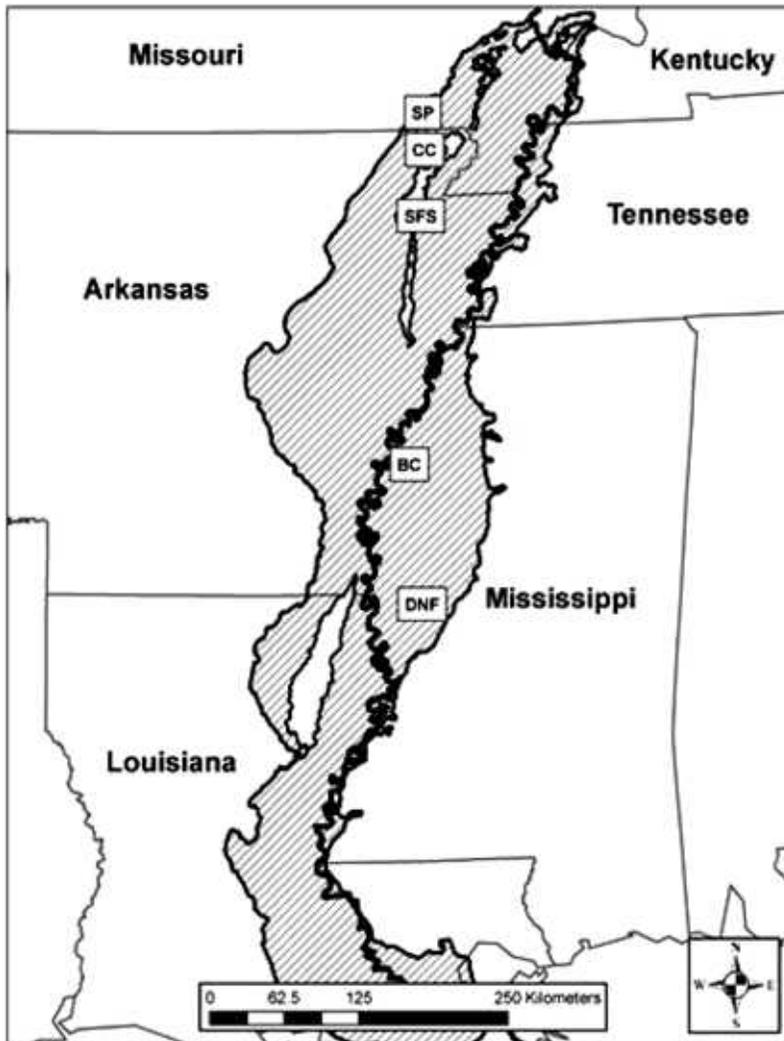


Figure 1. Map of the Lower Mississippi Alluvial Valley (hatched area) and locations of the five study sites.

and recorded by species. In a 0.02 ha circular plot nested in the center of each 0.04 ha plot, woody stems with a d.b.h. of 2.54 cm–10.15 cm (subcanopy) were measured and recorded by species. Presence or absence of a *Lindera melissifolia* colony within each 0.04 ha plot was noted.

Data Analysis

Data collected for canopy and subcanopy strata were used to calculate density, relative density, basal area, relative basal area, frequency, and relative frequency. Summation of the relative values gave an importance value (IV) with a maximum of 300 (Barbour et al. 1987, Curtis and McIntosh 1950). Forest community ordination was performed using

non-metric multidimensional scaling (NMDS) with proportional similarity used as the resemblance measure (Kwak and Peterson 2007).

For each study site, *t* tests were used to compare tree stem density and mean d.b.h. between sampling plots with and without *L. melissifolia* colonies. Results of *t* tests revealed no significant differences in mean d.b.h. or stem density in either stratum between plots with or without *L. melissifolia* colonies; therefore, these data were pooled, and Protected Least Significant Difference tests (PLSD, $P = 0.05$) were used as the multiple comparison procedure among sites. The SAS procedures GLM and MDS were used to perform statistical analyses (SAS Institute Inc. 2001).

