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Populations of *Phaeophyscia leana* (Tuck.) Essl. within the Ohio River Basin

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ABSTRACT

Phaeophyscia leana (Tuck.) Essl., an endemic North American lichen species presently known to occur only within the Ohio River basin, is state-endangered in Illinois and a potential candidate for the Federal Endangered Species list. Since it utilizes periodically inundated corticolous substrates associated with river channels, oxbow lakes, and sloughs, this imperiled lichen is sensitive to landuse patterns within river floodplains. Surveys for *P. leana* were conducted to recensus previously documented populations, thereby assessing their stability, and to identify additional populations within the Ohio River Basin. Watercraft surveys were conducted on the Little Wabash River, from Carmi to New Haven, Illinois, and on the Wabash River from Darwin, Illinois, to the terminus at the Ohio River. Watercraft surveys resulted in the discovery of five new populations of *P. leana*, two in Illinois and three in Indiana, all of which were located south of Illinois State Route 141. Land-based surveys in Illinois identified new populations within the floodplain formed at the confluence of the Wabash and Ohio Rivers in Gallatin County and within the Black Bottom of Massac County. Nine large oxbow lake communities and backwater slough channels were found to support populations of *P. leana* within the Gallatin Bottoms which is the population center for *P. leana* in Illinois. Additions to the Illinois core site list include large populations at Fehrer Lake, Big Lake, and Saline Mines, all within the Gallatin Bottoms floodplain. Watercraft reconnaisance of the Wabash River and Ohio River floodplains (the Big Rivers Region) in Indiana led to the discovery of *P. leana* populations in Posey, Spencer, Perry, Crawford, and Switzerland County, Indiana, as well as a population in Trimble County, Kentucky. The population located at Vevay, Indiana, in Switzerland County is the closest documented population to the type locality near Cincinnati, Ohio. Land-based surveys conducted in the Hoosier National Forest and the Harrison-Crawford State Forest elucidated the only core site in Indiana, the Mano Point population, near Derby. A population was also discovered in Tennessee at the Hartsville boat launch on the Cumberland River (Old Hickory Lake). Core sites in Tennessee include the Hartsville population as well as populations discovered by Loy R. Phillippe on the Caney Fork River near Hell Bend (downstream from Carthage) and below the Center Hill Dam located on Wolf Island. A total of six core sites were located in this survey and eighty-five positions, where *P. leana* was observed growing, were recorded with UTM coordinates.

INTRODUCTION

Phaeophyscia leana (Tuck.) Essl., an endemic North American lichenspecies presently known to occur only within the Ohio River Basin (Thomson 1963, Wilhelm and Masters 1994), is recognized as state-endangered in Illinois and a potential candidate for the Federal Endangered Species list (Herkert and Ebinger 2002, Wilhelm and Masters 1994). This imperiled lichen is especially sensitive to landuse patterns associated with riverine corridors and disturbed floodplains of midwestern rivers leave little suitable riparian habitat in which this unique lichen can subsist. *Phaeophyscia leana* was originally described by Thomas Lea from Riddley's Bog, near Cincinnati, Ohio (Thomson 1963, Wilhelm and Masters 1994). After the loss of this station through the expansion of the city of Cincinnati, it was believed that *Phaeophyscia leana* was globally extinct (Thomson 1963). However, *P. leana* was rediscovered by A. C. Skorepa in 1978 in southern Illinois along the Ohio River at Tower Rock Recreation Area (T12S, R8E, S19, 20), Hardin County, 400 kilometers from the type locality (Skorepa 1984).

Skorepa (1984) observed numerous thalli at Tower Rock Recreation Area within 50 m of the Ohio River shoreline but noted that as the flood zone gradually gave way to the upland topography of the Tower Rock overlook thalli of *P. leana* were no longer present. Skorepa also noted a difference in the elevation of thalli on trees as the distance from the river increased and that thalli were found exclusively below the high water mark. Although trees near the river supported thalli that were up to 2.5 m above the soil surface, thalli which were distant from the river were located primarily on the boles of substrate trees. As a result, Skorepa (1984) suggested that *P. leana* was limited to trees that are inundated by spring flood events, since trees which are not in the floodplain at Tower Rock do not support *P. leana*. Skorepa (1984) also commented on the lack of other lichen species in association with *P. leana* at the Tower Rock site, suggesting that other lichen species are not suited to the regimen of flooding disturbances to which *P. leana* is adapted.

Skorepa's rediscovery of *P. leana* prompted the Illinois Department of Natural Resources and the USDA Forest Service to commission Wilhelm and Masters to assess the status of *P. leana* in Illinois (1994). At the conclusion of their study, 25 populations of *P. leana* had been documented, eight of which were considered to be large populations or core sites (Wilhelm and Masters 1994, Wilhelm, Masters, and Shimp 2000). The present study was undertaken to re-examine previously documented populations, survey habitats which had not been surveyed, and to expand the known range of populations of *P. leana*.

Demographic Analysis of the Tower Rock Study Site

In addition to surveillance of the lower Ohio River for populations of *P. leana*, Wilhelm and Masters (1994) analyzed the demographics of Skorepa's rediscovered population at Tower Rock. The population of *P. leana* is confined to a 1.2 ha area bordered to the west by a stream entering the Ohio River that separates the study site from the Tower Rock campground. The population is further confined by the rising Tower Rock escarpment to the north and east. Wilhelm and Masters (1994) and Wilhelm, Masters, and Shimp (2000) sampled 380 individual trees at Tower Rock within the limits of the lowest terrace in the study site. Eleven species of trees supported nearly all of the 1,540 lichen thalli

reported in their demographic analysis of the Tower Rock population. They determined that substrate area available for colonization below the mean flood crest was 452.6 m^2 and that thalli covered a total area of 1.6 m^2 or 0.35% of the total substrate area available for colonization. The southern aspects of substrate trees sampled were 41% colonized, while the more easterly aspects supported 35% of the thalli observed and the northern aspect was utilized by 8% of the thalli.. Thallus position on trees varied from ground level on the exposed roots of trees distant from the river to 3.7 m up the trunk on trees closer to the river channel.

Wilhelm and Masters (1994) and Wilhelm, Masters, and Shimp (2000) divided the trees supporting *P. leana* thalli into four cohorts based on diameter at breast height (DBH), elevation above the normal pool level, and distance from the river's edge. Cohort 1 featured large diameter trees (commonly 50 cm in DBH) located in close proximity to the river including *Populus deltoides* Marsh., *Acer saccharinum* L., and *Platanus occidentalis* L.. Forty eight percent of all *P. leana* thalli observed were located within this cohort and 46% of all trees measured fell into this category. Cohort 2 included a *Carya illinoensis* (Wang.) K. Koch-*Ulmus americana* L. grouping of slightly smaller individuals (diameters of 40-50 cm DBH) located further from the river. Thirty-one percent of the thalli observed at Tower Rock utilized the trees represented in this cohort as substrates. Cohort 3 was composed of *Acer negundo* L., *Diospyros virginiana* L., and *Liquidambar styraciflua* L.with DBH's near 30 cm. This cohort was situated even further from the river and higher up the elevation gradient towards the parking area, approximately 50 m from the river's edge. These trees constituted 14% of the substrates sampled and supported 19% of the thalli observed. Cohort 4 included a *Celtis occidentalis* L. , *Fraxinus pennsylvanica* var. *subintegerrima* (Vahl) Fern. group which were the highest on the terrace and most distant from the river. Only 3% of the thalli were found on these trees.

Populus deltoides supported the highest number of thalli at the Tower Rock site (42%) followed by *Carya illinoensis* (27%), and *Liquidambar styraciflua* (15%). Although Wilhelm, Masters, and Shimp observed preferences by *P. leana* for different tree species, preference analysis was confounded by tree size and frequency within the study area making elucidation of a discernible pattern of substrate selection difficult to quantify. Of the *Liquidambar styraciflua* substrates available, 63% supported thalli, while 70% of the *Populus deltoides* substrates supported thalli of *P. leana* (Wilhelm, Masters and Shimp 2000). Both substrate trees are readily colonized by *P. leana* and support healthy populations of the lichen when conditions are optimum.

