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Changes in Land Cover and Breeding Bird Populations with Restoration of Riparian Habitats in East-central Iowa

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Conversion of Midwestern riparian areas for agricultural production has greatly altered their function and suitability for birds and other wildlife. Recently, however, restoration of riparian functions has been a major focus of land management agencies in the Midwest. We used historic land-use data to describe land-cover changes since European settlement and the subsequent effects of habitat restoration efforts on the landscape along a section of the Iowa River in east-central Iowa. We then used bird-density data collected in a subset of the study area in 2001 and 2002 to estimate changes in breeding bird populations of the entire study area resulting from these habitat restoration efforts.

Before settlement, the (>24,000 ha) Iowa River Corridor was dominated by herbaceous vegetation (72%), with wooded areas accounting for less than one-third of the area. Between the mid-1800s and 1992, agricultural conversion decreased the amount of herbaceous cover by >75%, and the cover of woody vegetation increased by >25%. After the 1993 flood, establishment of USDA conservation easements increased the amount of herbaceous cover in the corridor by >135% (>5,000 ha).

Populations of most grassland and wetland bird species in the corridor (13 of 17) increased with habitat restoration, although some species associated with open habitats, such as those that often breed in rowcrop fields, decreased. We estimated that these restored habitats provide habitat for >12,000 additional birds of grassland- or wetland-dependent species in the Iowa River Corridor, 5,000 of which are members of eight species that are of moderate or high conservation priority.

An understanding of presettlement land cover, the extent of land-cover alteration, and the effects of habitat restoration on the landscape and breeding bird populations provides a useful guide for both evaluating the efficacy of past restoration and for guiding future conservation and restoration efforts.

INDEX DESCRIPTORS: emergency Wetlands Reserve Program, grassland birds, Partners in Flight, presettlement, habitat restoration, restoration ecology, riparian, Wetlands Reserve Program.

Land cover in the Midwest has undergone substantial modification since European settlement. This is especially true in intensive agricultural states such as Iowa where conversion of native landscapes for agricultural production has resulted in the loss of >95% of wetland and >99% of prairie habitat (Bishop 1981, Smith 1998). Riparian areas, which are transitional between terrestrial and aquatic habitats, likewise have been severely altered. Indeed, loss of riparian habitat has been more extensive in the Midwest than any other region of the United States (Brinson et al. 1981, National Research Council 2002). This conversion of riparian areas to agricultural uses has resulted in the loss of many natural functions, including storage of flood-water, nutrient and sediment filtration, and habitat for fish and wildlife.

Associated with the loss and degradation of native habitats has been a general decline in native wildlife populations. In particular, grassland birds have shown more widespread population declines than any other group of birds since the initiation of the Breeding Bird Survey in 1966 (Peterjohn and Sauer 1999). Although many factors have contributed to population declines in grassland birds, loss of herbaceous habitats throughout the United States likely has been a major factor (Herkert et al. 1996).

Implementation of Farm Bill programs, such as the Conservation Reserve Program (CRP) in 1985 and Wetlands Reserve

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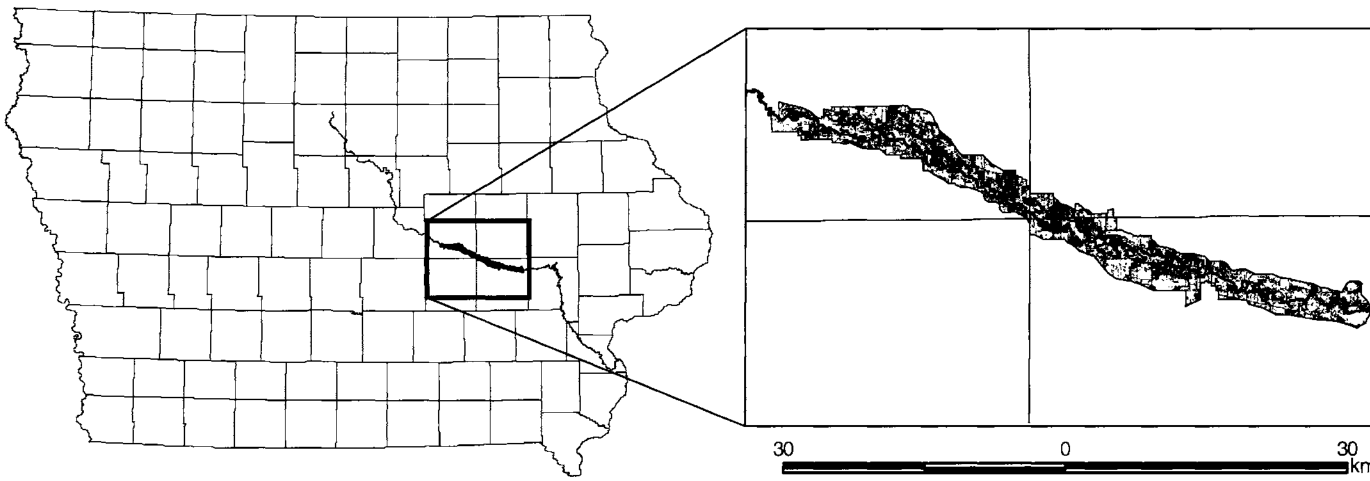

Fig. 1. Location of the >24,000 ha Iowa River Corridor in east-central Iowa. Grassland/herbaceous habitats as of 2002 are shown in black.

Program (WRP) in 1990, has led to reestablishment of millions of hectares of grassland and wetland habitat in the upper Midwest. Emergency flood-mitigation programs such as the Emergency Wetlands Reserve Program (EWRP) have created additional opportunities for restoration of riparian habitats. Through implementation of these programs, >100,000 ha of riparian habitat are presently under long-term easement in the upper Midwest.

Traditional approaches used to evaluate the contributions of habitat restoration to bird populations have compared bird populations in newly restored habitats with those in the previous land-cover type (typically agricultural fields; Johnson and Schwarz 1993, Best et al. 1997). Alternatively, restoration success has been assessed by comparing bird communities between restored and natural habitats (Delphey and Dinsmore 1993, Dault 2001, Fletcher and Koford 2002). More recently, approaches using geographic information systems (GIS) have been used to quantify the effects of restored habitats on bird populations or predict the potential impact of future restoration (Fletcher and Koford 2003, Murray et al. 2003).

To better understand wildlife use of existing conservation easements and to guide and predict the effects of future riparian restorations in the upper Midwest, a quantitative assessment of bird responses to habitat restoration was undertaken for a segment of the Iowa River in east-central Iowa, a focus area for riparian conservation efforts. The specific objectives of this research were (1) to describe land-cover changes from presettlement (mid-1800s) to before initiation of habitat restoration efforts (1992), (2) to describe changes in land cover associated with habitat restoration efforts (between 1992 to 2002), and (3) to use land-cover and bird-density data to model the estimated changes in grassland and wetland bird populations associated with habitat restoration in the Iowa River Corridor.

METHODS

Study area

We conducted our research in open habitats, primarily dominated by grasses or other herbaceous cover, in Tama, Benton, and Iowa counties of east-central Iowa. Our study sites were located within the >24,000 ha Iowa River Corridor Project (IRC; Fig. 1), a cooperative project between the Natural Resources Conservation Service (NRCS), United States Fish and Wildlife Service, and Iowa Department of Natural Resources (IDNR). Currently, there are >100 riparian WRP and EWRP easements totaling about 5,000 ha of former agricultural land enrolled in NRCS conservation programs within the IRC. The watershed drains about 1.25 million ha, about 1 million of which were cropland prior to habitat restoration (United States Department of Agriculture 1976).

The plant species composition in IRC easements varied depending on hydrology, previous land use, and extent of restoration efforts. Based on flood frequency, easements were placed into 2 groups: fields that flood rarely (mesic fields), and those that flood frequently (hydric fields). Mesic fields within the IRC were planted to native grass species, generally switchgrass (*Panicum virgatum*) or big bluestem (*Andropogon gerardii*). Grassland/herbaceous seed mixes for hydric soils were not readily available; consequently, these areas were allowed to revegetate naturally and were generally dominated by reed canarygrass (*Phalaris arundinacea*), an invasive perennial species (Hoffman and Kearns 1997, Merigliano and Lesica 1998). We collected data on 20 mesic and 30 hydric fields in 2001 and 2002. All fields were >8 ha and were dominated by herbaceous vegetation, generally grasses.

GIS data

We used GIS to estimate change in land cover from presettlement (mid-1800s) to prerestoration (1992), and from prerestoration to postrestoration (2002). Presettlement data were collected between 1832 and 1859 by United States General Land Office (GLO) Surveyors and have been digitized as GIS data (Anderson 1994). The 1992 National Land Cover Data (Vogelmann et al. 2001) were used to estimate the extent of alteration from the time of settlement, and represent the prerestoration condition of the IRC. Land-use data from 2002 were available from IDNR (Iowa Department of Natural Resources 2004) and were used to estimate the changes in land

Table 1. Land cover (ha) in the Iowa River Corridor in east-central Iowa before settlement (1832–1859), before (1992) and after initiation of habitat restoration efforts (2002).

Land cover	Presettlement[a]		1992[b]		2002[c]		Pre → 1992 % Change[d]	1992 → 2002 % Change[e]
	Area	%	Area	%	Area	%		
Herbaceous cover	17735.3	71.6	3730.7	15.1	8849.8	35.7	−79.0	137.2
Mesic[f]	8241.7	33.3	2281.8	9.2	3765.4	15.2	−72.3	65.0
Hydric[f]	9493.6	38.3	1448.9	5.9	5084.4	20.5	−84.7	250.9
Wooded	6408.3	25.9	8234.0	33.3	6449.8	26.0	28.5	−21.7
Mesic	2248.8	9.1	2147.3	8.7	1674.7	6.8	−4.5	−22.0
Hydric	4159.5	16.8	6086.8	24.6	4775.1	19.3	46.3	−21.6
Wetland	300.4	1.2	1307.5	5.3	913.6	3.7	335.3	−30.1
Water	—	—	928.9	3.8	953.0	3.8	—	2.6
Rowcrop agriculture	305.5	1.2	9938.5	40.1	6718.8	27.1	3153.2	−32.4
Mesic	225.5	0.1	5449.4	22.0	4330.6	17.5	2316.6	−20.5
Hydric	80.1	<0.1	4489.1	18.1	2388.2	9.6	5504.4	−46.8
Other[g]	15.1	<0.1	625.0	2.5	879.6	3.6	4039.1	40.7
Total	24764.6		24764.6		24764.6			

[a]Between 1832 and 1859 (Anderson 1994).
[b]Before habitat restoration, from National Land Cover Data (Vogelmann et al. 2001).
[c]After habitat restotation, from Iowa Department of Natural Resources (2004).
[d]Presettlement to prerestoration.
[e]Prerestoration to postrestoration.
[f]Based on hydric soil classification.
[g]Includes area not accounted for by other classes, including artificial, barren, and clouds.

cover between 1992 and 2002. Additional GIS coverages from the NRCS and IDNR were used to delineate the boundaries of the IRC, easements within the corridor, and hydric soils.