Table 1. Importance values for canopy (d.b.h. ≥ 10.16 cm) species at the five study sites (sites listed latitudinally from southernmost to northernmost. ^aStudy site and species with an IV of less than ten across all five sites

Species	DNF	BC	SFS	CC	SP
<i>Liquidambar styraciflua</i> L.	98.8	2.5	61.8	22.7	24.9
<i>Celtis laevigata</i> Willd.	36.1	41.4	7.9	28.2	—
<i>Acer rubrum</i> L.	30.1	—	32.6	101.3	16.2
<i>Quercus nuttallii</i> Palmer	28.5	66.8	8.2	27.7	23.2
<i>Acer negundo</i> L.	24.8	—	0.5	—	—
<i>Quercus lyrata</i> Walt.	18.0	16.2	47.0	19.4	28.2
<i>Quercus phellos</i> L.	16.8	57.3	10.8	21.7	40.6
<i>Carya illinoensis</i> (Wangenh.) K. Koch	14.6	9.7	—	—	—
<i>Ulmus americana</i> L.	10.8	29.6	14.6	19.0	23.1
<i>Carya aquatica</i> (Michx. f.) Nutt.	7.9	12.5	8.7	—	—
<i>Diospyros virginiana</i> L.	5.2	9.7	5.1	14.8	3.7
<i>Fraxinus pennsylvanica</i> Marsh.	3.6	30.8	9.9	24.2	26.5
<i>Quercus nigra</i> L.	3.0	3.5	19.9	—	5.9
<i>Sassafras albidum</i> (Nutt.) Nees	2.0	—	15.3	—	12.2
<i>Betula nigra</i> L.	—	—	16.0	—	—
<i>Ulmus alata</i> Michx.	—	—	1.1	2.4	10.9
<i>Quercus alba</i> L.	—	—	—	5.3	23.5
<i>Quercus velutina</i> Lam.	—	—	—	—	15.6

^a*Asimina triloba* (L.) Dunal^{SP}, *Carpinus caroliniana* Walt.^{SFS,SP}, *Carya glabra* (P. Mill.) Sweet^{SP}, *C. laciniata* (Michx. f.) G. Don^{SFS}, *C. ovata* (Mill.) K. Koch^{BC}, *Gleditsia triacanthos* L.^{BC,SFS}, *Ilex decidua* Walt.^{SFS}, *Morus rubra* L.^{SFS}, *Nyssa sylvatica* Marsh.^{SFS,SP}, *Platanus occidentalis* L.^{SFS,CC}, *Populus heterophylla* L.^{SFS}, *Prunus serotina* Ehrh.^{SP}, *Quercus falcata* Michx.^{SP}, *Q. michauxii* Nutt.^{CC,SP}, *Q. pagoda* Raf.^{BC,SFS,CC,SP}, *Salix nigra* Marsh.^{SFS}, *Taxodium distichum* (L.) L.C. Rich.^{SFS}, *Ulmus crassifolia* Nutt.^{BC}.

Within each study site, canopy and subcanopy species composition was compared between sampling plots with and without *L. melissifolia* using proportional similarity indices (Cox 1990). EcoStat software (Trinity Software Inc. 1999) was used to calculate these indices.

RESULTS A total of 40 tree species were identified in the canopy and subcanopy among the five study sites. Scientific names with authorities are in Tables 1 and 2.

Based on importance values for canopy species, BC ($N_{\text{plot}} = 38$) and SP ($N_{\text{plot}} = 20$) are Mixed *Quercus* forest types (Table 1). The canopies at DNF ($N_{\text{plot}} = 34$), SFS ($N_{\text{plot}} = 60$), and CC ($N_{\text{plot}} = 14$) are *Liquidambar* dominant, *Liquidambar-Quercus*, and *Acer* dominant, respectively (Table 1). However, the NMDS plot (final stress = 0.13) indicated canopy composition at DNF is most similar to SP, and that at BC is most similar to SFS (Figure 2). Relative to these four sites, CC showed little similarity in canopy composition (Figure 2). *Quercus* spp. are an important canopy component at all five sites with species collective IVs ranging from 66.3 to 143.8 (Table 1). Mean canopy d.b.h. at CC and SP was significantly greater

($p < 0.0001$), and mean density was significantly less ($p < 0.0001$) than at DNF, BC, and SFS (Table 3).

Acer rubrum is the dominant subcanopy species at SFS. In this stratum, *A. rubrum* shares importance with *A. negundo* at DNF, *Diospyros virginiana* and *Ulmus americana* at CC, and *Asimina triloba* and *Aralia spinosa* at SP (Table 2). Subcanopy at BC is dominated by *Celtis laevigata* with *Fraxinus pennsylvanica* and *U. americana* of secondary importance (Table 2). Within this stratum, ordination of subcanopies (final stress = 0.10) showed little similarity in composition (Figure 2) and PLSD tests showed significant differences in mean d.b.h. ($p = 0.0014$) and stem density ($p = 0.0013$) among sites (Table 3).