Populations Identified by Wilhelm, Masters, and Shimp

Wilhelm, Masters, and Shimp (2000) recorded 25 populations of *P. leana* in the lower Ohio River Valley and provided impetus and direction for further surveillance within the Ohio River Basin (Fig. 1). The study site identified by Wilhelm, Masters, and Shimp (2000) at Tower Rock was the largest population identified in Illinois. It was followed by large populations in Gallatin County associated with the oxbow lake communities within the Gallatin Bottoms including: the Round Pond / Long Pond oxbow lake complex, Hulda Lake, Hulda Woods, and Beaver Pond. Large stands of *P. leana* documented in Kentucky were located at Bell Island (Union Co.) near Old Shawneetown, Illinois, and at Bayou Swamp in

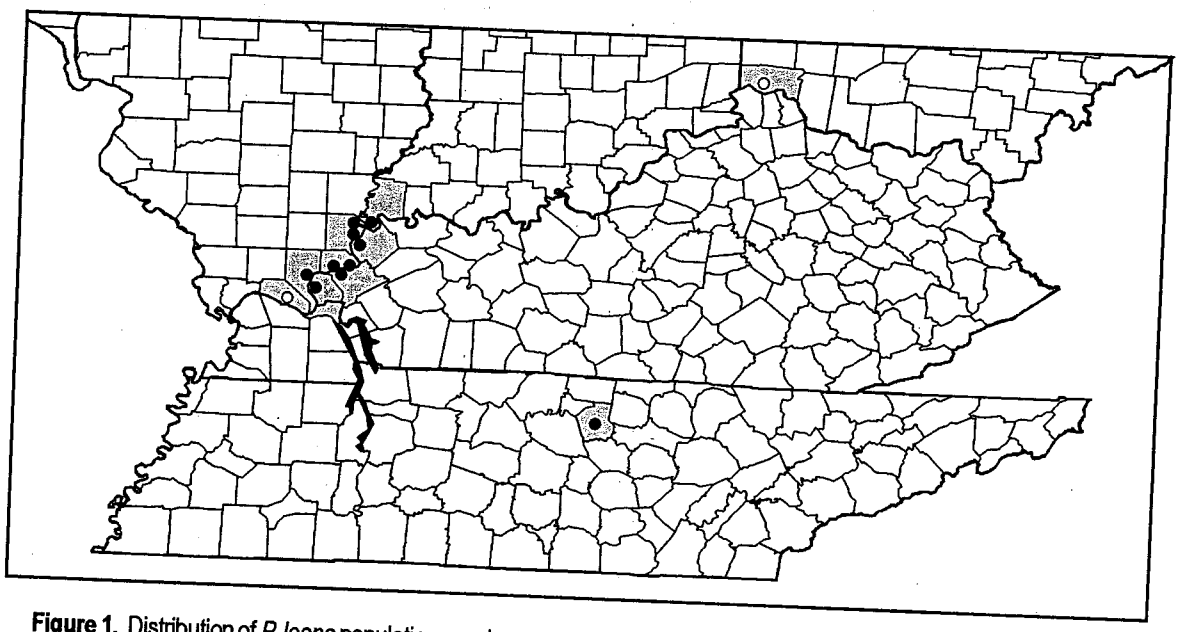

Figure 1. Distribution of *P. leana* populations as documented by Wilhelm, Masters, and Shimp (2000). Solid circles (●) represent extant populations, open circles (o) designate populations which were known to be extirpated at the conclusion of their study (n=2). Counties with documented stands of *P. leana* are shaded. Smaller populations may be grouped within single solid circles.

the vicinity of Birdsville (Livingston County). The single large Tennessee population, documented by Loy R. Phillippe, is located at Hell's Bend near Carthage (Smith Co.). Wilhelm, Masters, and Shimp (2000) also identified eleven smaller populations of *P. leana* in southern Illinois, a single population in Indiana, and five small populations in Kentucky (Wilhelm and Masters 1994).

Smaller populations in Illinois were located in Gallatin, Hardin, Pope, and Massac County. The Gallatin County populations included the New Haven IDOC boat landing, Clark Pond, Horseshoe Pond, Big Lake, and Cow Pond Slough. Populations in Hardin County were located near Finneyville, east of the Cave-in-Rock ferry landing, and near Elizabethtown. A population of *P. leana* discovered by Shimp near the confluence of Haney Creek and the Ohio River, in Hardin County, is considered extinct since the tree supporting the population was lost to bank erosion (Shimp pers. comm. 2002). In Pope County a small population is located south of Golconda at the southern end of a fishing village. Lastly, Massac County supported a population of *P. leana* at Fort Massac State Park in 1990 but further study of the Fort Massac lowlands in 1994 by Wilhelm and Masters led to the conclusion that thalli composing the population had been lost.

A single population was reported from Indiana in southeastern Posey County, adjacent to the Wabash River downstream from New Haven. Small populations were also discovered in Crittenden, Livingston, and Union County in Kentucky. In Crittenden County, populations were documented at the Ohio River boatlaunch near Tolu and at the southeast end of Hurricane Island. Livingston County populations were documented at the Givens Creek boat ramp, opposite Golconda, IL, and along the western shore of the Cumberland River, 2.5 miles upstream from the terminus near

Smithland. In Union County, a single population was located downstream from the Old Shawneetown bridge on the Kentucky-side of the Ohio River.

TAXONOMY AND HABITAT

The genus *Phaeophyscia* was segregated by Moberg (1977) from the genus *Physcia* by the lack of atranorin, brownish coloration of the thallus, a paraplectenchymatous lower cortex, and ellipsoid conidia less than 4um in length. Esslinger (1978) amended the genus *Phaeophyscia* to include taxa that may exhibit darkened rhizines at the base of apothecia, hyaline cortical hairs, medullary anthraquinones, and a black lower cortex.

Phaeophyscia leana is a foliose lichen with narrow (1-2 mm), linear, di- to trichotomously branched lobes (Thomson 1963). Thalli have a mean diameter of 3.1±1.9 cm (n=1530), but can be 13 cm in diameter or larger and form confluent mats in healthy populations (Wilhelm, Masters, and Shimp 2000). Rhizinae are white in coloration, reduced, and rarely project beyond the margins of the lobes (Thomson 1963, Skorepa 1984). Apothecia are sessile, reddish when young but turn black with age, and bear 8-spored asci that produce 2-celled *Physcia*-type ascospores (Esslinger 1978, Thomson 1963). *Phaeophyscia leana* does not produce soredia, isidia or specialized diaspores (Thomson 1963, Esslinger 1978). Spot tests (K, C, KC) are negative and no lichen substances (secondary metabolites) are detected with thin layer chromatography (Thomson 1963, Esslinger 1978). Although members of the genus *Phaeophyscia* typically display a black lower cortex, *Phaeophyscia leana* exhibits a white lower cortex. *Phaeophyscia leana* is an epiphytic corticolous lichen which utilizes deciduous trees in floodplains and exhibits diagnostic characteristics that allow it to be unobtrusively and easily identified during survey operations. Moistened thalli, observed after spring rain events or morning dew falls, are a distinctive bright apple green readily discerned against dark, dampened tree bark. The distinctive linear, forked branching pattern of the lobes and presence of black apothecia facilitates identification in the field.

Suitable habitats are well-defined and limited to floodplain and riparian communities along major river systems. *Phaeophyscia leana* utilizes bark substrates and although it is often found on mature cottonwoods (*Populus deltoides*), *P. leana* displays minimal substrate preferences and will grow on a number of different tree species and woody vines such as *Toxicodendron radicans* L. Kuntze and *Aristolochia tomentosa* Sims. *Phaeophyscia leana* occupies an explicitly recognizable zone on the lower trunks of bottomland trees, requires seasonal inundation by floodwaters, and is limited to that portion of a tree's trunk below the high water mark. Flooding is essential for the exclusion of other lichen species which might displace *P. leana* from a substrate. This spatial adaptation limits competitive interactions with other lichen species that are adversely affected by periodic immersion and allows *P. leana* to occupy a niche available to few other lichen species (Barkman 1958). *Phaeophyscia leana* is further limited to habitats that are best described as park-like. Park-like habitats include sandy, wooded shorelines with little dense vegetation, open groves of bottomland trees, fencerows, woodland openings, woodland edges, fishing camps, and emergent stands of bald cypress (*Taxodium distichum* (L.) Rich.) in swamp communities. These habitats characteristically have high levels of incident light, although the portion of the trunk colonized by *P. leana* may be sun-dappled and receive fluctuating levels of radiation through the day.

REPRODUCTION AND DISPERSAL

Vegetative Diaspores

Foliose lichens often produce well-developed vegetative diaspores or propagules such as isidia and soredia dedicated to asexual reproduction (Hale 1974). Although *P. leana* does not produce specialized vegetative diaspores, fragmentation of the thallus as a result of natural disturbance events may lead to effective vegetative dispersal. Whole thalli or fragments of thalli may be stripped from trees by floodwaters, transported downstream with the flood surge, and lodge on tree bark in an environment conducive for growth to form new thalli.

Historically, habitats would have had more continuity along river corridors and backwaters and populations of *P. leana* would have formed more continuous bands. Historical populations of *P. leana* likely spread gradually, through dissemination along shoreline, floodplain habitats, and within regularly flooded areas of the basin. Swollen river systems would have pervaded floodplain communities depositing propagules and transporting newly displaced thalline fragments downriver. Dispersal over great distances would have been the result of numerous fragment displacement events. *Phaeophyscia leana* dispersal is dependent on population size since large populations would produce more fragments in a flood disturbance event and more effectively colonize new habitats. Smaller populations characteristic of contemporary conditions produce proportionately few propagules, are found in smaller, more restricted wetland habitats, and continue to decline with the loss of thalli.