Land-cover classifications differed between data sources, so land-use categories for all datasets were combined into ecologically similar categories where necessary (Table 1). Specifically, all land-cover classifications that were dominated by woody vegetation (e.g., forest, woodland, savanna, shrubland) were combined as wooded land cover. Different grassland (e.g., cool- and warm-season grasses) and cropland categories (e.g., corn and soybeans) were combined into herbaceous cover and rowcrop classes, respectively. To adjust for misclassification in 1992 data, we included land classified as temporary or seasonal wetlands with rowcrops in areas that were known to be cropped.

Bird density data

We conducted bird surveys four times between 17 May and 25 July 2001, and again between 23 May and 30 July 2002. Four non-overlapping, 50-m radius point-counts were randomly placed in each field. Counts were 5 min in length and were completed between sunrise and 1000 CST. Observers were trained before initiation of field work and were rotated among sites to minimize bias. Surveys were not done during mornings with high winds (>24 km/h) or rain. All birds identified visually or by song within the survey area were recorded, as were the method of identification (visual, song, call) and sex of each individual. Birds identified visually were placed into one of five distance classes, 0–10 m, 11–20 m, 21–30 m, 31–40 m, or 41–50 m. Birds flying over the count circle were noted but excluded from analyses. When possible, the same point-count locations were used in both years (197 of 200).

In order to generate bird popularion estimates for the entire IRC, we extrapolated our bird-density data to unsampled habitats throughout the study area. Because we do not have data on bird abundance in other types of herbaceous habitat in the IRC, (e.g., herbaceous strip-cover, pasture, hayland), and GIS data do not distinguish between these types, densities were assumed to be similar to those observed in sampled easements. Differences in bird density between sampled fields and other grassland/herbaceous habitats are likely small for most species, although some species may occur at greater densities in strip-cover habitats and others may avoid these linear habitats (e.g., Best et al. 1995). Population estimates, then, may be biased high or low for some species in a particular year, but because the extent of these habitat types in the IRC likely changed little between pre- and postrestoration, these differences should have little effect on our estimates of population change. Density of grassland birds in other habitat types (e.g., wooded, open water) was assumed to be zero. Bird densities for rowcrop fields were taken from another study conducted in nearby areas of Iowa (Patterson and Best 1996). Density estimates for rowcrop fields were used for 15 species (Patterson and Best 1996); the remaining two were assumed to be absent in rowcrops because of their known habitat associations (Best et al. 1995).

Statistical analyses

Because detectability of birds may decline with increasing distance from an observer, particularly in dense habitats, we calculated density of birds (birds/ha) for species with ≥40 observations using the program DISTANCE (Buckland et al. 1993). Detectability models were evaluated using Akaike's Information Criterion and, because detection functions were similar across habitat types (i.e., mesic or hydric), and years, density was estimated with a global detection function (Buckland et al. 1993, Burnham and Anderson 1998, Benson 2003). For species with ≤40 observations, density values were calculated as average number of birds at a point divided by the area of the fixed-radius point count (birds/ha). Density values for fields (using replicate surveys) were used to obtain estimates of mean density of each species for each habitat type and year. To estimate the change in bird abundance with habitat restoration, we used survey-based estimates of mean density for each species in a given land-cover type multiplied by the change in area of that land-cover type between pre- and postrestoration. We constructed 95% confidence intervals of estimated change for each species using the delta-method approximation of variance (Williams et al. 2002).

RESULTS

Land-cover change

Before settlement, the Iowa River Corridor was dominated by herbaceous vegetation, with other land-cover types, including wooded areas, comprising less than one-third of the area (Table 1). The earliest European settlers arrived in the area around 1840, so there was some evidence of rowcrop agriculture in the presettlement data (Table 1; Dinsmore 1994). From the mid-1800s to 1992, there was a large decrease in cover of herbaceous vegetation, a slight increase in wooded areas, and a large increase in rowcrop agriculture. Restoration substantially increased the cover of herbaceous vegetation (Fig. 2), particularly in hydric areas. Although the amount of area that was wooded or in rowcrops decreased, rowcrop agriculture was still a dominant land use.

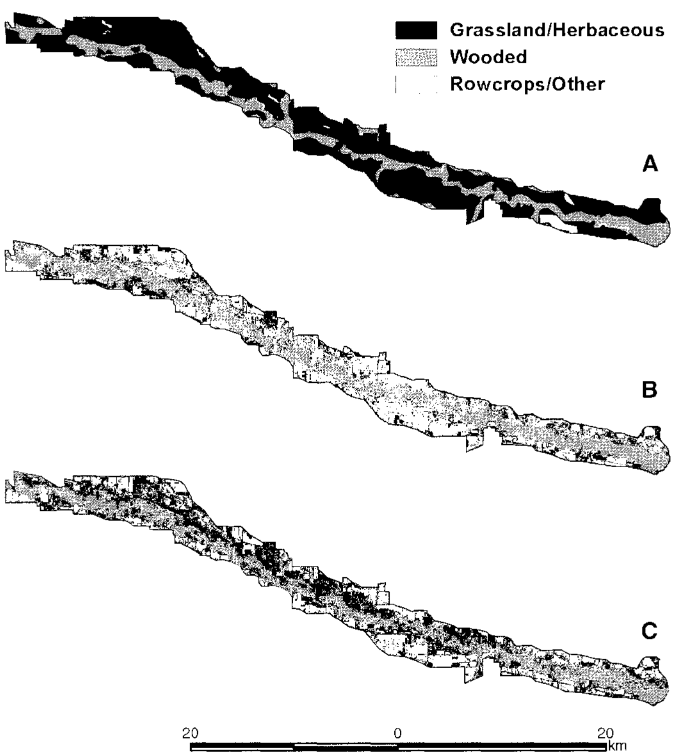

Fig. 2. Land-cover of the >24,000 ha Iowa River Corridor (A) before European settlement (mid-1800s), (B) before initiation of grassland/herbaceous habitat restoration efforts (1992), and (C) after initiation of grassland/herbaceous habitat restoration efforts (2002).

Bird density

In 2001 and 2002, we observed 25 bird species in mesic grasslands and 33 in hydric grasslands, with 39 species overall (Benson 2003). Of these, 17 were obligate or facultative grassland or wetland bird species and were considered for further analyses (Table 2; Vickery et al. 1999, Dault 2001). Based on Partners in Flight priority scores for the Dissected Till Plains, four species (Grasshopper Sparrow, Henslow's Sparrow, Dickcissel, and Bobolink; scientific names in Appendix) were recognized as high conservation priority, five as moderate, six as low priority, and two as not at risk (Table 2; Carter et al. 2000, Fitzgerald and Pashley 2000, Nuttle et al. 2003).

Bird population responses to land-cover changes

Using mean estimates of change, populations of 13 species increased with habitat restoration and four decreased (Table 2). Species showing positive population responses included eight species that are recognized as either moderate or high conservation priority. However, not all of the estimated changes in bird populations were significantly different from zero. Confidence intervals for 11 species included zero, indicating no significant change between time periods. There were significant increases in the populations of five species, and a significant decrease for one species (Table 2). Of the five significantly increasing species, four (Sedge Wren, Common Yellowthroat, Dickcissel, and Bobolink) were of moderate or high conservation concern.

DISCUSSION

Land-cover change

Before settlement, the floodplain of the Iowa River was dominated by herbaceous vegetation. This is counter to the view that presettlement riparian areas in the Midwest were primarily forested (e.g., Brinson et al. 1981, Malanson 1993). Accounts of early settlers often noted that these areas were dominated by herbaceous cover (Owen 1852), and previous research using GLO data has found similar results (Nelson et al. 1998). Although many herbaceous areas were classified as prairie by GLO surveyors, these areas were likely a mix of mesic and hydric grasslands and temporary and seasonal wetlands. These habitats were likely vegetated by a diversity of grassland and wetland plants, including prairie cordgrass (*Spartina pectinata*), rice cutgrass (*Leersia oryzoides*), Virginia wild-rye (*Elymus virginicus*), sedges (*Carex* spp.), flat-sedges (*Cyperus* spp.), smartweeds (*Polygonum* spp.), and other hydric species (Weaver 1968, Fredrickson 1996, Nelson et al. 1998).

As in this study, widespread conversion of native grasslands to agricultural purposes has been well documented in the Midwest and throughout the United States (Samson and Knopf 1994, Smith 1998). The observed increase in wetlands and water between presettlement and 1992, however, is initially counter-intuitive (Table 1). As with grasslands, conversion of wetlands for agriculture has been extensive (Bishop 1981, Dahl 1990). More area was recognized as wetland or water in 1992 than in the mid-1800s, however, for three reasons. First, the digitizing of GLO records did not include waterways; the added coverage of water, particularly rhe Iowa River, accounts for most of the water in 1992. Secondly, presettlement wetlands in the floodplain were likely temporary or seasonal and were recorded as prairie by GLO surveyors who likely did their work after seasonal flooding had

Table 2. Estimated bird abundance (number of individuals) before (1992) and after (2002) initiation of habitat restoration, and estimated change in abundance (number of birds, lower and upper 95% confidence limits) of grassland and wetland bird species resulting from habitat restoration in the >24,000 ha Iowa River Corridor, east-central Iowa.

	1992	2002	Estimated Change			
Species	$\bar{X}$	$\bar{X}$	$\bar{X}$	LCL	UCL	Conservation Priority[a]
Killdeer[b, c]	252	184	−68	−196	59	Low
Ring-necked Pheasant[c]	391	595	204	−328	736	Low
Mourning Dove[c]	110	192	82	−31	195	Low
Eastern Kingbird[c]	117	124	7	−77	90	Moderate
Sedge Wren[d]	1005	1980	975	718	1232	Moderate
Marsh Wren[c]	6	20	14	−26	55	Moderate
Common Yellowthroat[d]	877	1897	1020	740	1299	Moderate
Vesper Sparrow[c]	1199	820	−379	−665	−93	Low
Savannah Sparrow[c]	131	221	90	−21	201	Not at risk
Grasshopper Sparrow[d]	502	910	408	−315	1131	High
Henslow's Sparrow[c]	5	8	3	−5	11	High
Dickcissel[d]	2463	5107	2644	1467	3821	High
Bobolink[c]	52	139	87	59	115	High
Red-winged Blackbird[d]	7066	13703	6637	4280	8994	Low
meadowlark species[c]	64	48	−16	−88	56	Moderate
Brown-headed Cowbird[c]	1135	869	−266	−636	104	Low
American Goldfinch[d]	570	1284	714	−56	1483	Not at risk
Total change	15944	28098	12154	9195	15114	

[a]Based on ranking system using Partners in Flight priority scores (Carter et al. 2000, Fitzgerald and Pashley 2000, Nuttle et al. 2003).
[b]For scientific names see Appendix.
[c]Uncorrected density calculated as average number of individuals observed per 50-m radius point count.
[d]Density corrected for detectability using the program DISTANCE (Buckland et al. 1993).

subsided. Lastly, most of the wetland area in 1992 is accounted for by a wetland complex constructed by the IDNR in 1965 and 1966 (Otter Creek Marsh, Tama County).