Lindera melissifolia colonies were present in 38%, 29%, 65%, 36%, and 80% of the plots sampled at DNF, BC, SFS, CC, and SP, respectively. Similarity in canopy composition between plots with and without *L. melissifolia* colonies declined as site (population) location went from south to north in the LMAV. Proportional similarity indices for subcanopy composition between plots with and without *L. melissifolia* were lower than those of the canopy, with values ranging from 0.35 to 0.70 (Table 4).

Table 2. Importance values for subcanopy (d.b.h. 2.54–10.15 cm) species at the five study sites (sites listed latitudinally from southernmost to northernmost). ^aStudy site and species with an IV of less than ten across all five sites

Species	DNF	BC	SFS	CC	SP
<i>Acer negundo</i>	68.9	—	—	—	—
<i>Acer rubrum</i>	64.1	—	100.1	72.8	38.6
<i>Celtis laevigata</i>	50.3	97.0	7.3	—	6.2
<i>Ilex decidua</i> Walt.	40.8	8.4	6.6	—	14.3
<i>Forestiera acuminata</i> (Michx.) Poir.	21.0	—	2.0	—	—
<i>Liquidambar styraciflua</i>	17.7	—	33.8	—	17.1
<i>Cornus amomum</i> P. Mill	13.2	—	28.8	—	—
<i>Fraxinus pennsylvanica</i>	12.2	54.8	4.3	36.0	9.2
<i>Ulmus americana</i>	3.4	69.2	26.8	61.1	33.8
<i>Carya aquatica</i>	3.0	11.5	3.3	—	—
<i>Carya ovata</i>	—	15.1	—	—	—
<i>Quercus phellos</i>	—	11.2	1.5	—	—
<i>Diospyros virginiana</i>	—	5.7	2.7	68.2	27.3
<i>Carpinus caroliniana</i>	—	—	43.0	14.9	3.4
<i>Nyssa sylvatica</i>	—	—	12.6	—	13.8
<i>Sassafras albidum</i>	—	—	5.0	—	13.7
<i>Ulmus alata</i>	—	—	1.8	24.8	15.5
<i>Aralia spinosa</i> L.	—	—	—	13.2	36.4
<i>Asimina triloba</i> (L.) Dunal	—	—	—	—	40.4
<i>Vaccinium arboreum</i> Marsh.	—	—	—	—	11.7

^a*Carya illinoensis*^{BC}, *C. laciniosa*^{SFS}, *Populus heterophylla*^{CC}, *Morus rubra*^{SFS,SP}, *Quercus alba* L.^{SP}, *Q. lyrata*^{DNF,BC,SFS}, *Q. nigra*^{DNF,BC,SFS,SP}, *Q. nuttallii*^{BC}, *Q. pagoda*^{BC,SFS}, *Ulmus crassifolia*^{BC}.

DISCUSSION Floristic composition of floodplain sites of river bottoms in the LMAV is strongly influenced by hydrologic events on the sites (Hodges 1997). Additionally, small differences in elevation, typically found in bottomland forests, will precipitate changes in floristic association due to the resultant differences in hydrology (Hodges and Switzer 1979). At the five study sites, the influence of hydrologic regime and topography was reflected in canopy and subcanopy composition. Seven tree species, *Diospyros virginiana*, *Fraxinus pennsylvanica*, *Liquidambar styraciflua*, *Quercus lyrata*, *Q. phellos*, *Q. nuttallii*, and *Ulmus americana* were components of all five forest canopies. Of these seven species, *F. pennsylvanica*, *Q. phellos*, and *U. americana* are designated facultative wetland species, and *Q. lyrata* and *Q. nuttallii* are designated obligate wetland species (Reed 1988). *Diospyros virginiana* and *L. styraciflua* are considered moderately flood tolerant (Hook 1984, Stanturf et al. 2004).