Sexual Reproduction

Phaeophyscia leana produces distinctive black apothecia which are sessile on the upper surface of the thallus. These ascomata contain asci in which meiosis occurs to form 8 ascospores per ascus (Thomson 1963). *Phaeophyscia leana* produces 2-celled ascospores that are fusiform or ellipsoid in shape with thickened apices and septa (Esslinger 1978). Ascospores produced by the fungal component of the lichen allow for sexual reproduction of the fungus (Purvis 2000). Once discharged into air currents from the asci, ascospores must encounter the proper substrate and habitat to germinate, and subsequently locate the proper photobiont in order for lichenization to occur. Ascospores that settle on suitable substrates may remain dormant until contact with a suitable alga. This pattern of establishment is considered the most common for lichens of temperate regions where growth rates are relatively slow (Hale 1974). Alternatively, ascospores may germinate on contact with a suitable substrate and form a hyphal system that functions as a saprotroph until it comes in contact with a suitable alga for lichenization (Hale 1974). Ascospores which germinate on a substrate and do not contact the proper photobiont most likely perish.

Encountering a symbiotic alga in nature is a fundamentally problematic step in the reproductive process of lichenized fungi. The genus *Phaeophyscia* belongs to the Order Lecanorales and the family Physciaceae (Brodo, Sharnoff, Sharnoff 2001). Members of the Physciaceae are currently known to only utilize the green alga *Trebouxia* as a photobiont (Ahmadjian 1988). The genus *Physcia*, which is closely related to *Phaeophyscia*, utilizes only two specific species of *Trebouxia*; *T. gelatinosa* and *T. impressa* (Ahmadjian 1988). Once an ascospore of *P. leana* is released,

settles on a suitable substrate, and germinates it must encounter a trebouxoid algal cell in order for a lichen thallus to form (i.e. lichenization). *Trebouxia* ssp. are exceedingly rare on corticolous substrates and it has been suggested that sources of *Trebouxia* available for lichenization are limited to free vegetative diaspores which come into contact with the prothallus of the mycobiont or ascospores (Hale 1974). It has also been suggested that during heavy rain events algal cells can be released by lichen thalli and become available for lichenization (Hale 1974). Although spring floods and rain showers or thalli damaged by spring flood events could be the source of free cells, the mechansim that occurs in nature is a matter of speculation. Many lichenologists believe that sexual reproduction in lichens is a vestigial event and that the diversity and success of asexual propagation is the derived condition (Nash 1996).

ORIGINS

Phaeophyscia leana is an Appalachian endemic species presently known to occupy floodplain habitats along the Ohio and Cumberland River systems (Thomson 1963). The position of populations discovered to date suggests an Appalachian origin and subsequent dispersal along the Cumberland and Ohio River drainages. At the closing of the PreCambrian eon (600 MYBP) and the beginning of the Paleozoic era, portions of proto-North America were inundated periodically by shallow equatorial seas. The continental margin of proto-North America that was involved in the eventual formation of the Appalachian Mountain range became an active plate boundary as the Iapetus Plate (oceanic) began to subduct beneath the North American craton. This region of subduction created a number of volcanic island arcs which accreted to the North American plate boundary (Skinner and Porter 1992). By the middle Devonian, the proto-Atlantic or Iapetus Ocean closed as two continental plate boundaries began to converge (Skinner and Porter 1992). The Taconic Orogeny, a middle Ordovician occurrence (440-480 MYBP), is recognized as the initial mountain building event of the Paleozoic era. It was followed by a second accretional event known as the Acadian Orogeny (350-450 MYBP) that was followed by the Alleghenian Orogeny (250-300 MYBP). Two hundred and fifty million years of volcanic events, accretion of terrane (micro-plates and island arcs), and uplift of the early Appalachians during the subduction of the Iapetus Plate, pale in comparison to the Alleghenian Orogeny, the final collisional event of the Pennsylvanian period when the African continental plate (Gondwanaland) collided with the North American craton to form the supercontinent amalgamation Pangea.

This collision zone is recognized today as the ancient eroded belt of fold and thrust mountains consisting of the Ozark-Ouachita region, the Marathon Mountains of Texas, and the Appalachian Highlands (Rodgers 1970). In the late Triassic period (220 MYBP) Pangea began to rift and a new passive tectonic margin formed as North America began todiverge from the African continent toward a more northerly global position. The tectonic coincidences which had formed the Appalachian range subsided and the mountains succumbed to the erosional processes of time. As Pangea fractured, the Atlantic Ocean began to form as did the Caribbean Ocean and the Gulf of Mexico. Crustal down-warping during the mid-Cretaceous (100 MYBP) resulted in the inundation of a portion of central North America known as the Mississippi Embayment which extended as far north as the present day city of Cairo, Illinois (Rodgers 1970). During the Cenozoic

era minor uplift events further altered the Appalachian Highlands causing the rapid downcutting of mountain stream systems particularly evident in the Kanawha and New Rivers, that are tributaries of the Ohio River (Schultz and Compton-Gooding 1991).

The geologic processes which created the Appalacian Highlands created ecological conditions conducive to speciation of organisms within the Appalachian Mountains. The resulting compartmentalization of habitats, particularly evident in the ridge and valley system of Appalachia, induced local ecological contrasts in climate and vegetational patterns, created barriers to gene flow, and supported the speciation of Appalachian endemic taxa (Thomson 1963). The genus *Physcia* includes several taxa that are North American endemics with origins in the Appalachian Mountains. *Physcia subtilis* Degel., *P. millegrana* Degel., and *P. frostii* Degel., as well as a host of subspecific variants, are believed to have arisen in the Appalachian center of endemism (Thomson 1963). The indigenous nature of *Physcia* to Appalachia, and the resultant variability brought about by evolutionary processes, suggest a great antiquity not only of *Physcia* and *Phaeophyscia* but lichen species which have dispersed from this geographical area (Thomson 1963).

The ability to utilize habitat areas which are disturbed by flood events is a unique characteristic of *P. leana* and provides clues to the environmental environmental conditions it may have been exposed during its inception. Scenarios proposed to account for the evolution of *P. leana* are as follows:

- Streams that flood frequently during rain events (typical of present Appalachian physiography) occupied valley floors and contributed a disturbance that an ancestral lichen species had to overcome in order to utilize available yet problematic habitats associated with the basement of the valley. Individuals which could withstand flood events would have been selected and a new species could have emerged to utilize substrates prone to flooding.
- The Appalachian coal basins associated with the western margin of the Appalachian orogenic belt are an indication of the presence of wetland communities during Paleozoic times. These coal swamps could have provided a habitat for the origin of a progenitor of *P. leana*.
- Glacial advancement into North America altered flow patterns of stream systems draining northward to the St. Lawrence River across Indiana, Illinois, and Ohio. At the toe of advancing glaciers, meltwater streams formed and drainage systems were diverted along the ice floe face. For example, it is believed that the ancient Kanawha-New River was dammed by glacial ice that disrupted its northward flow, diverted the river's drainage, and formed the precursors of the present Ohio River drainage system (Lindsey 1966). Fluctuations in the seasonal release of meltwater into drainage systems carrying effluent away from continental glaciers could have led to the adaptation of an ancestral lichen species to frequent flooding disruptions. Habitation of the Ohio River basin by *P. leana* would then be a direct result of the glaciation of continental North America. The formation of the Ohio River drainage could also have provided *P. leana* with a dispersal route from Appalachia (Thomson 1963, Lindsey 1966).

THE OHIO RIVER WATERWAY

The Ohio River flows 1,578 kilometers (981 river miles) from its origin at the confluence of the Allegheny and Monongahela rivers in Pittsburgh, Pennsylvania, before it empties into the Mississippi River at Cairo, Illinois (USACE 2002). Political jurisdictions within the basin include New York, Pennsylvania, Ohio, Virginia, West Virginia, North Carolina, Maryland, Tennessee, Kentucky, Indiana, and Illinois. The Ohio River Basin drains approximately 203,940 square miles (528,204.6 km^2) and major tributaries from its origin to terminus include the Muskingum, Kanawha-New, Guyandotte, Big Sandy, Scioto, Licking, Great Miami, Kentucky, Green, and Wabash Rivers (ORSANCO 2002). The Ohio River Valley Ecosystem Team of the U. S. Fish and Wildlife Service (1999) divides the Ohio River basin into three physiographic provinces, the Appalachian Plateau, the Central Lowlands, and the Interior Low Plateau. The Appalachian Plateau, in the eastern third of the drainage, has the rugged topography inherent to the Appalachian Highlands. This province is characterized by ridge and valley systems with steep gradient streams that commonly flood during seasonal rain events, extensive mixed mesophytic forests, and minimal agriculture due to poor soils. The Central Lowlands province occupies the northwestern third of the basin and has been greatly modified by Pleistocene glaciation. Soils of this province are relatively level owing to glacial advances and deposition, and due to high soil fertility, supports a rigorous agricultural industry. The Interior Low Plateau province located in the southwestern third of the Ohio River drainage is characterized by limestone formations and rolling terrain of the Lexington Plains and Bluegrass regions of Kentucky and the Shawnee Hills of southern Illinois. The floodplain areas in this province are dominated by agriculture while the rugged hills and bluff-lines are forested.