Although wooded areas were a substantial component of the corridor before settlement, trees were primarily confined to areas adjacent to the river. In fact, the area that was wooded increased between settlement and 1992 (Table 1). Although about 2,500 ha of formerly wooded areas were converted to other uses, about 3,600 ha of formerly herbaceous habitat became dominated by woody vegetation between settlement and 1992 (T.J. Benson, unpublished data). This is consistent with other studies of rivers in the Midwest that have found human modifications to provide areas suitable for the establishment and survival of woody plants (Knopf and Scott 1990, Johnson 1994). In spite of continued commercial and private logging, alteration of disturbance regimes, including suppression of fire and changing of hydrology, likely allowed the expansion of trees.

Habitat restoration efforts substantially increased the amount of herbaceous habitat in the corridor (Table 1). Because lands were primarily restored through WRP and EWRP, most of these restored habitats are on hydric soils. Altogether, >100 easements totaling about 5,000 ha have been restored to grassland/ herbaceous cover through these programs. Additionally, there were decreases in the cover of wooded areas and wetlands between 1992 and 2002. The observed decrease in wooded areas are likely the result of either active timber harvesting in the corridor, or a misclassification of habitat types in either the 1992 or 2002 data. The decrease in wetland cover between 1992 and 2002 is largely accounted for by classification of portions of Otter Creek Marsh as wetland in 1992 and grassland herbaceous in 2002.

Bird responses to land-cover changes

Land-cover changes associated with the establishment of conservation easements in the Iowa River Corridor affected birds both positively and negatively. Conversion of rowcrops to permanent herbaceous cover appeared to negatively affect Killdeer, Vesper Sparrows, and Brown-headed Cowbirds, three species known to use open habitats, including rowcrops, for foraging and nesting (Best et al. 1995, Best et al. 1997). However, the confidence interval for estimated changes included zero for all but Vesper Sparrows. Greater availability of herbaceous cover provided habitat for many species, including an estimated 1,000 additional Sedge Wrens and Common Yellowthroats, which are of moderate conservation priority, and >400 additional Grasshopper Sparrows and >2,500 additional Dickcissels, both of which are considered high conservation priorities. The confidence interval for estimated change in Grasshopper Sparrow abundance, however, included zero. Although Red-winged Blackbirds are a species of low conservation concern, this species benefited most from habitat restoration, with habitat provided for >6,500 additional birds (Table 2). Altogether, we estimate that restoration of herbaceous cover in the Iowa River Corridor provided habitat for an additional 12,000 grassland and wetland birds, >5,000 of which are individuals of species that are considered conservation priorities (Table 2).

Conclusions

Knowledge of presettlement, prerestoration, and current habitat conditions of the Iowa River floodplain along with estimates of the contributions of restoration to bird species of conservation concern will allow for effective planning of future efforts. Assuming that presettlement conditions are the ultimate goal of habitat restoration, future efforts should focus on maintaining and increasing the amount of grassland/herbaceous habitat while controlling or decreasing woody vegetation.

Although this approach provides a useful estimate of bird use resulting from habitat restoration, estimates of reproduction and survival of these birds is ultimately needed. Understanding the effects of restoration on productivity of all of these grassland and wetland species would provide a clearer picture of the large-scale conservation benefits of this area to birds. Additionally, information on how to increase habitat utilization, reproduction, and survival through management is critical to maximizing the benefits of these conservation easements.

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APPENDIX. Density estimates [mean birds/ha, standard error (SE)] of common grassland and wetland bird species used to estimate changes with habitat restoration in the >24,000 ha Iowa River Corridor in east-central Iowa, 2001–2002.

	Herbaceous Cover					
	Mesic		Hydric		Rowcrop[a]	
Species	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
Killdeer[b] (*Charadrius vociferous*)	0.01	0.01	0.00	0.00	0.02	0.01
Ring-necked Pheasant[b] (*Phasianus colchicus*)	0.02	0.00	0.07	0.05	0.02	0.01
Mourning Dove[b] (*Zenaida macroura*)	0.03	0.03	0.02	0.00	0.00	0.00
Eastern Kingbird[b] (*Tyrannus tyrannus*)	0.01	0.00	0.01	0.00	0.01	0.01
Sedge Wren[c] (*Cistothorus platensis*)	0.37	0.02	0.12	0.02	0.00	0.00
Marsh Wren[b] (*Cistothorus palustris*)	0.00	0.00	0.00	0.00	0.00[d]	0.00
Common Yellowthroat[c] (*Geothlypis trichas*)	0.23	0.04	0.20	0.02	0.01	0.01
Vesper Sparrow[b] (*Pooecetes gramineus*)	0.00	0.00	0.00	0.00	0.12	0.02
Savannah Sparrow[b] (*Passerculus sandwichensis*)	0.05	0.03	0.01	0.00	0.00	0.00
Grasshopper Sparrow[c] (*Ammodramus savannarum*)	0.13	0.10	0.07	0.06	0.01	0.01
Henslow's Sparrow[b] (*Ammodramus henslowii*)	0.00	0.00	0.00	0.00	0.00[d]	0.00
Dickcissel[c] (*Spiza americana*)	0.81	0.01	0.40	0.12	0.00	0.00
Bobolink[b] (*Dolichonyx oryzivorus*)	0.01	0.01	0.02	0.00	0.00	0.00
Red-winged Blackbird[c] (*Agelaius phoeniceus*)	1.29	0.26	1.48	0.17	0.20	0.07
meadowlark species[b] (*Sturnella* sp.)	0.00	0.00	0.00	0.00	0.01	0.00
Brown-headed Cowbird[b] (*Molothrus ater*)	0.00	0.00	0.02	0.02	0.11	0.02
American Goldfinch[c] (*Carduelis tristis*)	0.13	0.06	0.15	0.07	0.01	0.01

[a]Data from Patterson and Best (1996).
[b]Uncorrected density calculated as average number of individuals observed per 50-m radius point count.
[c]Density corrected for detectability using Program Distance (Buckland et al. 1993).
[d]Based on known habitat associations, density was assumed to be zero.

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Bixby State Park and Preserve: History, Biota, Roles in Conservation, Human Effects and Future Potential

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Bixby State Park and Preserve (184 ac; 74.5 ha) is located in the Paleozoic Plateau of northeast Iowa (Clayton Co.). A vascular plant inventory was conducted here between 1993 and 2005, resulting in the documentation of 466 species (398 native) in the preserve. Included in the annotated checklist of plants presented in this paper is a federally endangered species, northern monkshood (*Aconitum noveboracense* Gray), nineteen plant species listed by the State of Iowa as threatened, endangered or of special concern, and the first report of a grass species, drooping woodreed (*Cinna latifolia* (Trevir.) Griseb.), in the Iowa flora. During the above inventory, a vegetation map was prepared on which six forest types were identified. Seven microhabitats were also recognized as occurring in the preserve; although these are not noted on the map, they are described. The results of other inventories conducted at Bixby of fungi (115 species), amphibians (7), reptiles (4), summer birds (40) and mammals (10) are also presented in this paper.

As a vegetation remnant, Bixby fulfills several roles in conservation as described by Saunders et al. (1991). The numerous habitats at Bixby support populations of many uncommon to rare organisms and their gene pools and thus serve a species oriented role. By preserving a diversity of forest types and microhabitats, including rare *Betula alleghaniensis* forest and algific talus slope habitats, Bixby fulfills an example oriented role. The climatic conditions (temperature, precipitation) and topographic diversity that occur here allow the persistence of numerous "special plants" at the edge of their distribution or disjunct from floras elsewhere in North America, thus preserving evolutionary opportunities and successional states (i.e., a process oriented role). Bixby is commonly visited by the general public and is frequently utilized by educators and conservationists as a site for field trips and natural history hikes; hence, it fulfills a social values oriented role in conservation.

Numerous human effects have been observed or inferred to have occurred at Bixby that have altered population dynamics and community composition of the residing biota. These impacts include fire suppression, introduction of non-native species of vascular plants such as garlic mustard (*Alliaria petiolata* (Bieb.) Cavara & Grande) and disease-causing fungi including Dutch elm disease (*Ophiostoma ulmi* (Buisman) Nannf. and *O. nova-ulmi* Brasier) and butternut canker (*Sirococcus clavigignenti-juglandacearum* N.B. Nair, Kostichka & Kuntz), increased abundance of white-tailed deer (*Odocoileus virginianus* Zimmermann) and brown-headed cowbirds (*Molothrus ater* Boddaert), forest fragmentation, and increased edge habitat.

Bixby is an ideal site for future research that might include inventory of the bryoflora, study of population dynamics of herbs in disturbed versus mature forests, and resurvey of forest vegetation plots to monitor successional dynamics in northeast Iowa forests. Future management at Bixby should include removal of woody vegetation from the prairie opening, annual removal of garlic mustard, and acquisition of adjacent forest lands to act as a buffer surrounding the preserve.

INDEX DESCRIPTORS: Bixby, Clayton County, conservation, floristic survey, fungi, human impacts, northeast Iowa, Paleozoic Plateau, vascular plants, vegetation remnant.

As early as 1919, Louis Pammel recognized Bixby State Park and Preserve as a remarkable site. He noted the picturesque nature, as well as the outstanding plant and geological diversity of the park, calling it "a real mecca of the lover of nature" and "a paradise for the lover of plants and the lover of wildlife in general" (Pammel 1919). Today, the State Preserve designation continues to recognize Bixby's outstanding biological and geological features. As a remnant of Iowa's once extensive deciduous forests, Bixby State Park and Preserve provides a window into the vegetational history of northeast Iowa, and its special geological features create the habitat for rare components of the flora and fauna. Thus Bixby provides a resource for examining a small vegetation remnant in a broader context of current and potential roles.

Saunders et al. (1991) define and characterize vegetation remnants as patches of native vegetation around which most or all of the original vegetation has been removed. Consequently, remnants are usually small, have a high edge to area ratio, and are generally isolated from one another (though they sometimes are connected by corridors of native vegetation). Furthermore, ecosystem processes within remnants (e.g., hydrology, nutrient cycling, erosion, and fire regimes) are often negatively affected by human activity on adjacent land. Human effects can also include introduction of livestock and domestic pets that frequently results in trampling of native vegetation, introduction of exotic weed species, and increased rates of herbivory and predation. Hence, remnants often do not contain the full range of pre-settlement plant and animal communities (Saunders et al. 1991).