Further evidence of the hydric nature of the sites was the collective importance of *Quercus* species in the canopy. Nine *Quercus* species are common to bottomland forests in the southeastern United States: *Quercus alba*, *Q. laurifolia* Michx., *Q. lyrata*, *Q. michauxii*, *Q. nigra*, *Q. nuttallii*, *Q. pagoda*, *Q. phellos*, and

Q. shumardii Buckl. (Gardiner 2001). *Quercus lyrata* has the greatest tolerance to anaerobic soil conditions (Gardiner 2001), and is typically found on hydric soils of poorly drained sloughs and low flats of the LMAV, where it may contribute up to 60% canopy composition in association with *Carya aquatica* (Tanner 1986). *Quercus nuttallii*, *Q. nigra*, and *Q. phellos* often grow along a continuum from ridges to low flats in association with other bottomland species such as *Celtis laevigata*, *F. pennsylvanica*, *L. styraciflua*, and *U. americana* (Hook 1984, Tanner 1986). On the other hand, *Taxodium distichum*, a wetland indicator species (Reed 1988), was absent from all but one study site, which further supports the fact that forests at these sites are influenced by seasonal high water tables rather than by permanent inundation (Hodges 1997).

Ordination revealed that canopy composition at DNF was similar to SP, and canopy composition at BC was similar to SFS. This most likely reflects the influence of site topography on species abundance. The BC and SFS sites are characterized by slight, gradual rises. In contrast, the dune and swale topography at SP, and sloughs and deep depressions at DNF result in steeper and more numerous topographic shifts. Although topography at CC is like that found at BC and

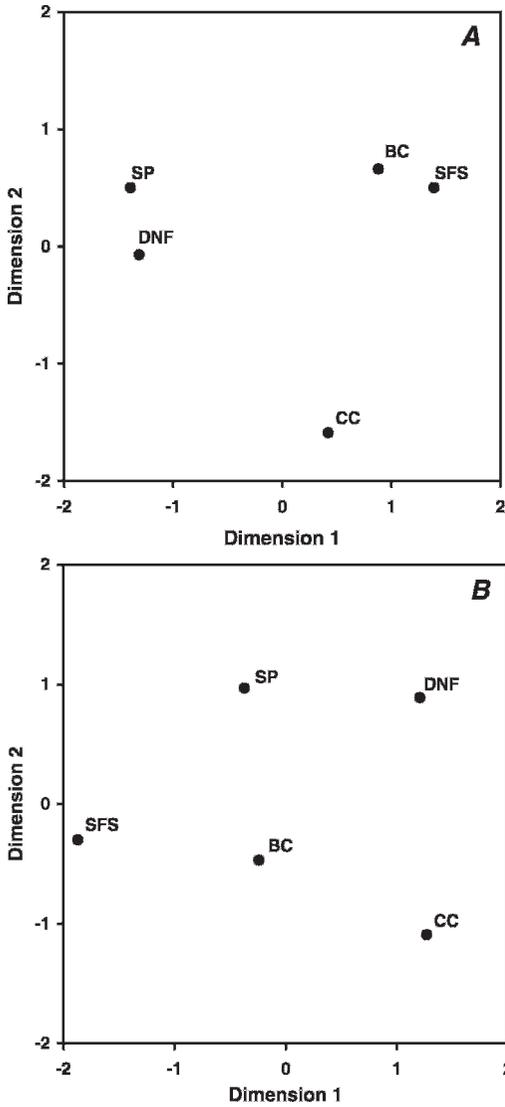


Figure 2. NMDS ordination of canopy (A) and subcanopy (B) composition at five disjunct bottomland forests in the Lower Mississippi Alluvial Valley, each with a *Lindera melissifolia* population present.

SFS, the high proportion of *A. rubrum* in the canopy, probably set this site apart from the other four.

In the subcanopy, only *F. pennsylvanica* and *U. americana* are common to all five sites. The former is a facultative wetland species, while the latter is simply facultative (Reed 1988). Presence of these two species, in association with *C. laevigata* and *D. virginiana* on four of five sites, is an indication of periodic inundation (Kabrnick and Dey 2001, Stanturf et al. 2004).