The historic river bed dropped a half foot per mile resulting in a fast, shallow flowing stream with pools, riffles, and falls. By 1820, 102 obstructions to navigation were identified between Pittsburgh, Pennsylvania and Louisville, Kentucky that made navigation of the waterway a treacherous undertaking (Ohio River Fisheries Management Team 1995). Improvements to navigation began in 1825 and the first lock and dam was completed below Pittsburgh in 1885 (ORFMT 1995). Channelization of the river was completed in 1929 with 50 low lock and dam structures in operation (ORFMT 1995). These were later modernized with 20 higher navigation dams that support a 2.7m minimum depth for commercial navigation (ORFMT 1995). The locks and dams on the Ohio River and its major tributaries have decreased the velocity of the river and the advent of modern high-lift facilities have created a deeper (average depth of 7.3 m), more languid river system than existed before anthropogenic modification (ORSANCO 2002). The Ohio River is the busiest inland waterway system in the United States and sustains the transport of twice the barge tonnage of the Great Lakes system. The average annual commercial cargo shipped on the Ohio River averages 230 million tons, and includes coal, crude oil, and petroleum goods as well as major commodities such as aggregates, iron, steel, chemicals, and grain (ORFMT 1995, ORSANCO 2002).

DESCRIPTION OF PRINCIPAL STUDY AREAS

Surveys were conducted in all counties bordering the Wabash and Ohio Rivers in Illinois as well as selected areas along the Mississippi River. The physiography of southern Illinois, as well as landuse patterns present in floodplains or riparian corridors, dictate which areas are most conducive for populations of *P. leana* and where survey work should be concentrated. In Illinois, the Gallatin Bottoms in Gallatin County, the Black Bottom in Massac County, and the White County floodplain of the Wabash River were most important in this study (Fig. 2). These three counties have large floodplains, limited industrial buildup along the rivers, and large wetland features located within the floodplains. Due to their position within the dissected uplands of the Shawnee Hills Division, Pope and Hardin Counties have bluff lines along the Ohio River and do not have large areas of floodplain habitat. The river shorelines of Pulaski and Alexander County are heavily industrialized due to their proximity to the confluence of the Ohio and Mississippi Rivers. Facilities for the loading of commodities to be transported by barge and tow on the inland waterway system and electrical power generating stations are prevalent and have negated potential shoreline habitats for *P. leana*.

Gallatin, Hardin, Massac, Pope, and White counties have continental climates with an annual temperature range of 100 degrees, with maximum temperatures reaching 38° C two-thirds of the summers with the hottest months being July and August (Martin 1996, Parks 1975, Wallace and Fehrenbacher 1969). Winter minimums of -18° C or less are reached half of the winter season with January and February being the coldest months (Parks 1975). Annual precipitation averages 112-116 cm (Parks 1975, Martin 1996, Wallace and Fehrenbacher 1969). The first six months of the year (January through June) receive the highest average precipitation annually, averaging nearly 10 cm or more precipitation per month, and September and October are the driest months (Wallace 1969). The growing season averages 200 days at Paducah, Kentucky (McCracken Co.), which correlates closely with the Black Bottom of Massac County, and 187 days at New Burnside, Illinois (Johnson Co.), which corresponds to the Burden Falls Wilderness in northern Pope County (Parks 1975). December, January, and February are characterized by annual seasonal snowfalls of up to 15.8 inches in White County (Martin 1996).

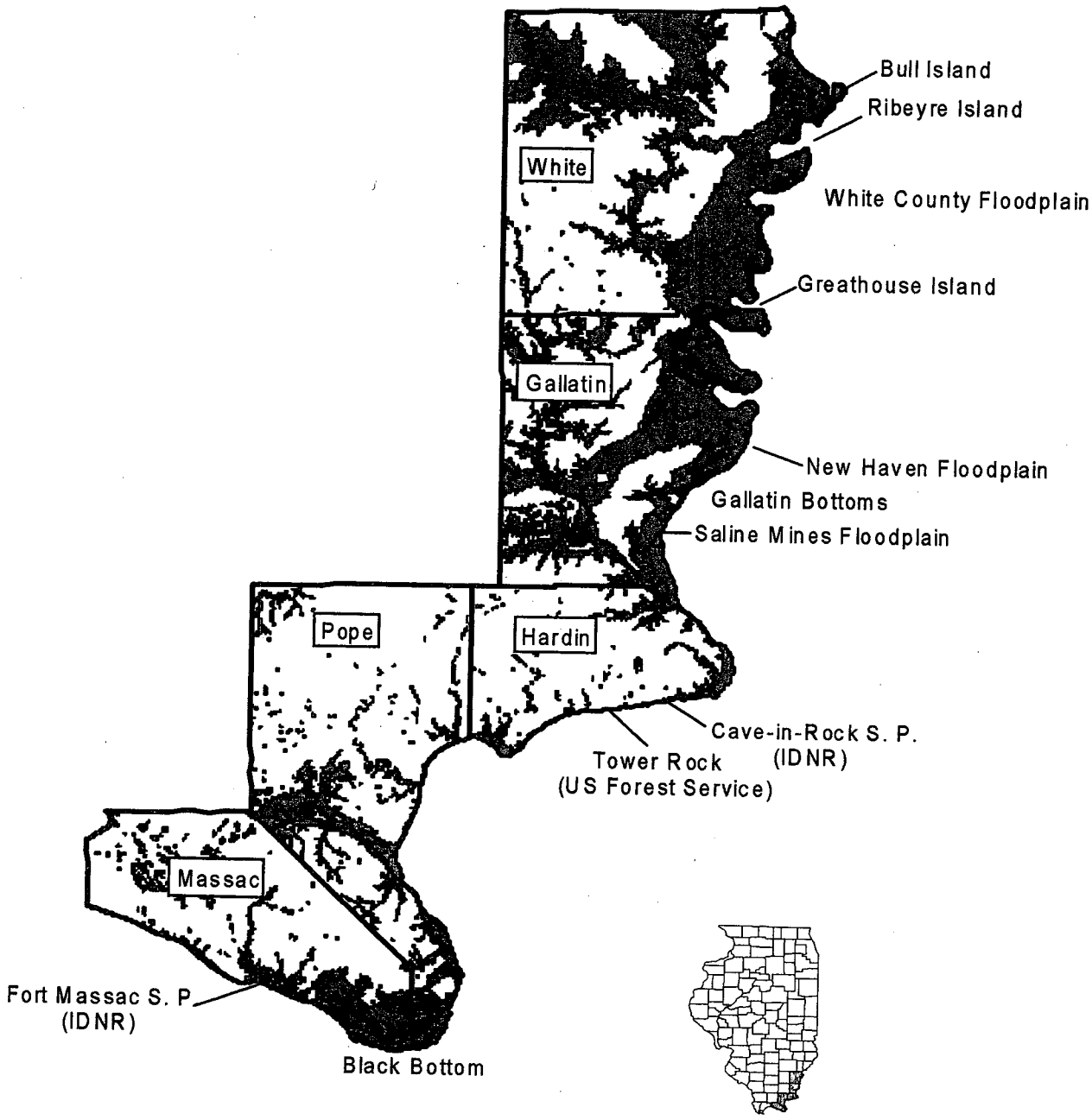

Figure 2. Principle floodplain study areas in Illinois

The Black Bottom, Massac County, Illinois

Physiographic Characteristics

Located east of Brookport and south of the village of Unionville, the Black Bottom makes up the southeastern toe of Massac County. The Black Bottom is a crescent shaped meander loop floodplain approximately 55 square kilometers (21.5 mi.^{2}) in area (Butler 1977). The bottom is 5 kilometers wide from the Ohio River towards Unionville and 16 kilometers long from east to west. The bottom is characterized by long, narrow, natural lakes interconnected by sloughs and cutoffs. Loon Lake, Brushy Lake, and Allard Lake, located within sections 20 and 29, are situated within the western bottom. Kinneman Lake, which spans the center of the study area, traverses sections 28, 34, and 35 and terminates at the boundary of section 36. Several smaller, channel-like lakes, the largest of which is Beaver Dam Lake, lie south of Kinneman Lake and the Redbird Ridge area. Avery Lake, Sugar Camp Lake, and Clear Lake lie to the northeast of Kinneman Lake. The floodplain surface has a washboard topography of long, low, flat, crested ridges, paralleling each other and the curvature of the Ohio River, that are separated by shallow depressional areas or swales. Ridgetop elevations vary from 102 meters above sea level in the eastern bottoms in the vicinity of New Liberty to 97 meters in the western bottom (Butler 1977).