It is interesting to note that the authors of the above description are Australian and that their characterization of vegetation remnants draws primarily on work conducted in that continent. This characterization could be applied almost

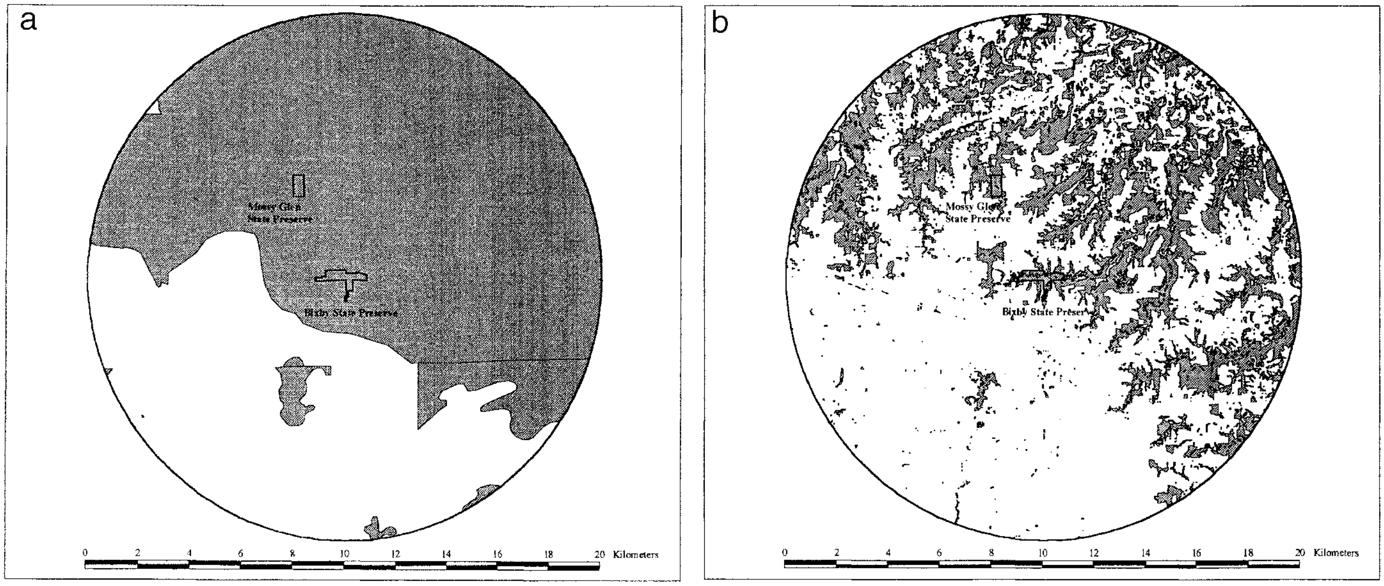

Fig. 1. Tree cover in the vicinity of Bixby State Park and Preserve. a) 1830s; b) 1992. See text for further discussion.

verbatim to the majority of vegetation remnants in Iowa, including Bixby State Park and Preserve (Clayton County). Historically (1830s), the majority of the land surrounding the current preserve boundary at Bixby was tree covered (Fig. 1a), with 64% of the land within a 10-km radius of the preserve covered with trees at that time (Anderson 1995). This historic tree cover has been highly reduced and fragmented in the intervening 130 years (Fig. 1b); in 1992, only 24% of the land within a 10-km radius of the preserve was covered with trees (based on analysis of a land-use raster coverage classified from recent (1992) 30-m resolution Thematic Mapper (TM) satellite imagery). Virtually all land taken out of timber in this region has been converted to crop fields and pasture, which impacts ecosystem processes (e.g., watershed and nutrient regimes) and biotic communities in much the same way described by Saunders et al. (1991) for vegetation remnants in Australia.

Saunders et al. (1991) cite four specific reasons why vegetation remnants should be retained. *Species oriented reasons* include the value of remnants in preserving individual species and their gene pools. *Example oriented* reasons cite the role of vegetarion remnants in preserving representatives of particular ecosystems, communities, habirats and vegetation assemblages. *Process oriented* reasons include the value of remnants in preserving important ecological and evolutionary processes. Finally, *social values oriented* reasons acknowledge the opportunities provided by remnants for people ro experience nature in ways (aesthetics, education, recreation) appropriate to their needs and desires. We feel that the above exposition provides an excellent framework for land managers and conservationists in Iowa to consider when evaluating the merits of a given vegetation remnant during preserve selection, selecting among alternative land management strategies proposed for a given preserve, and justifying the very existence of the Iowa State Preserve system.

Bixby State Preserve, in our opinion, fulfills all of the above roles of a vegetation remnant. In this paper, we provide example of the ways in which Bixby fulfills each of these four roles. Many of the examples we present are drawn from inventories of the biota (vascular plants, fungi, diatoms, amphibians, reptiles, birds, mammals) of Bixby, especially the results we present of a thirteen-year floristic inventory of Bixby conducted by us between 1993 and 2005. Despite Bixby's exemplary status as a preserve, it has been significantly impacted by human activities, either directly (e.g., fire suppression, introduction of exotic species such as garlic mustard (*Alliaria petiolata*), fragmentation of forest habitat, agricultural runoff) or indirectly (e.g., increased populations of brown-headed cowbirds (*Molothrus ater*) and white-tailed deer (*Odocoileus virginianus* Zimmermann)). In this paper, we also discuss the implications of these human activities at Bixby, either observed by us or inferred from research conducted elsewhere in deciduous forest habitat. Finally, we offer suggestions for future research and land management at Bixby State Preserve.

THE STUDY AREA

Natural History

Bixby State Park and Preserve (Fig. 2) is one of about 20 state preserves located in the northeast corner of Iowa, often referred ro as the Paleozoic Plateau (Herzberg and Pearson 2001). Shallow Paleozoic-age sedimentary bedrock in this region of the state has been eroded to create a rugged landscape, unlike any other area in the state. Several of Iowa's most biologically diverse preserves, including Bixby, are located along rhe Silurian Escarpment, which marks the western and southern boundary of the Paleozoic Plateau (Prior 1991).

In the preserve, the Silurian-aged dolomite is exposed as bluffs, large slump blocks on the steep slopes, algific talus slopes, and an ice cave, the preserve's most prominent geological feature. Big Springs, a permanent, coldwater spring, runs into Bear Creek, which flows through the steep, narrow valley. Sinkholes are another feature of the so-called karst topography of the area (Prior 1991, Herzberg and Pearson 2001).

The biological diversity is undoubtedly influenced not only by the deep valleys and these special geological features that provide a variety of microhabitats, but also the glacial history of this area. Historically called the "Driftless Area," the Paleozoic Plateau was not covered during the Illinoian and Wisconsinan glacial advances and perhaps served as a refugium for at least plants and

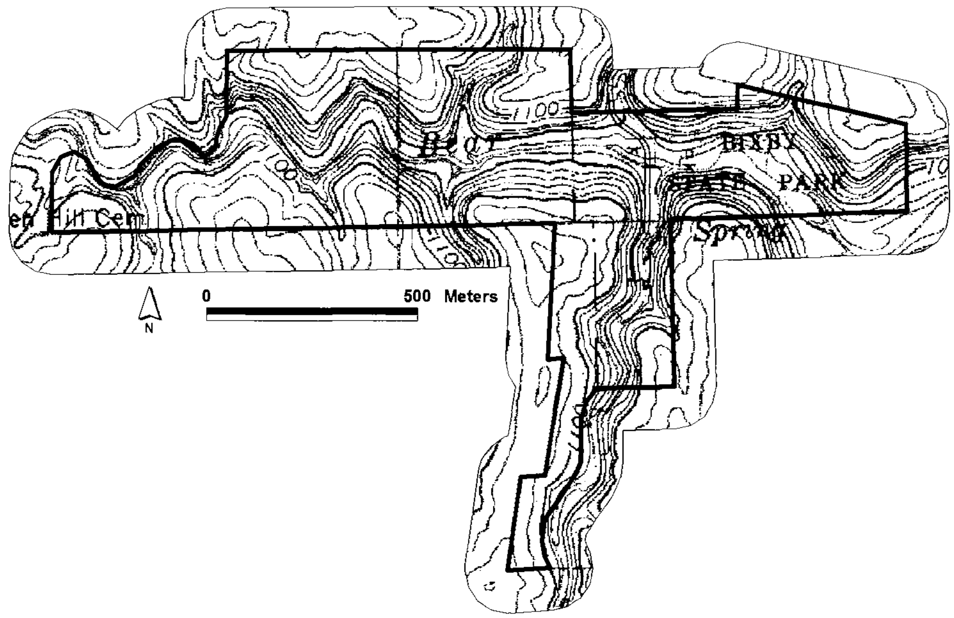

Fig. 2. Topographic map (USGS 7.5' Edgewood quadrangle, 20' contour interval) showing boundaries of Bixby State Park and Preserve.

invertebrates during this time (Eilers and Roosa 1994). Pusateri et al. (1993) propose that the boreal vegetation, which dominated during the glacial maxima, persisted; yet later, eastern deciduous and prairie vegetation characteristic of the post-glacial warming of some 9,000 to 5,500 years ago began to migrate into the region.

Cultural History

The property that is now Bixby State Park and Preserve was originally owned by W.J. Bixby of Edgewood. His son, Ransom J. Bixby, a teacher, farmer and legislator, built a cabin in what is now the preserve and allowed the public to use the area (300 ac; 121.4 ha) as a "park" free of charge. Iowa State College Botanist L.H. Pammel visited the Bixby's "Park" and wrote, "Not a tree has been cut in this area, except where it was necessary to do so for the general good of the preserve, since it is the idea of Mr. Bixby that this place shall be a park, in the true sense of the word" (Pammel 1919). The part of the property containing the most significant features was eventually sold to I.P and Ella Gates. The original 69 ac (27.9 ha) parcel was purchased by the state from the Gates in 1926. Bixby was dedicated as a state park in 1931. In 1978, a 115 ac (46.6 ha) addition was purchased from Don Woeste, bringing the preserve to its current size of 184 ac (74.5 ha). In 1979, Bixby was dedicated as a biological and geological state preserve. Until 1987, the preserve was managed by the Clayton County Conservation Board. Since that time, it has been under management of the Iowa Department of Natural Resources, and locally overseen by the staff of Backbone State Park (Wolf 1991, Herzberg and Pearson 2001).

Bixby's cabin is no longer present, but cultural features include the road (with low-water bridge) bisecting the park, steps and iron grating at the ice cave, and a picnic shelter and latrine (unusable). The latter two were built by the Civilian Conservation Corps in the 1930s. Adverse impacts include off-road vehicle use, vandalism of the picnic shelter, encroachment on areas occupied by sensitive species, beaver impoundment of Bear Creek, and the introduction of invasive species. There is no buffer protecting the preserve, and logging and agricultural practices are currently occurring just beyond the preserve boundary.