Table 3. Mean d.b.h. and stem density (\pm SE) for canopy (d.b.h. \geq 10.16 cm) and subcanopy (d.b.h. 2.54–10.15 cm) strata at the five study sites. Values in a column with different lowercase letters are significantly different (PLSD; $P < 0.05$)

	Mean d.b.h. (cm)	Density (stems/ha)
CANOPY		
DNF	29.7 \pm 0.9 ^a	385 \pm 19 ^a
BC	27.2 \pm 1.1 ^a	414 \pm 24 ^a
SFS	27.3 \pm 0.6 ^a	429 \pm 18 ^a
CC	39.2 \pm 1.7 ^b	241 \pm 12 ^b
SP	36.2 \pm 1.7 ^b	234 \pm 18 ^b
SUBCANOPY		
DNF	5.9 \pm 0.2 ^a	227 \pm 24 ^a
BC	5.1 \pm 0.4 ^{a,b}	138 \pm 20 ^b
SFS	5.5 \pm 0.2 ^{a,b}	241 \pm 22 ^a
CC	3.7 \pm 0.8 ^c	114 \pm 29 ^b
SP	4.6 \pm 0.5 ^{b,c}	278 \pm 52 ^a

The significantly greater mean d.b.h. and lower stem density of canopy species at CC and SP, relative to the other three study sites suggest that CC and SP are older stands. Harvesting at CC and SP most likely occurred in the early 1900's (Douglas 1912), and harvesting at DNF (Devall and Ramp 1992) and SFS (Robert Zachary, Arkansas Game and Fish Commission, pers. comm.) occurred later in the century. To our knowledge, BC has not been subject to forest management; however, given its location, the surrounding land use, and tree species composition, it is possible that this site was heavily logged in the mid 1900's and has succeeded into an oak forest. Lack of *Quercus* spp. in the subcanopies of all study sites is typical of bottomland forests in the LMAV and reflects absence of recent disturbance, as well as decreasing light availability from canopy closure (Oliver et al. 2005).

Within each study site, stem density and mean d.b.h. of canopy and subcanopy trees were not significantly different between sampling plots with and without *Lindera melissifolia* colonies. Species composition of both strata in plots with and without *L. melissifolia*

Table 4. Canopy and subcanopy proportional similarity indices (%) for plots with and without *L. melissifolia* at each of the five study sites

Stratum	DNF	BC	SFS	CC	SP
Canopy	93	87	83	77	67
Subcanopy	70	43	65	50	35

was similar, with the exception of the subcanopy at BC and SP (proportional similarity index < 0.50). The low index for BC was influenced by the topography which is characterized by a gradual rise in elevation yielding a transition in tree species associations along the gradient. With increased elevation, albeit slight, occurrence of *L. melissifolia* decreases. Similarly, subcanopy composition at SP, as well as occurrence of *L. melissifolia* within sampling plots, is highly affected by the dune and swale topography. Although similarity coefficients between plots with and without *L. melissifolia* colonies at BC and SP were relatively low, we found no consistent association between presence of *L. melissifolia* colonies and shade tolerant or shade intolerant species, or flood tolerant and flood intolerant species. This absence of association, in tandem with no significant differences in mean tree d.b.h. and density between plots with and without *L. melissifolia* seemingly does not support the hypothesis that *L. melissifolia* establishes in canopy gaps (Smith 2003), and lends support to Wright's (1990) suggestion that colony establishment exploits both light availability from canopy gaps in concert with periodic inundation that acts to limit competitors. Additionally, Aleric and Kirkman (2005) have shown that *L. melissifolia* plants are able to adapt to a wide range of light availability. This further explains the lack of association between *L. melissifolia* colonies and tree species sensitive to light availability at the five study sites.

In general, canopy and subcanopy composition at the five study sites is typical of many bottomland hardwood forests in the LMAV. We found no single arborescent indicator species, nor forest structure parameter, associated with the presence of *L. melissifolia* at each forested site or distribution of *L. melissifolia* colonies within each site. However, results of our study in combination with abiotic factors common to all five sites could discern bottomland forests with presence of *L. melissifolia* from those where the species does not occur. All study sites were bottomland hardwood forests underlain by hydric soils (*sensu* U.S. Department of Agriculture, Natural Resources Conservation Service 2007) with a seasonal high water table confined to late winter and early spring. Forests are cut-over stands with a history of disturbance, and are similar in species composition, but differ in

relative importance of these species. Although forest composition may range from obligate wetland species to those considered upland species, the relative importance of flood tolerant species exceeds that of flood intolerant species. By combining the results of our study with geomorphology, it may be possible to narrow the choices of bottomland forests in the LMAV to search for new *L. melissifolia* populations. Further, biotic and abiotic factors elucidated in our study must be considered collectively in assessing forested sites for reintroduction of *L. melissifolia* and in developing forest management plans aimed at ensuring sustainability of existing *L. melissifolia* populations.

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