Floral Characteristics

Analysis of the General Land Office survey records for Massac County, compiled by Augustus Stone, Sr. and B. F. Stone in 1806, led Butler (1977) to identify three primary floral zones within the Black Bottom. The Hardwood Bottom, Swamp (divided into deep and shallow swamp communities), and Cane Bottom (divided further into the cane bottom proper and the river-lakeshore subzones)were specified by Butler as the primary communities composing the Black Bottom prior to European settlement. The Hardwood Bottom zone is the most elevated but receives overflow from the Ohio River and remains ponded during the winter and early spring flood seasons. This zone occupies ridgelines and areas distant from the Ohio River and supports a higher number of *Quercus* and *Carya* species than swale areas. The Swamp grouping correlates with Mohlenbrock's Deep Swamp community or the *Taxodium, Nyssa aquatica / Rosa palustris* Marsh. community (Voigt & Mohlenbrock 1964). Dominants of Deep Swamp communities are *Taxodium distichum, Nyssa aquatica, Populus heterophylla* L., *Carya aquatica* (Michx. f.) Nutt., *Fraxinus profunda* (Bush) Britt., *Gleditisia aquatica* Marsh., and *Acer drummondii* Hooker & Arnott (Voigt & Mohlenbrock 1964). Buttonbush (*Cephalanthus occidentalis* L.) is a ubiquitous understory component that often forms "thickets" in shallow water areas present along the peripheries of oxbow lakes. Deep Swamps of the Black Bottom are undergoing transitional changes as a result of local agricultural practices. Drainage and land clearing have significantly reduced deep swamp areas within the Black Bottom. Sedimentary filling of these wetlands is responsible for the conversion of deeper water communities to more disturbed shallow water wetlands.

Black Bottom shallow swamp communities, as well as shallow swamp communities in Gallatin County, such as the Goose Pond INAI site and Goose Pond Scatters, are disturbed by high sediment loads and have shrub layers dominated by *Cephalanthus occidentalis*. After the subsidence of overflow events, the shrub layer and tree trunks exposed to flood waters are heavily coated with deposited silt. Voigt and Mohlenbrock (1964) recognize Shallow Swamps, areas of less than one foot of standing water, as the *Taxodium, Fraxinus tomentosa* Michx. f. / *Itea virginica* L. community. In Shallow Swamps, *Nyssa aquatica* is replaced *by Fraxinus tomentosa* and its associates, *Liquidambar styraciflua, Ulmus rubra* Muhl., and *Acer rubrum* L..

The Cane Bottom, as described by Butler (1977), is the area of bottom land composed of fertile soils of the Armiesburg series associated with the Ohio River and encompassing the channel lakes. Descriptive elements of the General Land Office survey notes for this area include "thick cane brakes," "good bottom," "thick cane," and "thick cane bottom." Tree species present within the cane bottom include *Carya* spp., *Carya ovata* (Mill.) K. Koch, *Carya illinoensis, Ulmus* spp., *Fraxinus* spp., *Juglans nigra* L., *Quercus bicolor* Willd., *Acer saccharum, Quercus macrocarpa* Michx., *Liriodendron tulipifera* L., *Morus rubra* L., and *Gleditsia triacanthos* L. (Butler 1977). Within swale areas *Quercus palustris* Muench., *Liquidambar styraciflua*, and *Fraxinus* ssp. are common. Areas along the lakeshores or along the river, within the cane bottom, have slightly different floral assemblages. Dominants include *Salix nigra* Marsh., *Populus deltoides, Platanus occidentalis, Acer rubrum, Gleditsia triacanthos, Acer saccharinum, Acer negundo, Ulmus rubra,* and *Ulmus americana* (Butler 1977). The riverbank subzone of the Black Bottom was at one time dominated by *Populus deltoides*. According to Butler (1977), the survey record refers to the area near the Ohio River along the section line between Sections 33 and 34 (T16S R6E), roughly from Pearcy Camp along the north shore of Kinneman Lake perpendicular to the Ohio River channel, as a "cottonwood bottom." Whether or not *P. leana* occupied this cottonwood bottom historically is a matter of speculation, but it is likely that it did due to the importance of *Populus deltoides* as a substrate and the presence of the lichen within the floodplain at present time. *Taxodium distichum* and *Nyssa aquatica* are emergent along the shorelines of the channel lakes and the survey notes document dense stands of cane encompassing the channel lakes as well. Although remnants of the cane bottoms can still be observed along lakes, and within areas which are still forested, the preponderance of the cane bottom has long since been converted to rowcrop agriculture.

Soils of the Black Bottom

Seven percent or 4381.7 hectares of Massac County remain in wetland habitats, 5.4% or 3387.4 hectares remain in bottomland forest, and an additional 1335.7 hectares are open water areas (IL Land-Use Clearinghouse 2002). Soils of the Black Bottom chiefly belong to the Armiesburg-Emma association, a moderately permeable soil formed in alluvial deposition inherent to river floodplains (Parks 1975). The soils are nearly level to moderately sloping and well drained to moderately well drained. Particular soils of importance within the Black Bottom include Armiesburg silty clay loam and Huntington silt loam that surround the large natural channel lakes situated within the Bottom. The Armiesburg

series is a group of soils which are created from water-deposited sediments and consist of deep, nearly level to gently undulating, well-drained soils of bottom lands and areas surrounding the channel lakes and drainageways of the Black Bottom. The Huntington series consists of deep, nearly level, well-drained soils adjacent to the Ohio River, formed in silty water-borne sediments more than 50 inches thick (Parks 1975). Huntington silt loam is located 1.5 to 6 meters lower than the main floodplain and is often situated between broad plains of Armiesburg soils (Parks 1975). Slopes are generally gradual but may be steeper when associated with wetland features or the natural channel lakes of the Black Bottom. The rich alluvial soils of the Black Bottom supported a diverse forest and wetland flora which was well suited for *P. leana* before European anthropogenic disruption. Owing to the natural productivity of these soils, the Black Bottom is now utilized for row crop agriculture rather than to support floral communities and substrates utilizable by *P. leana*.

Presettlement Conditions

Earthen mounds constructed by ancient Mississippian peoples have drawn the interest of the archeological community and much is known about the historical conditions of areas supporting major Mississippian centers. Fortuitously, the Black Bottom of Massac County shows evidence of a particularly large Mississippian settlement known as the Kincaid Site (Butler 1977). The Kincaid Site is located along the northern shore of Avery Lake, a kilometer from the present Ohio River channel, situated along the Massac-Pope county border 5.7 kilometers from the village of New Liberty. Avery Lake is a long, narrow, permanent channel-like lake similar to Allard, Kinneman, and Loon Lakes. A Mississippian population established agricultural encampments throughout the lower Black Bottom and significantly affected the floral composition of the Cane Bottom zone (Butler 1977). All settlements located within the Black Bottom were situated within or in close proximity to the cane bottom. Stands of *Arundinaria gigantea* (Walt.) Chapm. indicate the presence of fertile well drained soils located on higher stations of the floodplain which are affected by inundation less regularly than areas of lower elevation(Butler 1977). Canebrakes are easily cleared with fire and cane is a fast burning, light fuel, similar to tallgrass species of prairie ecosystems. The combination of highly fertile soils positioned in less-flood-prone areas and the ease by which this land could be cleared for cultivation provided sufficient inducement for the selection of field sites in canebrake areas (Butler 1977).

The ignition of canebrakes within the Black Bottom by Mississippian peoples would have had certain ramifications for the understory of surrounding bottomland forest communities. Ground fires originating from the canebrakes would have traveled into adjacent forested areas where the understories of riverbank-lakeshore subzones and associated forested bottomland areas would have been drastically altered. Understories would have been more open as a result of shrub layer die-back and more fire tolerant tree species would have been selected. The clearing effect of these fires presumably would have provided more park-like habitats well suited for the growth of *P. leana*. River slack-water periods would have allowed fires to move from upland areas onto floodplains where fires would burn up to permanent, deep water, wetland communities. Floodplain fires would have promoted open understories and park-like habitats within areas which seasonally flood and provide a particularly conducive combination of factors for the support of larger historical populations of *P. leana*.

The White County Floodplain

Physiographic Characteristics

In White County, 74% of the available acreage is dedicated to rowcrop agriculture, 6% remains forested, and 895 hectares of natural wetland features remain (IL Land-Use Clearinghouse 2002). The primary floodplains are located in southeastern White County where the Wabash and Little Wabash River drainages coincide. Alluvial sediments have been deposited due to flooding of the Wabash River systems and old river channels and slack water sloughs present within the floodplain. Ribeyre Island and Greathouse Island are two large abandoned river channels of the Wabash River present within the White County floodplain. Sandy Slough, Goose Pond Swamp, The Bayou, and Brushy Slough represent slackwater sloughs of both the Wabash and Little Wabash Rivers.

Soils of White County Floodplains

Soil associations in White County include the Armiesburg-Petrolia-Nolin and the Skelton-Ruark-Crawleyville associations (Martin 1996). The Armiesburg association is present along the Wabash River on rises and ridges. Poorly drained Petrolia type soils are located within sloughs. Although native vegetation was principally bottomland forest, wetland flora or wet prairie communities, the land is utilized principally for cultivation even though overflow hazards are prevalent. The Skelton-Ruark-Crawleyville association was formed in outwash deposits on terraces and lake plains and is characterized by gradual, broad, low flats with some ridges, side slopes, and sand dunes. Skelton soils are permeable, internally draining sandy loams, Ruark soils are nearly level, poorly drained and common on broad lowland flats and drainageways, and Crawleyville soils are nearly level soils on broad rises and terraces (Martin 1996).