METHODS

Norris conducted a plant inventory of Bixby State Preserve during the 1997 and 1998 field seasons (Norris 1998), visiting the preserve fifteen times during that time period. We also conducted intermittent surveys of the Bixby flora at least once a year between 1993 and 2005. During each plant survey, we walked through as many habitats as time allowed and recorded lists of all vascular plant species that we encountered in specific habitats (e.g., prairie opening, floodplain forest, algific talus slope) in a field book. We also collected at least one voucher specimen for the majority of species observed in the preserve; these have been deposited in the Ada Hayden Herbarium (ISC) at Iowa State University. [Photographs were taken in lieu of a voucher specimen for several rare species, including northern monkshood (*Aconitum noveboracense*), a federally endangered plant. These photographs are likewise deposited at ISC.]

We used our field notes from the above surveys to compile a list of all vascular plant species that we encountered at Bixby between the years 1993 and 2005. This list was supplemented by several other sources: 1) a comprehensive plant list compiled by Roosa (1990) and included in a management plan for the preserve on file with the IDNR; 2) several published reports (Nekola 1990, Peck et al. 1997); and 3) voucher specimens deposited at ISC by other researchers. For each species listed in this plant list, we present the scientific name, the common name, its status (i.e., native, introduced), and the habitat(s) in the preserve where we observed the species to occur. Nomenclature follows Eilers and Roosa (1994) except for pteridophytes (Flora of North America Editorial Committee (1993), the genus *Rubus* (Widrlechner 1998), the family Cyperaceae (Flora of North America Editorial Committee 2003a), and the family Poaceae (Flora of North America Editorial Committee 2003b, Clark and Gardner 2004).

Common names follow Eilers and Roosa (1994) and Swink and Wilhelm (1994).

We also created a vegetation map of Bixby after conducting woody vegetation surveys at 79 different sample points throughout the preserve. During each survey, we recorded the percent cover by woody species for canopy, subcanopy and shrub layers at each point as well as the dominant woody species present in each layer. The latter data were transcribed onto a topographic map of the preserve. Visual inspection of dominant canopy and subcanopy species at each point on this map allowed us to delineate six forest types: *Betula alleghaniensis* Forest (BA), *Acer saccharum* Forest (AS), *Acer saccharum/Quercus borealis* Forest (ASQB), *Quercus alba* (Disturbed) Forest (QA(D)), *Pinus strobus* Forest (PS), and Floodplain Forest (FF). In this paper, we present this map and general descriptions of each forest type. Although not identified on this map, we also provide descriptions of seven microhabitats (aquatic, algific talus slope, glade, prairie opening, riparian, ruderal, vertical cliff face) that we encountered at Bixby.

There has also been a long history of collecting the fungi of Bixby State Preserve. During the current survey, the more obvious fungi were collected by Lewis and determined by Lois Tiffany (Department of Ecology and Evolutionary Biology, Iowa State University). A list of fungi known from Bixby, including both historic and recent collections from the preserve (deposited at ISC), has been compiled by Rosanne Healy and Lois Tiffany and with their permission is presented in this paper.

A list of summer resident bird species for Bixby was compiled from data collected during a study of avian habitat relationships in northeast Iowa forests in 1995 and 1996 (Hemesath and Norris 1998, Norris et al. 2003) and is presented here. The bird census data from Bixby were collected at two bird census points within the preserve following point count census protocol (Ralph et al. 1993). Waterfowl, raptors and nightjars were not recorded during the above study, and hence are not included in this list. Nomenclature follows American Ornithologists' Union (1998).

VanDeWalle (1997) conducted surveys of amphibians, reptiles and mammals at Bixby in 1997. Salamander trapping, aural surveys, small mammal trapping, mist-netting, walking surveys and night driving were all employed during these inventories, which were conducted in 1996 and 1997. Lists of all species in each of the above vertebrate groups observed at Bixby were compiled by VanDeWalle (1997) and are presented in this paper with his permission.

RESULTS

Vascular Plants

We documented the occurrence of 466 vascular plant species (398 native, 68 non-native) within the preserve boundaries through our own surveys and the supplementary sources mentioned above (Appendix A). By major groups, 26 pteridophytes, 3 gymnosperms, and 437 angiosperms occur at Bixby (Table 1a). Plant families with the greatest number of taxa were Asteraceae (53 species), Poaceae (51) and Cyperaceae (28) (Table 1b). Eleven genera were represented by at least five species, of which *Carex* was the most diverse genus with 25 species (Table 1c). Among the 466 vascular plant species at Bixby is a grass previously unknown in Iowa: drooping woodreed (*Cinna latifolia*), which we encountered at the base of a yellow birch (*Betula alleghaniensis*) in the vicinity of the ice cave. The Bixby flora contains a federally endangered plant (northern monkshood (*Aconitum noveboracense*)) as well as nineteen vascular plant species considered to be endangered, threatened or of special concern by the state of Iowa (Iowa Natural Resource Commission 2002; Table 2).

Table 1. Floristic composition of Bixby State Preserve.

A. Species, genera and families			
Major Groups	Species	Genera	Families
Pteridophytes	26	18	7
Gymnosperms	3	3	3
Dicotyledons	328	196	65
Monocotyledons	109	57	9
B. Ten most numerous families			
Family	Native	Non-Native	Total
Asteraceae	45	8	53
Poaceae	36	15	51
Cyperaceae	28	0	28
Rosaceae	22	2	24
Liliaceae	14	2	16
Ranunculaceae	16	0	16
Aspleniaceae	14	0	14
Lamiaceae	9	4	13
Apiaceae	10	2	12
Caprifolicaceae	10	2	12
C) Eleven most numerous genera.			
Genus	Native	Non-Native	Total
Carex	25	0	25
Aster	7	0	7
Polygonum	5	2	7
Muhlenbergia	6	0	6
Poa	2	4	6
Solidago	6	0	6
Galium	5	0	5
Quercus	5	0	5
Rubus	5	0	5
Elymus	4	1	5
Salix	5	0	5

Vegetation Communities

A map of major forest types that occur at Bixby State Preserve is presented in Fig. 3. Descriptions of these forest types follows below.

ACER SACCHARUM FOREST (AS). This vegetation assemblage is well represented on most north- and east-facing slopes at Bixby, particularly those south of Bear Creek. Sugar maple (*Acer saccharum*) is consistently the dominant canopy tree species, occasionally with basswood (*Tilia americana*) and/or red oak (*Quercus borealis*) as subdominants. Sugar maple and ironwood (*Ostrya virginiana*) are the common trees in the subcanopy of this forest type on upper slopes; blue beech (*Carpinus caroliniana*) replaces them in the subcanopy on lower slopes, often just above algific talus slopes.

A particularly diverse example of this forest type at Bixby is that occurring on the north- and north-east facing slopes in the vicinity of the ice cave. Beneath the canopy and subcanopy here one can find uncommon shrubs such as American yew (*Taxus canadensis*), witch hazel (*Hamamelis virginiana*), round-leaf dogwood (*Cornus rugosa*) and leatherwood (*Dirca palustris*); uncommon herbs encountered here include Canada mayflower (*Maianthemum canadense*), twisted stalk (*Streptopus roseus*), nodding

Table 2. Vascular plant species during inventory of Bixby State Preserve that are listed as Endangered (E), Threathened (T) or of Special Concern (SC) by the Iowa Department of Natural Resources (Iowa Administrative Code 1994).

Aconitum noveboracense Gray (northern monkshood) T
Adoxa moschatellina L. (moschatel) SC
Allium cernuum Roth (nodding onion) T
Amelanchier sanguinea (low serviceberry) SC
Calystegia spithamaea (L.) Putsh SC
Carex careyana Dewey (Carey's sedge) SC
Chrysosplenium iowense Rydb. (golden saxifrage) T
Crataegus coccinea L. (red hawthorn) SC
Dryopteris intermedia (glandular woodfern) T
Equisetum scirpoides Michx. (dwarf horsetail) SC
Gymnocarpium dryopteris (L.) Newman (oak fern) T
Hybanthus concolor (T.F. Forster) (green violet) Sprengel T
Lycopodium dendroideum (tree clubmoss) T
Oryzopsis asperifolia Michx. (mountain ricegrass) SC
Poa wolfii Scribner (meadow bluegrass) SC
Rhamnus alnifolia L'Her. (alder buckthorn) SC
Ribes hudsonianum Richardson (northern currant) T
Streptopus roseus Michx. (twisted stalk) T
Vitis vulpina L. (frost grape) SC

onion (*Allium cernuum*), yellow lady slipper (*Cypripedium calceolus* ssp. *pubescens*), common beach sedge (*Carex communis*), Wood's stiff sedge (*Carex woodii*), squirrel corn (*Dicentra canadensis*), ginseng (*Panax quinquefolia*), and green violet (*Hybanthus concolor*).

BETULA ALLEGHANIENSIS FOREST (BA). This uncommon forest type is represented on several north-facing slopes at Bixby. Yellow birch (*Betula alleghaniensis*) is dominant in the canopy of this forest type, with blue beech (*Carpinus carolinianus*) the most frequent subcanopy tree. In the herbaceous layer of this forest type are found rare plants including dwarf scouring rush (*Equisetum scirpoides*, shining clubmoss (*Huperzia lucidula*), wood rush (*Luzula acuminata*) common beach sedge (*Carex communis*) and long-stalked hummock sedge (*Carex pedunculata*).

ACER SACCHARUM/QUERCUS BOREALIS FOREST (ASQB). One could make a case for merging this forest type with the *Acer saccharum* type described above because the tree species typical for both types are essentially the same. However, the forest vegetation on dry south-facing slopes in Bixby (primarily north of Bear Creek) is consistently dominated by both sugar maple and red oak; hence, we feel that this distinction is warranted. White oak (*Quercus alba*) and red elm (*Ulmus rubra*) are conspicuous subdominant canopy trees in this forest type; on drier slopes, bur oak (*Quercus macrocarpa*) becomes conspicuous. The subcanopy of *Acer saccharum/Quercus borealis* forests at Bixby is dominated by ironwood and sugar maple.

The herbaceous flora of these forests is the best place in the preserve to look for blunt-lobed woodsia (*Woodsia obtusa*), green bracted orchid (*Coeloglossum viride* var. *virescens*), three species of muhly grass (*Muhlenbergia tenuiflora*, *M. sobolifera*, and *M. sylvatica*), rock cress (*Arabis laevigata*), wild licorice (*Galium circaezans*), and bare-stemmed tick-trefoil (*Desmodium nudiflorum*) in the preserve. Yellow lady slipper is also found in this forest type in the preserve.

PINUS STROBUS FOREST (PS). A narrow grove of white pines (*Pinus strobus*) occurs on a northwest-facing slope at the west end of the preserve. This is the only location in the preserve where we encountered shinleaf (*Pyrola elliptica*).

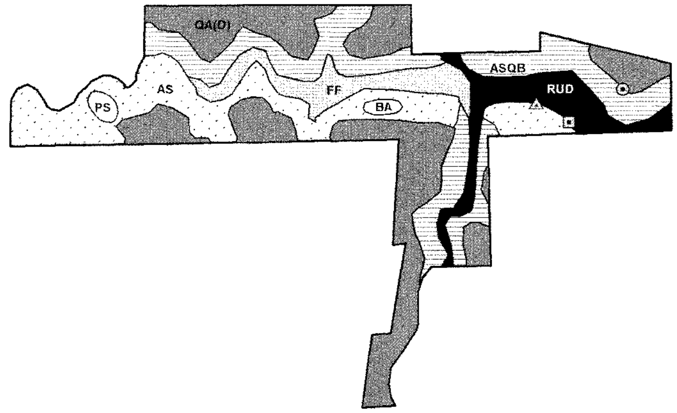

Fig. 3. Map of major forest types at Bixby State Park and Preserve. AS = *Acer saccharum* forest; ASQB = *Acer saccharum/Quercus borealis* forest; BA = *Betula alleghaniensis* forest; FF = floodplain forest; PS = *Pinus strobus* forest; QA(D) = *Quercus alba* (disturbed) forest. RUD = ruderal; Δ = Ice Cave; □ = Big Springs; O = Steamboat Rock.

QUERCUS ALBA (DISTURBED) FOREST (QA(D)). On flat ridgetops at Bixby, forest composition is influenced by edge effects that include frequent tree-fall and invasion by successional tree species. Here, large canopy tree species such as white oak (*Quercus alba*) and shagbark hickory (*Carya ovata*) co-occur with shade intolerant tree species such as yellowbud hickory (*Carya cordiformis*), elm (*Ulmus* spp.), black walnut (*Juglans nigra*) and big-toothed aspen (*Populus grandidentata*) that invade recent canopy gaps. Dead butternut (*Juglans cinerea*) and paper birch (*Betula papyrifera*) snags can also be found on ridgetops.

Several uncommon plant species are restricted to this thin-soiled habitat at Bixby, including Indian pipe (*Monotropa uniflora*) and fall coral root (*Corallorhiza odontorhiza*). Although we did not personally find dissected grape fern (*Botrychium dissectum*) or puttyroot (*Aplectrum hyemale*) in the preserve, they were reported by Roosa (1990) and may still occur in Bixby, probably in this habitat.

FLOODPLAIN FOREST (FF). This forest, limited in extent, occurs primarily along Bear Creek west of the entrance road. No predictable pattern of canopy dominance can be described for floodplain forests at Bixby; elm, hackberry (*Celtis occidentalis*), black walnut, willow (*Salix amygdaloides* and *S. nigra*) and basswood all grow here. The herbaceous layer of this floodplain forest is diverse but unremarkable, except perhaps for streambank wild rye (*Elymus riparius*), which occurs at the junction of bottomland and slope.

Although not identified on the plant community map of Bixby (Fig. 3), we present the following general descriptions of microhabitats that occur at Bixby.

ALGIFIC TALUS SLOPE (ATS). A complex series of algific talus slopes occurs along the north-facing slopes (south of Bear Creek) spanning the breadth of Bixby. These unique microhabitats are maintained at Bixby (and elsewhere in northeast Iowa) on north-facing slopes, overlain with carbonate talus, where cold air flows out of ice-filled caves. With their surface temperatures buffered from the surrounding warm summer air, algific talus slopes probably function as "paleorefugia" for organisms unable to survive elsewhere in the surrounding landscape (Nekola 1999).

Vertical rock faces associated with algific areas in the preserve are covered with numerous bryophyte species, bulbet fern (*Cystopteris bulbifera*, slender rockbrake fern (*Cryptogramma stelleri*, and sullivantia (*Sullivantia sullivantii*). On open talus slopes, one finds uncommon shrub species such as American yew (*Taxus canadensis*), alder buckthorn (*Rhamnus alnifolia*), northern currant (*Ribes hudonianum*), and beaked hazelnut (*Corylus cornuta*). Rare herbs occurring in this habitat include meadow horsetail (*Equisetum pratense*), oak fern (*Gymnocarpium dryopteris*), northern monkshood (*Aconitum noveboracense*), golden saxifrage (*Chrysosplenium iowense*), Forbes' saxifrage (*Saxifraga forbesii*), dwarf enchanter's nightshade (*Circaea alpina*), moschatel (*Adoxa moschatellina*), false medic grass (*Schizachne purpurascens*), Peck's sedge (*Carex peckii*) and Dewey's hummock sedge (*C. deweyana*).

AQUATIC (AQ). Big Spring and Bear Creek provide an aquatic habitat for several plants at Bixby that live almost entirely in water. Duckweed (*Lemna minor*) can be found floating on the water's surface at various locations on Bear Creek, and the introduced meadow grass (*Poa trivialis*) has most of its foliage emergent within the cold water flowing at Big Spring.

GLADE (GL). Groves of red cedar (*Juniperus virginiana*) trees occur where flat ridgetops meet south-facing slopes at Bixby, particularly on the east end of the preserve. A unique assemblage of herbs found nowhere else in the preserve is found underneath these cedar trees, including lousewort (*Pedicularis canadensis*), yellow false foxglove (*Aureolaria grandiflora*), yellow pimpernel (*Taenidia integerrima*), pale gentian (*Gentiana alba*), alumroot (*Heuchera richardsonii*), broad-leaved panic grass (*Dichanthelium latifolium*) and poverty oat grass (*Danthonia spicata* var. *obovata*).

Glade habitats at Bixby are probably smaller now than in the past because of woody encroachment due to current fire suppression. However, glade habitats have probably never been extensive in the preserve because their occurrence has always been limited by shallow, droughty soil over bedrock, and that extreme habitat has only a very limited physical extent in the preserve (personal communication, John Pearson, Conservation and Recreation Division, Iowa Department of Natural Resources). Indeed, the vegetation changes quickly to forest on the deeper loess soil on the ridgetops or on the mesic steep slopes. One could argue that the glade (G) and prairie opening (PO) plant assemblages at Bixby represent different points along a continuum of vegetation (occurring in upland, semi-open habitats over thin soil) and should be lumped together. However, we feel that these two assemblages differ significantly in forb composition and extent of cover by graminoids (prairie opening: dense; glade: diffuse); hence, we recognize each as a separate plant assemblage at Bixby.

PRAIRIE OPENING (PO). A small but diverse prairie remnant occurs on top of a dolomite pillar (Steamboat Rock) at the northeast corner of the preserve (Fig. 3). This prairie remnant is dominated by a thick mat of graminoids, especially wire sedge (*Carex eburnea*) with lesser amounts of porcupine grass (*Hesperostipa spartea*), big bluestem (*Andropogon gerardii*) and little bluestem (*Schizachyrium scoparius*). Growing out of this mat are prairie forbs including rough blazing star (*Liatris aspera*), silky aster (*Aster sericeus*), hoary puccoon (*Lithospermum canescens*, bastard toadflax (*Comandra umbellata*) and flowering spurge (*Euphorbia corollata*). This prairie opening is currently being encroached upon by staghorn sumac (*Rhus typhina*) and red cedar, which will undoubtedly take over Steamboat Rock within the next decade if not controlled.

RIPARIAN (RIP). The mostly gravelly edge of Bear Creek just beyond the canopy cover of floodplain forest (FF) provides an open, moist habitat for many plant species at Bixby. Some of the plant species found here, especially weedy exotics (e.g., yellow rocket (*Barbarea vulgaris*), soapwort (*Saponaria offinalis*), Lady's thumb (*Polygonum persicaria*), curly dock (*Rumex crispus*), and annual bluegrass (*Poa annua*)), can also be found in ruderal habitats away from the creek, but other taxa are almost entirely restricted to the water's edge. These include shrubs (sandbar willow (*Salix exiguua* ssp. *interior*), sedges (spikerush (*Eleocharis* spp.), foxtail sedge (*Carex vulpinoidea*), dark green bulrush (*Scirpus atrovirens*), nut sedge (*Cyperus squarrosus*) and numerous forbs (crooked stem aster (*Aster prenanthoides*), cup plant (*Silphium perfoliatum*), marsh cress (*Rorippa palustris*), giant chickweed (*Myosoton aquaticum*), wild mint (*Mentha arvensis*), ditch stonecrop (*Penthorum sedoides*), monkey flower (*Mimulus rigens*) and great lobelia (*Lobelia siphilitica*).

RUDERAL (RUD). This "catch-all" category encompasses roadside, the lawn adjacent to the parking area and the old-field vegetation that extends from just east of the picnic shelter in the valley to well beyond the ice cave. This vegetation is dominated by introduced weed species, as well as native species adapted to severe disturbance.

VERTICAL CLIFF FACE (VCF). This exposed bedrock habitat occurs intermittently throughout Bixby, but is especially apparent north of Bear Creek on the east end of the preserve. Vertical cliff faces are superficially similar to algific talus slopes in providing steep, rocky environments for plants but differ from the latter microhabitat in their lack of cold air flow from underlying bedrock. Species that occur here include smooth cliff-brake (*Pellaea glabella*), bulblet bladder fern (*Cystopteris bulbifera*), frost grape (*Vitis vulpina*), cliff goldenrod (*Solidago sciaphila*), harebell (*Campanula rotundifolia*), columbine (*Aquilegia canadensis* var. *coccinea*, alumroot (*Heuchera richardsonii*), prickly gooseberry (*Ribes cynosbati*), clearweed (*Pilea pumila*) and stinging nettle (*Urtica dioica*).

Other Organisms

In all, 115 fungus species are documented to occur at Bixby (Appendix B). A total of 26 ascomycetes, 53 basidiomycetes, 3 deuteromycetes, 23 lichens, 6 myxomycetes and 2 oomycetes were found in the preserve. The majority of these species are common in Iowa (personal communications, Rosanne Healy and Lois Tiffany, Department of Ecology and Evolutionary Biology, Iowa State University).

The list of summer resident bird species documented from Bixby in the mid 1990s (total: 40 species) appears in Appendix C. Five avian orders are represented in this list: Cuculiformes (1 species), Trochliiformes (1), Coraciiformes (1), Piciformes (4) and Passeriformes (33). Twelve of these species are neotropical migrants considered by the U.S. Fish and Wildlife Service to be of high management concern in the Midwest. Birds considered to be of "high management concern" are neotropical migrants with high values (≥ 3.00) for a conservation priority index developed by the U.S. Fish and Wildlife Service (Thompson et al. 1993).

VanDeWalle (1997) observed seven amphibian, four reptile and ten mammal species in the preserve during his study (Appendix D). None of these species are considered to be endangered, threatened or of special concern in Iowa.

DISCUSSION

The Roles of Bixby State Preserve in Conservation

The Iowa State Preserve system was established in 1965 to protect the best examples of Iowa's natural and cultural heritage.