Landuse

The floodplain of southern White County, as well as the bottomland areas of northeastern Gallatin County, are intensively cultivated and center pivot irrigation is utilized on the most productive farmland. An aquifer, influenced by the proximity of the Wabash River, allows for the alteration of soil surface moisture levels during the growing season and further increases the potential of floodplain agriculture in Gallatin and White counties. As a result, forested communities are highly residual within river floodplains. Rowcrop agriculture, logging, and drainage have resulted in the demise of expanses of forested bottomlands along the Lower Wabash River as well as the bottomland forests of the Ohio and Cumberland Rivers. Cultivation of river floodplains involves an element of risk due to flooding hazards, however levee construction has alleviated some crop losses within significant floodplain areas. Short-season soybeans are commonly seeded in order to maximize the available growing season. Fields often stay wet long into the spring planting period due to the characteristic overflow of flood zones in late winter and early spring. Flood events characteristically deposit swaths of debris across the floodplain, including piles of uprooted trees and associated woody flotsam. Compared to upland sites, spring dryout and planting comes later. Lower terraces, containing swales on particularly wet years, will have ponded areas that will be left for "patch-planting" at a later time when these plots dry sufficiently for access and proper seeding.

During the summer, the low water level of rivers provides a period of safety from flooding for growing crops but the agricultural season is often terminated by fall rain events which raise river stages and produce floods.

The Gallatin Bottoms

Physiographic Characteristics

The Gallatin Bottoms lies within the bottomlands section of the southern extent of the Wabash Border Division. Here, the Little Wabash River joins the Wabash River near New Haven, upstream of the terminus of the Wabash River. The Wabash River then converges with the Ohio River, just north of Wabash Island, Kentucky (Ohio River Mile 848) within sight of the John T. Myers Locks and Dam (US ACE 2000). The union of these three rivers has produced an expansive floodplain which retains wetland communities including deep flowing slough channels, large oxbow lakes, and cypress swamps that support populations of *P. leana* in relative abundance.

Within the Gallatin Bottoms, 8.8 km^2 consist of wetland areas larger than 16 hectares in size or more than 0.2 kilometers in width (Wallace and Fehrenbacher 1969). Original land survey records refer to "low drownded bottoms," "flat drownded land," "overflowed land," or simply "all swampy." Survey records also include descriptive phrases concerning the wetland features present within the Gallatin Bottoms such as "1st 3850 swamp the rest pond impassable," "pond too deep to wade," "mile continues in willow pond all the length," "all swamp impassable," and, in reference to present day Hulda Lake, "open lake deep as Ohio." Approximately 8.6% of Gallatin County is composed of wetland ecosystems including 1747.6 hectares of lakes, rivers, and streams (IL Land-Use Clearinghouse 2002). In addition to wetland communities, 7.3% (6231 hectares) of the county remains in bottomland forest (IL Land-Use Clearinghouse 2002). The Gallatin Bottoms can be subdivided into primary floodplains, the New Haven floodplain and the Saline Mines floodplain. The New Haven floodplain lies between New Haven and Old Shawneetown and includes the New Haven Ponds (Clark, Horseshoe, and Beaver Pond), the Gallatin Sloughs (Yellowbank, Cattail, Running Slough, and others), and the Old Shawneetown Lakes, (Hulda, Round Pond, Long Pond, Fehrer, Black, Big, and Fish Lakes). The Saline Mines floodplain is formed at the confluence of the Saline and Ohio Rivers and now supports a single oxbow lake community, Mud Lake. Although large wetland communities still persist, the remainder of Gallatin County is classified as built-up land, woodland areas, or land converted to agricultural use.

Floral Characteristics

Voigt and Mohlenbrock (1964) studied the composition of bottomland forests along the Lower Wabash River in Gallatin and White counties. Forest composition based on basal area was interpreted in several areas in the vicinity of New Haven. Of particular relevance to this study is ecological / floristic data obtained by Mohlenbrock at Cattail Slough (Sect. 31, T7S, R10E). Trees of greatest ecological importance within this wetland feature (with composition percentage values) and available for colonization by *P. leana* included *Quercus palustris* (0.4), *Fraxinus pennsylvanica* var.

subintegerrima (5.6), *Quercus bicolor* (0.8), *Ulmus americana* (6.5), *Liquidambar styraciflua* (2.6), *Acer saccharinum* (27.4), *Platanus occidentalis* (16.6), *Juglans nigra* (0.5), *Ulmus rubra* (1.3), *Nyssa sylvatica* Marsh. (0.4), and *Quercus macrocarpa* (5.5). East of Inman, in the vicinity of Willow Pond or Joes Slough, (Sect. 12, T8S, R9E), Mohlenbrock reported a different set of major compositional species, including *Quercus alba* L. (10.1), *Carya ovata* (17.5), *Quercus lyrata* Walt. (1.4), *Quercus velutina* Lam. (13.4), *Quercus palustris* (1.1), *Fraxinus pennsylvanica* var. *subintegerrima* (1.4), *Quercus bicolor* (1.8), *Ulmus americana* (9.0), *Carya illinoensis* (1.1), *Liquidambar styraciflua* (8.8), *Ulmus rubra* (3.9), *Nyssa sylvatica* (6.4), *Quercus macrocarpa* (5.9), and *Celtis occidentalis* (1.6). Voigt and Mohlenbrock also ranked the most abundant components of the herbaceous understory including *Toxicodendron radicans* (100% constance); *Campsis radicans* (L.) Seem (77% constance); and *Parthenocissus quinquefolia* (L.) Planch. (44% constance); and, *Arundinaria gigantea*; (44% constance).

Soils of the Gallatin Bottoms

The soils of the Karnak-Allison-Wakeland association prevalent within the Gallatin Bottoms are deep, slowly permeable, nearly level, silty and clayey soils that were formed from the deposition of alluvial river sediments and are generally productive, fertile agricultural soils (Wallace and Fehrenbacher1969).

Landuse

Wetland communities in Gallatin County have been adversely affected by oil exploration and agricultural practices that are the economic mainstay of the area. Pollution from oil field enterprises that dot the Gallatin floodplain impinge on the health of wetland and riverine systems. Land clearing, drainage programs, and levee protection of bottomlands intended to produce more productive farmland have significantly altered floodplain ecosystems and environmental processes of the Gallatin Bottoms. Agricultural pesticides and siltation from field erosion have transfigured wetland habitats that remain. The destruction of wetland communities within the Gallatin Bottoms, whether as obvious as the drainage of a backwater slough or insidious as the slow siltation of an oxbow lake, threaten to change the specialized habitats required by *P. leana* and raise concern as to the continued survival of *P. leana* in Gallatin County.

THE CUMBERLAND RIVER BASIN

The headwaters of the Cumberland River originate on the Cumberland Plateau at the conflux of the Poor and Clover Forks Rivers in Harlan County, Kentucky, between the Pine Mountain and Cumberland Mountain ridgelines. The Cumberland River traverses approximately 1115 km (693 river miles) before converging with the Ohio River (Ohio River Mile 920.4) at Smithland, Kentucky. The total basin area covers 46412.8 km^2 (ORSANCO 2002). A commercially navigable channel is maintained from the terminus to the head of navigation on the river at Celina, Tennessee, 381 river miles (613 km) from Smithland (USACE 2002). Primary tributaries entering the Cumberland River of importance to this study include the Obey and Caney Fork Rivers.

Cordell Hull Lock and Dam is located 5 river miles upstream from Carthage, Tennessee. At full pool, 504.0 ft

above MSL, Cordell Hull Reservoir has 11,900 surface acres (ORSANCO 2002, USACE 2002). Below Carthage the mainstem storage impoundment, Old Hickory Lake, is maintained by the Old Hickory Dam and powerstation at river mile 216.2 in Sumner and Davidson counties, 25 river miles upstream from Nashville, Tennessee (ORSANCO 2002, USACE 2002). At full pool, 455 ft above MSL, the surface acreage of Old Hickory Lake is 22,500 acres (ORSANCO 2002, USACE 2002). Important large impoundments on tributaries of the Cumberland include the Dale Hollow Lake Reservoir on the Obey River and a large impoundment located on the Caney Fork River, the Center Hill Lake Reservoir. The Center Hill Dam on the Caney Fork River is approximately 20 km southeast of Carthage, Tennessee.

Impoundments constructed on the Cumberland and Caney Fork Rivers are intended to control damaging flood events, create a commercially navigable waterway, generate hydroelectric power, and provide recreational opportunities and tourist trade to local economies in Kentucky and Tennessee (ORSANCO 2002). While these activities have been generally successful,the river systems and associated floodplains have been significantly altered. Stream continuity has been disrupted and natural flood disturbances have been dampened. Mainstem reservoirs such as Old Hickory and Cordell Hull Lake, among others, inundate vast portions of the river corridor. The Cumberland River is impounded along much of its length in order to produce reliable hydropower and fluctuations in water levels are monitored throughout the Cumberland drainage to optimize power output.

Cumberland River impoundments are uninhabitable by *P. leana* along the majority of the drainage basin due to the lack of adequate water level fluctuations. The flooding processes required by *P. leana* are rarely evident as proximity to the impounding structures increases although "backwater" areas of the lakes have water level fluctuations that most closely resemble conditions within the drainage prior to dam emplacement. Populations of *P. leana* located in Tennessee utilize backwaters of Old Hickory Lake or are situated in areas where river systems are less influenced by impoundment. The Center Hill Dam population is located immediately below the hydroelectric dam of the Center Hill Reservoir and although the Hell Bend population is further down the drainage it still lies within areas in which river stages are allowed to fluctuate. Impoundments on the Cumberland River destroyed available substrates and inundated populations of *P. leana* when filling. Farther from dam facilities, the riverine zone was not permanently inundated, and whereas some substrate trees were lost, populations of *P. leana* were able to persist. Segments of the Cumberland River between the lakes act as refugia for *P. leana* bounded by "dead zones" of large impoundments. The reservoirs also limit the dispersal of propagules into suitable habitats downstream. Propagules which are carried into the lake systems will not be supported by flooding disturbance events needed for persistence and are doomed as transport through the reservoirs is unlikely.

METHODS

Reconnaisance of *P. leana* populations began in winter 2001 and continued through summer 2002. Watercraft, automobile, and foot surveys were implemented during searches for populations of *P. leana*. Previously reported populations were visited initially to ascertain whether known populations had been lost and to develop a search image for habitats required by the lichen. Accurate documentation of known and new populations discovered during surveys was accomplished with global positioning technology in order to facilitate relocation of populations. UTM position data was recorded with a 12 parallel-channel-processing GPS instrument, (Garmin II+ unit), calibrated to map datum WGS 84. All UTM positions recorded were averaged for a 60 second time interval prior to final tabulation. UTM coordinates were then entered into MapTech mapping software for accurate positioning of waypoints onto topographic maps and digital orthoquadrangle images.

Watercraft surveys were conducted on the Wabash River from the mouth of the Wabash to the Illinois/Indiana border above Darwin Ferry at Darwin, Illinois (Wabash River Mile 200). Surveys on the Wabash began in January of 2002 and were completed after the fall of the spring flood crest in July of 2002. In addition to reconnaissance of the Wabash River, the Little Wabash River from Carmi, Illinois to its confluence with the Wabash River was also surveyed. During watercraft surveys, all populations of *P. leana* located were recorded as waypoints as were major disembarkment locations for surveys on foot along the shoreline corridor.

Land surveys were guided by analysis of aerial USGS digital orthoquadrangle images, USDA Soil Survey aerials, USGS topographic maps, and US ACE Ohio River Navigation Charts (2000). Surveys on foot were conducted in the sloughs of Gallatin, Massac, and White counties in Illinois, where suitable habitats are most abundant and access by any other means is impractical, as well as within large floodplain habitats of Posey County, Indiana. Vehicular surveys were initiated along the Ohio, Wabash, and portions of the Mississippi River floodplains in Illinois; the Ohio and Wabash River floodplains in Indiana; portions of the Ohio and Cumberland Rivers in Kentucky; and segments of the Cumberland and Caney Fork Rivers in Tennessee. Attention was directed to riverside and floodplain roadways as well as river access points during vehicular surveys.

Large populations which appear secure and likely to persist are labeled as core sites. Smaller populations which recieve higher levels of disturbance are labeled as vulnerable sites and have made up the majority of populations discovered. The smallest populations located, consisting of few individuals often on single substrates, are labeled as point populations and are most susceptible to extirpation.

In this study populations of *P. leana* have been designated by geographical boundaries. Areas of inhabitance are characteristically limited by the continuity of habitats present. Park-like habitat areas are often bordered by land which will not sustain populations of *P. leana*, such as agricultural fields, eroded river bends, shoreline development, etc. Individual substrates with a number of *P. leana* thalli are populations, but during this study and in previous studies (Wilhelm and Master 1994, Wilhelm, Masters, and Shimp 2000) the term population has been utilized to identify groups of substrates colonized by *P. leana*. This study has labeled these groups of thalli from geograpically seperated habitats as populations of *P. leana* for ease of discussion.

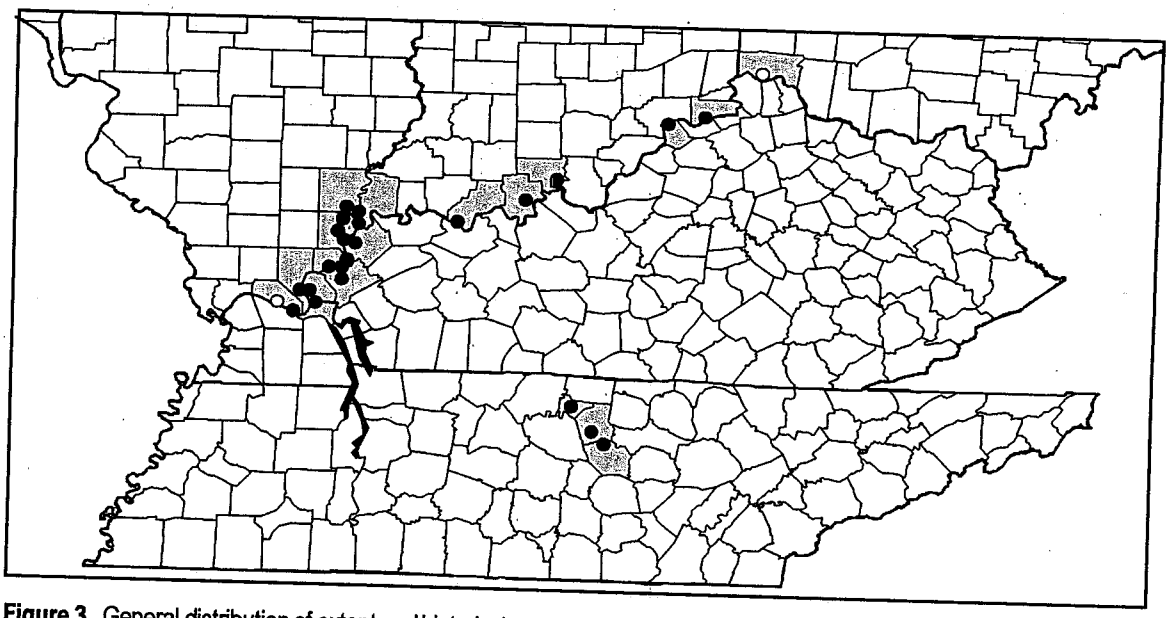

Figure 3. General distribution of extant and historical populations of *P. leana.* Solid circles denote (●) principle populations (n=23); open circles (○) represent the type locality and the Fort Massac population which are no longer extant (n=2). Smaller populations present within major population centers are combined within single circles. Counties inhabited by *P. leana* are shaded in grey.

RESULTS

Eighty-five waypoints were recorded to document populations of *P. leana* during surveys conducted within the Ohio River basin. Of these, 78 waypoints were recorded within floodplain communities of southern Illinois, particularly within the Gallatin Bottoms of eastern Gallatin County and the Black Bottom of Massac County. Wilhelm, Masters, and Shimp (2000) suggested that further surveys of Gallatin County sloughs would yield additional populations of *P. leana.* This study demonstrated that additional sloughs and oxbow lake communities in Gallatin County were indeed colonized by *P. leana.* After observing the density of lichen stands associated with Gallatin County oxbow lakes, natural lake communities were recognized as important wetland habitats for *P. leana* and areas in which survey work should be concentrated. Populations of *P. leana* located in association with the oxbow lake communities of the Black Bottom are not as dense or abundant as observed in Gallatin County. In addition, bottomland woodlands in the Black Bottom were less inhabited than woodlands present within the Gallatin Bottoms. This suggests that natural lakes, bottomland forests, and other wetland habitats in the Black Bottom are not as well suited to support *P. leana* populations because of higher levels of disturbance. Natural lake communities or deep swamps are more likely to retain ecological requirements essential to support populations of *P. leana* and display more resistance to conversion to less suitable habitats than sloughs or shallow water wetland features.

Seven waypoints document newly discovered populations in Indiana, Kentucky, and Tennessee. The new Indiana populations were located during watercraft surveys of the Wabash River and automobile surveys of Ohio River floodplains in southern Indiana. Watercraft surveys documented populations in Posey County, including the River Mile 18

Island Population, the Mackeys Island Population, and the Hovey Lake WMA Population. Populations were also discovered in Spencer, Perry, Crawford, and Switzerland County. Single populations were located across from Madison, Indiana at Milton, Kentucky (Trimble County) and near Hartsville, Tennessee (Trousdale County), during surveys of the Cumberland River. Although four states (Illinois, Indiana, Kentucky, and Tennessee) are currently known to support populations of *P. leana,* it is unclear if *P. leana* still occurs in Ohio. Of the seventeen counties that currently support populations of *P. leana,* the population located in Switzerland County, Indiana is the most easterly population and is the closest population to the type locality near Cincinnati. Populations in the Black Bottom in Massac County, Illinois are the most westerly extant populations. The documented range of *P. leana* reaches its most southerly extent at the Center Hill Dam population in DeKalb County, Tennessee . Of the 25 populations of *P. leana* documented by previous surveys (Wilhelm and Masters 1994, Wilhelm, Masters, and Shimp 2000), all but four localities were revisited during this study. All unvisited populations were small; one was located on Hurricane Island within the Ohio River channel, and the remaining three were unmapped and difficult to locate and reverify.