Iowa's preserves, including Bixby, are overseen by a seven-member State Preserves Advisory Board whose duties and responsibilities include identifying unique natural and cultural areas in the state for possible inclusion in the preserve system (State Preserves Advisory Board and Iowa Department of Natural Resources 2001). We argue that the reasons put forth by Saunders et al. (1991) to justify preservation of vegetation remnants (i.e., species oriented, example oriented, process oriented, social values oriented) provide a useful framework for evaluation of lands nominated for biological preserve status in Iowa. Below, we examine how well Bixby State Preserve fulfills each of the above criteria.

1) Species Oriented Role. The diverse habitats at Bixby support populations of many uncommon to rare organisms and their gene pools. Groups of organisms at Bixby that have been inventoried include diatoms (Johnson http://bgsu.edu/departments/biology/facilities/algae/html/Bixby.html), fungi (Appendix B), vascular plants (Appendix A), amphibians (Appendix D), reptiles (Appendix D), birds (Appendix C), and mammals (Appendix D). Of the 466 vascular plants known to occur at Bixby, one (northern monkshood) is federally endangered, and 19 are listed (Table 2) by the state of Iowa as endangered, threatened or of special concern (Iowa Natural Resource Commission 2002). In the Bixby flora are numerous "special plants" that do not occur in Iowa outside of its northeast corner; among them are six species disjunct from other floras, a species endemic to the Driftless Area, and numerous species occurring at the southwestern periphery of their North American distribution (Table 3) (Pusateri et al. 1993). A diverse bryophyte flora of mosses and liverworts also occurs at Bixby, including northern species (e.g., *Rhytidiadelphous triquetrus* (Hedw.) Warnst., *Hylocomium splendens* (Hedw.) BSG., and *Pleurozium schreberi* (Brid.) Mitt.) associated with algific talus slopes. However, no systematic inventory of bryophytes at Bixby has been conducted to date (personal communication, Diana Horton, Department of Biological Sciences, University of Iowa).

Bixby is home to a diverse forest avifauna during the summer breeding season. During a two-year study of forest birds in northeast Iowa in 1995–1996 (Hemesath and Norris 1998; Norris et al. 2003), 40 species of birds (excluding waterfowl, raptors and nightjars) were detected in the preserve (Appendix C). These include twelve neotropical migratory bird species of high management concern in the Midwest to the U.S. Fish and Wildlife Service (Appendix C).

Genetic diversity in plant and animal species associated with algific talus slopes in northeast Iowa has been a topic of great interest to biologists. The relative scarcity and isolation of these habitats as well as small population size of organisms that occur here can influence genetic structure through isolating mechanisms and genetic drift. Genetic structure in three such plant species in northeast Iowa (golden saxifrage (*Chrysosplenium iowense*), sullivantia (*Sullivantia sullivantii*), and northern monkshood (*Aconitum noveboracense*) has been studied.

Pleasants and Wendel (1992) studied six northeast Iowa populations of golden saxifrage and found genetic variation in 6 of 12 enzyme systems examined (including polymorphisms for 8 out of 39 (21%) loci). The four southern-most populations of this species were genetically distinct from populations in more northern sites. Pleasants and Wendel (1992) proposed two alternative hypotheses to explain the latter results: i) genetic differentiation between sites within northeast Iowa, or ii) broad genetic divergence between northern and southern populations of *Chrysosplenium iowense* across its entire range in the United States and Canada.

Table 3. Vascular plants occurring at Bixby State Preserve with special distributions (adapted from Pusateri et al. 1993).

A) Species distributions determined by regional climate.
Betula alleghaniensis Britton (yellow birch)
Circaea alpina L. (dwarf enchanter's nightshade)
Dryopteris intermedia (Willd.) Gray (glandular woodfern)
Gymnocarpium dryopteris (L.) Newman (oak fern)
Luzula acuminata Raf. (woodrush)
Pinus strobus L. (white pine)
Rhamnus alnifolia L'Her. (alder buckthorn)
Rubus pubescens Raf. (dwarf raspberry)
Sambucus racemosa L. ssp. pubens (Michx.) House (red-berried elderberry)
Sanicula trifoliata Bickn.(large-fruited black snakeroot)
Taxus canadensis Marsh. (Canada yew)
Viburnum trilobum Marsh. (highbush cranberry)

B) Species distributions representing range extensions into the Driftless Area by topographically determined microhabitats.
Carex peckii Howe (Peck's sedge)
Carex woodii Dewey (Wood's stiff sedge)
Corylus cornuta Marsh. (beaked hazelnut)
Equisetum scirpoides Michx. (dwarf scouring rush)
Lycopodium dendroideum Michx. (tree clubmoss)
Streptopus roseus Michx. (twisted stalk)

C) Northern disjunct species
Adoxa moschatellina L. (moschatel)
Chrysosplenium iowense Rydb. (golden saxifrage)
Ribes hudsonianum Richardson (northern currant)

D) Eastern disjunct species
Aconitum noveboracense Gray (northern monkshood)

E) Southern disjunct species
Hybanthus concolor (T.F. Forster) Sprengel (green violet)
Sullivantia sullivantii (T. & G.) Britton (sullivantia)

F) Species endemic to the Driftless Area
Solidago sciaphila Steele (cliff goldenrod)

No isozymic variation was detected in sullivantia (Soltis 1982) in populations sampled throughout the Driftless Area (including Bixby) and adjacent areas (Soltis 1982). Soltis (1982) theorized that low genetic variability in this species is due to founder effect of plants colonizing northeast Iowa after the last glacial event in Iowa and subsequent genetic drift. However, Soltis (1980, 1991) *does* report morphological diversity and variation in flavenoid constituents in sullivantia across its range in the Midwest.

Cole and Kuchenreuther (2001) studied genetic diversity of northern monkshood in three populations in northeast Iowa (all in close proximity to Bixby). They found polymorphisms for three of seven (42.9%) loci examined in each population. Traditionally, monkshood (*Aconitum* L.) populations in the eastern and midwestern United States (e.g., northern monkshood, *Aconitum noveboracense*) have been treated as species distinct from populations widespread in the western Rocky Mountains, especially Columbian monkshood, *A. columbianum* Nutt. (Brink 1992). However, recent studies (Flora of North America Editorial Committee 1997, Cole and Kuchenreuther 2001) have shown that morphological and genetic variation in *A. noveboracense* (found on algific talus slopes at Bixby) are subsets of variation in the western *A. columbianum.* Cole and Kuchenreuther (2001) concluded that these two species should be subsumed into one species: *A. columbianum* Nutt.

The algific talus slopes at Bixby are also home to the federally endangered Iowa Pleistocene snail, *Discus macclintocki* Baker (Anderson 2000, Ross 1999) and the Iowa threatened snail *Vertigo hubrichti* Pilsbry (Roosa 1990, Frest and Fay 1981). Ross (1999) studied genetic diversity (16S rRNA gene of the mitochondria) in ten populations of the Iowa Pleistocene snail in northeast Iowa (including Bixby) and Illinois. She detected great genetic diversity within this species, and identified three monophyletic groups within the Iowa populations that corresponded to their associated watersheds. Ross (1999) concluded that these watersheds were probably important historic avenues of gene flow for the Iowa Pleistocene snail and that the maintenance of high genetic diversity in this species may correlate with high fitness.

2) Example Oriented Role. Bixby preserves a diversity of forest types and microhabitats in a small area. The preservation of mature upland forests at Bixby is especially important because the majority of forests elsewhere in northeast Iowa, especially those in private ownership, are successional in nature (Norris and Farrar 2001). As part of an effort to characterize mature forest vegetation in northeast Iowa, Norris et al. (2006) have established and surveyed the vegetation in four 20 m × 50 m permanent plots at Bixby following protocol described in Raich et al. (1999). As for microhabitats, the nature trail in the vicinity of the Ice Cave and associated north-facing slopes provides botanists with some of the best access to algific talus slope vegetation in northeast Iowa.

3) Process Oriented Role. Saunders et al. (1991) state process oriented reasons to demonstrate the "value of vegetation remnants in the maintenance of evolutionary opportunities and successional states, as functional links or corridors between other remnants .. or for their role in nutrient cycling, groundwater movements, effects on salinity and erosion .. " In northeast Iowa (and Bixby), suitable climatic conditions (temperature, precipitation) and topographic diversity exist to allow numerous "special plants" (Table 3) to persist here at the periphery of their distribution or disjunct from floras elsewhere in North America (Thorne 1964, Pusateri et al. 1993), thus maintaining evolutionary opportunities and successional states not prevalent in more disturbed habitats of northeast Iowa.

The diverse native flora preserved at Bixby may also be important as a propagule source for recolonization of successional forests recovering from recent pasturing and/or timber harvest. Since the 1970s there has been significant conversion of wooded pasture and improved pasture to forest in virtually all counties in Iowa (Jungst et al. 1998). The herbaceous floras of grazed and ungrazed forests are quite different, with ungrazed forests having a higher proportion of perennial herbs, herbs with fleshy roots and herbs characteristic of moist forests with closed canopies (Mabry 2002). A recent study (Vellend 2003) of successional forests across eastern North America and Europe found that the diversity of "ancient forest herbs" in such forests correlated with the proportion of "ancient forest" in the surrounding landscape. This suggests that the system of forest preserves in northeast Iowa (including Bixby) may be a crucial element in the reestablishment of a rich forest herbaceous layer in former pasturelands. [It should be noted that numerous studies (Cain et al. 1998, Grashof-Bokdam and Geertsema 1998, McLachlan and Bazely 2001, Bellemare et al. 2002) suggest that this recovery will be a slow process, limited by slow dispersal rates of herbaceous species with ant- and gravity-dispersed seeds].

Habitat selection by forest-dwelling animal species is another process that occurs in northeast Iowa forests. In birds, this process is influenced by both landscape (e.g., patch area, proportion of core area, patch shape) and vegetation (e.g., structural diversity, plant species composition) characteristics (Ambuel and Temple 1983, Blake and Karr 1987, Cody 1985, Faaborg et al. 1995). In a recent study investigating the influence of forest management regime on bird community structure in northeast Iowa, bird species of high management concern (see "Species Oriented Role") were shown to be more diverse in mature, infrequently disturbed forests (including Bixby) than in frequently disturbed, successional forests (Norris et al. 2003).

4) Social Values Oriented Role. The citizens of northeast Iowa have long recognized the unique natural features of Bixby. In fact, its purchase by the State of Iowa in 1926 occurred after residents of nearby Edgewood petitioned to make Bixby a state park (Herzberg and Pearson 2001). During our fieldwork at Bixby (1993–2005), we frequently observed local citizens engaged in recreational hiking, bird watching, and picnicking within the preserve boundaries. On one occasion, we encountered a wedding in progress in front of the picnic shelter at Bixby. On another, we encountered highway construction workers huddled in front of the ice cave while eating lunch during a hot July day. We suspect that Bixby ranks high among Iowa state preserves in terms of awareness and use by the general public.