Four populations identified by Wilhelm and Masters (1994) and Wilhelm, Masters, and Shimp (2000) are no longer extant. The Fort Massac population along the banks of Massac Creek and the Ohio River within Fort Massac State Park was lost prior to the submission of the report to the Illinois Department of Conservation by Wilhelm and Masters in 1994. Surveys of the Fort Massac bottomlands by Wilhelm, Masters, and Shimp in 1994 failed to relocate this population and it was reported that the single *Populus deltoides* substrate supporting the population was lost to bank erosion. Surveys of areas along Massac Creek and the adjacent Ohio River shoreline during this study also failed to locate thalli of *P. leana.* A second population was lost at the New Haven boat launch on the Little Wabash River. The two thalli which were growing on *Fraxinus pennsylvanica* var *subintegrigma* at this locality, no longer exist on the substrate. The Elizabethtown population located west of Big Creek along the Ohio River shoreline has been converted to a quarry and loading facility. The final site, a population near the terminus of Haney Creek, was reported by Shimp (pers. comm. 2002) to have been lost as a result of shoreline erosion. These four populations, plus the type locality population, are the only sites where *P. leana* has been extirpated.

Status of Populations of *P. leana* discovered by Wilhelm, Masters, and Shimp

The present status of populations of *P. leana* discovered by Wilhelm, Masters, and Shimp are arranged in geographical descent, with the first population addressed being the most northerly locality and the last population being the most westerly and southerly population surveyed in Illinois. The status of *P. leana* populations in Indiana, Kentucky, and Tennessee reported by Wilhelm, Masters, and Shimp are presented following the Illinois populations.

Illinois Populations (Figs. 4, 5, 6, 7)

Population	Voucher Data	Status
Gallatin Co.		
1. New Haven Boat Launch	Wilhelm and Masters 22346	Defunct

The New Haven access site to the Little Wabash River at one time supported two thalli located at the base of *Fraxinus pennsylvanica var. subintegerrina* near the boatramp. These thalli could not be relocated and the population has been lost.

2. Clark Pond	Shimp 5274	Extant

The population is located adjacent to Big Barn Road, the primary roadway accessing the Gallatin Bottoms. Thalli are scattered on trees along the roadway.

3. Horseshoe Pond	Shimp 5273	Extant

Thalli were noted on trees near the bottomland roadway. The population is still extant although some vegetation in the right-of-way has been negatively affected by herbicide application.

4. Beaver Pond	Wilhelm & Masters 22343-22345	Extant

The population is located northeast of the bridge crossing the Beaver Pond channel in an area frequented by fishing parties. The population benefits from the alteration of the surrounding vegetation by visitors to the wetland.

5. Cow Pond Slough	Shimp 5271	Extant

The population is located near the roadway running through Cow Pond Slough.

6. Hulda Woods	Wilhelm & Masters 22339, 22341, 22342	Extant

Thalli are located predominantly on trees along the southern edge of the forest tract.

7. Hulda Lake	W. & Masters 22336-22338, Shimp 5272	Extant

The population is located at the southern extent of the Hulda Lake oxbow on trees associated with a former homesite. The population is stable at present, although the trees are located in very close proximity to the roadway and could be damaged or destroyed by road maintenance.

8. Long Pond (Long Pond / Round Pond Complex)	Shimp 5270	Extant

Although Shimp's collection was obtained on the western side of Long Pond, the majority of the population in this area is located along the bottomland roadway south of Round Pond within the Round Pond / Long Pond oxbow lake complex. Thalli are readily apparent on *Quercus palustris* and *Quercus pagodaefolia* Ell. in a park-like setting adjacent to the roadway east of Long Pond. The population extends to the southern shore of Round Pond, within the fishing village on the western shore of Round Pond, and along the eastern shoreline to lesser extents. This locality is considered a core site for Gallatin County.

9. Big Lake Shimp 5269 Extant

Considered a core site for *P. leana* in Gallatin County, Big Lake supports a large component of the total *P. leana* population in Illinois. The numbers of thalli observed within the fishing camp along the western shore of the lake are equivalent to larger populations observed elsewhere. Relatively undisturbed habitats surrounding the lake and the large assemblages of *Taxodium distichum* associated with the wetland support a large population of *P. leana*. Shimp's collection was obtained at the southern end of Big Lake. This population does not appear to be threatened at this time although timber harvest within the surrounding bottomland forest would certainly be detrimental.

10. Bell Island, KY Wilhelm & Shimp 22332 Extant

Discovered during watercraft surveillance, this population is considered a continuation of the Big Lake-Fish Lake oxbow lake area. The site actually lies within the state of Kentucky although it is a component of the Illinois shoreline adjacent to the Ohio River.

Hardin Co.

11. Finneyville Shimp & Basinger 5386, 5387 Extant

Shimp and Basinger surveyed this population from the Finneyville Road south to Ohio River Mile 870 near Sturgeon Island. Reconnaisance during this study identified additional thalli (approximately 20 individuals) extending from the Finneyville road to "Finney Rock" near Ohio River Mile 869. Thus the Finneyville population (T. 11S R. 10E S.21) extends from "Finney Rock" (near the southern section line of Section 16) to the Illinois shoreline adjacent to Sturgeon Island. This section of the Ohio River is fairly industrialized along the Kentucky shoreline in the vicinity of the Mulfordtown and Caseyville fleeting and loading areas. Commercial barge traffic tending the Kentucky facilities produces erosive wakes which are undermining shoreline substrates supporting the Finneyville population.

12. Cave-in-Rock Wilhelm & Masters 18802 Extant

The Cave-in-Rock population is located east of Illinois State Route 1 and the landing location of the Cave-in-Rock ferry. Analysis of this site identified eleven *Populus deltoides* utilized by *P. leana* east of the ferry landing. Approximately 160 thalli exist at the Cave-in-Rock site but many of the substrate trees are declining and disturbance of the substrates is drastic in some cases. Examples include the mooring of the ferry to colonized trees, disturbance of soil and root systems, the utilization of substrate trees for the support of electrical fixtures, and the compaction of soils within the supporting habitat by heavy equipment.

13. Tower Rock Recreation Area Skorepa 11975 Extant

Wilhelm & Masters 17802, 17807, 17812

Tower Rock Recreation Area, although still inhabited by *P. leana*, is diminishing in the number of thalli supported within the site. Wilhelm has expressed concern as to the future of the Tower Rock population (pers. comm.).

14. Elizabethtown Quarry Wilhelm & Masters 18769, 18770 Defunct

The Elizabethtown site located west of Big Creek is now a quarry. A single thallus was located to the east of the Big Creek terminus, near the Elizabethtown Ohio River access site, on *Populus deltoides*.

15. Haney Creek Population Shimp (pers. comm. 2002) Defunct

Shimp reported a population of *P. leana* at the confluence of Haney Creek and the Ohio River. Shimp subsequently reported that the population was lost after the substrate tree was dislodged from the riverbank due to shoreline erosion.

Pope Co.

16. Golconda Fishcamp — Wilhelm & Shimp 22332 — Extant

The population is located within a fishing village and camping area near Golconda.

Massac Co.

17. Fort Massac State Park — Wilhelm & Masters 18772 — Defunct

Extant in December, 1990, the population located west of Massac Creek is no longer present.

Indiana Populations

Posey Co.

18. New Haven vic. Site — Shimp & Shimp 5391 — Unknown

This population has not been revisited but is reported to be located 8.8km southeast of New Haven, Illinois along the Wabash River. This population is unmapped and could not be relocated.

Kentucky Populations

Crittenden Co.

19. Tolu River Access — Wilhelm & Masters 18801 — Extant

The population is located west of the village of Tolu near the Ohio River access site.

20. Hurricane Island Pop. — Wilhelm & Shimp 22331 — Unknown

This population was not revisited during this study due to the position of the population on an island within the Ohio River channel.

Livingston Co.

21. Givens Creek River Access — Wilhelm & Masters 18800 — Extant

A small population is located across from Golconda, Illinois that contains approximately ten thalli on *Populus deltoides* in the immediate vicinity of the Givens Creek terminus with the Ohio River. The population is located adjacent to Rondeau Island at the end of KY State Route 133.

22. Bayou Swamp — Wilhelm & Masters 18797, 18796, 18799 — Extant

Wilhelm & Shimp 22334

A large population projected at thousands of individuals is supported on *Taxodium distichum*, *Acer negundo*, and *Carya laciniosa* (Michx.f.) Loud. along the margins of the lake.

23. Cumberland River — Wilhelm & Shimp 22333 — Unknown

Three thalli were noted along the west shoreline of the Cumberland River, approximately 2.5 river miles (4km) above the terminus of the river at Smithland, KY. This small population could not be relocated and was therefore not revisited

Union Co.

24. Old Shawneetown — Wilhelm & Shimp 22329 — Unknown

Approximately 1.5 river miles (2.4 km) downstream on the Ohio River from the Old Shawneetown bridge (IL State Route 13 / KY State Route 56). This population was not revisited due to access limitations.

Tennessee Populations

Smith Co.

25. Carthage Population Phillippe L4046 Extant

Thousands of thalli were observed near the Bluff Creek confluence with the Caney Fork River at Hell's Bend south of Carthage.