Bixby plays an important role in natural resource education. It is a popular destination for field trips associated with courses in ecology and geology by universities and colleges in Iowa (e.g., Mount Mercy College, Iowa State University, Iowa Lakeside Laboratory) and elsewhere (e.g., Northern Illinois University). Since we began our fieldwork in 1993, Bixby has also been the focus of field trips offered by state (Iowa Native Plant Society, Iowa Department of Natural Resources) and national (American Fern Society) societies concerned with conservation and biological research.

Human Effects

Although we view Bixby as an exemplary preserve in the Iowa State Preserves system, we also acknowledge that it is in "semi-natural" condition, with numerous anthropogenic effects since European settlement. Conversion of adjacent forestland for agricultural purposes, forest fragmentation that increases the amount of edge habitat, introduction of exotic species, population spikes in several native species, and fire exclusion have all altered or disrupted ecological and evolutionary processes at Bixby. Below, we describe the observed and suspected results of some of these human effects.

Fire Suppression. With regard to the composition of forest vegetation, the most dramatic human effect since settlement has probably been fire exclusion. Upland oak species, including red oak and white oak, have low to intermediate shade tolerance; hence, the establishment of oak trees in Midwestern forests (including northeast Iowa) prior to European settlement probably depended on historic fires set by lightening and by Native Americans to open up the canopy (Abrams 1992, Jungst et al. 1998). Other upland tree species in northeast Iowa forests, especially sugar maple, can regenerate under closed canopies (i.e., they are shade tolerant) but are intolerant of fire. With fire virtually absent as a disturbance factor in Iowa for at least the past one hundred years, mature upland forests in northeast Iowa today (including Bixby) typically have closed canopies that preclude oak regeneration. Sugar maple and/or ironwood trees are currently dominant in the understory of these forests (Norris and Farrar 2001), and the former species seems poised to replace the oaks in the canopy as they die or are harvested (Jungst et al. 1998).

Introduction of Non-Native Species. Humans have affected the flora of Bixby by facilitating the introduction of exotic species. Garlic mustard (*Alliaria petiolata*), an herb native to northern Europe, has been able to invade the herbaceous flora of many deciduous forests in the eastern United States (Blossey et al. 2001) and Iowa (Lewis and Pope 2001, Walkowiak and Haanstad 2001). The ground-layer floras of sites invaded by garlic mustard frequently have low diversity (Anderson et al. 1996, McCarthy 1997), and it is assumed that garlic mustard out-competes many native species (though experimental evidence of garlic mustard's presumed competitive advantage is scarce) (Blossey et al. 2001). It has been proposed that garlic mustard produces phytotoxins that may inhibit activity of mycorrhizal fungi associated with vascular plant species (Vaughn and Berhow 1999). Garlic mustard is also suspected to alter habitat suitability for salamanders, mollusks, earthworms and butterflies (Blossey et al. 2001). Although garlic mustard has not yet overwhelmed the herbaceous flora at Bixby, it is conspicuous throughout the preserve, particularly in the vicinity of the ice cave and in floodplain forests bordering Bear Creek. Common buckthorn (*Rhamnus cathartica*), multiflora rose (*Rosa multiflora*), Tartarian honeysuckle (*Lonicera tatarica*), Canada thistle (*Cirsium arvense*), and other invasive vascular plant species are also found in the preserve.

Several tree species native to northeast Iowa (and Bixby) have been impacted by fungal diseases. Both American elm (*Ulmus americana*) and red elm have been decimated since the early 20th century by two strains of Dutch elm disease, which is caused by the fungal parasites *Ophiostoma ulmi* (Buisman) Nannf. and *O. nova-ulmi* Brasier (Karnosky 1979, Tiffany 2001). Large trees of both elm species were once common in floodplains and moist wooded slopes throughout Iowa, but they are currently encountered most frequently as small trees, saplings and seedlings in forest understories (van der Linden and Farrar 1993). Likewise, populations of butternut (*Juglans cinerea*) have been devastated throughout most of Iowa since the 1960s by butternut canker, *Sirococcus clavigignenti-juglandacearum* N. B. Nair, Kostichka & Kuntz (Renlund 1971, van der Linden and Farrar 1993). We have observed only a few butternuts at Bixby, all of them dead trees occurring in disturbed upland forest habitat.

Harvest of Ginseng and Goldenseal. Ginseng (*Panax quinquefolius*) and goldenseal (*Hydrastis canadensis*) have been harvested for more than two centuries to supply the Asian herbal market, resulting in lowered natural population size throughout much of its range (McGraw 2001, Van Der Voort et al. 2003). Although we have not personally observed harvest of either species at Bixby, we have encountered individuals collecting goldenseal in a privately owned forest less than a mile away. Likewise, the presence of a large sign at the south entrance of nearby White Pine Hollow State Preserve (Dubuque Co.) prohibiting the harvest of ginseng there suggests that preserve status is no barrier to unscrupulous collection of these herbs. We did not observe a single goldenseal plant at Bixby despite its earlier report here by Roosa (1990), and our few encounters of ginseng in this preserve have always been of single plants. Several studies conducted elsewhere (Hackney and McGraw 2001, Cruse-Sanders and Hamrick 2004) demonstrated the negative consequences of ginseng harvest (i.e., shift towards smaller, non-reproductive age classes) and small population size (i.e., reduced fruit production) in this species.

Increased Abundance of White-Tailed Deer. Although white-tailed deer were nearly extirpated from Iowa by 1900, they are now abundant and considered to be a pest in some parts of the state (Dinsmore 1993). This population explosion is probably due, in large part, to the abundant food supply in Iowa's cornfields (Dinsmore 1993). Numerous effects of increased deer densities and browsing pressure on woody plants (individuals, populations, and communities) have been documented in eastern forests of the United States and Canada (Russell et al. 2001). These effects include reduced survival and growth rates in red oak seedlings, reduced survival rates in sugar maple seedlings, reduced sapling and/or sprout density, exhaustive acorn consumption during mast years, reduced strobilus and seed production in American yew, altered forest understory composition, and reduced species richness (numerous references cited in Russell et al. 2001). Furthermore, the composition and abundance of forest bird communities may be affected by the alterations in understory vegetation associated with heavy deer browsing (McShea and Rappole 2000).

Negative effects of deer browsing on forest herbs have also been reported. Populations of golden seal (*Hydrastis canadensis*), false Solomon's seal (*Smilacina racemosa*), Jacob's ladder (*Polemonium reptans*), and violet (*Viola* spp.), herbs which all occur at Bixby, are heavily browsed in southern Illinois forests with high deer densities (Frankland and Nelson 2003). White-tailed deer have also been shown to selectively browse large, reproductive plants in trillium (*Trillium* spp.) populations in southeastern Minnesota forests, thus skewing population structure towards smaller plants and causing drastic declines in reproduction (Augustine and Frelich 1998).

It is reasonable to assume that white-tailed deer browsing is currently affecting the vegetation and avifauna at Bixby in many of the ways described above. We can add several anecdotal observations to supplement these published reports. First, we have observed American yew to occur primarily on steep talus slopes at Bixby (and elsewhere in northeast Iowa). The restriction of American yew to these habitats is probably due to their inaccessibility to white-tailed deer, which browse heavily on this shrub elsewhere (personal communication, Donald R. Farrar, Department of Ecology and Evolutionary Biology, Iowa State University). We have also observed the decimation of a large (>15 plants) northern monkshood population by probable deer browsing in the mid-1990s.

Increased Abundance of Brown-Headed Cowbirds. Reduction and fragmentation of historic forest cover in the Driftless Area are probably responsible for the invasion of brown-headed cowbirds into these forests from the Great Plains since the late 1800s (Mayfield 1965, Gustafson et al. 2002). Cowbirds are nest parasites that lay their eggs exclusively in the nests of other bird species, often resulting in reduced nest productivity in the host species (Robinson et al. 1995a). Breeding birds residing in fragmented forests are especially vulnerable to cowbird parasitism because female cowbirds can travel up to 7 km from their feeding grounds (cropfields, pastures) while searching for potential host nests (Robinson 1996).

Cowbirds are currently one of the most abundant bird species in northeast Iowa forests (Hemesath and Norris 1998), including Bixby (Norris, unpublished data), which suggests negative effects on populations of breeding birds that reside here. Eighteen of the 40 bird species known to reside in forest habitat at Bixby during the breeding season are frequent to regular hosts to cowbird parasitism (Appendix C) (Best et al. 1996).

Forest Fragmentation. The historic forest cover surrounding Bixby (Fig. 1a) has been reduced to a mosaic of forest patches within an agricultural matrix (Fig. 1b). Many features of this altered landscape, including area, shape, and degree of isolation of forest patches can influence the presence and abundance of insects, amphibians, birds and mammals (Faaborg et al. 1995, Mazerolle and Villard 1999). Of the forty bird species detected at Bixby during the summer months in the mid-1990s, twenty-three have exhibited positive area sensitivity (greater abundance, frequency of occurrence and/or nest success with increasing patch size) in studies conducted elsewhere in the eastern United States (Appendix C) (Best et al. 1996). Landscape attributes can also affect reproductive output in some animal species. For example, proportion of core area in a forest patch has been shown to influence nest success of breeding songbirds in the Driftless Area, including northeast Iowa (Knutson et al. 2004). Furthermore, rates of nest parasitism by brown-headed cowbirds in the Midwest can be affected by abundance of forest habitat (Robinson et al. 1995b) and degree of fragmentation (Donovan et al. 1995, Gustafson et al. 2002). Finally, animal community diversity is often related to patch size, a trend that is especially well documented for forest bird communities in southern Wisconsin (Ambuel and Temple 1983) and central Illinois (Blake and Karr 1987).

There is growing evidence for influence of landscape characteristics on plant populations in fragmented landscapes via effects on population distribution patterns, reproductive success, colonization rates and extinction probabilities. For instance, forest patch area and degree of spatial isolation explain occurrence patterns of the forest herb oxlip (*Primula elatior* (L.) Hill) persisting in a fragmented landscape in Belgium (Hans et al. 2002). In deciduous forests of southern Sweden, patch isolation negatively affects the distribution of selected ground layer plants, especially habitat specialists, clonal perennials and plants with low seed production (Dupre and Ehrlen 2003). Numerous studies suggest that habitat fragmentation is associated with reduced seed production in populations of forest herbs (Aizen and Feinsinger 1994, Hans et al. 2002, Tomimatsu and Ohara 2002). Possible mechanisms for reduced seed production in fragmented habitats include increased isolation between populations and changes in habitat suitability for plants and pollinators (Tomimatsu and Ohara 2002).

Patch size and isolation can also influence plant colonization rates by affecting the spread of plant propagules and disturbance (e.g., fire) from one patch to another (Chapin et al. 2002). Ant-dispersed plant species, such as wild ginger (*Asarum canadense*) (which occurs at Bixby), are particularly limited in their dispersal capabilities (Cain et al. 1998), and source populations would have difficulty colonizing distant forest patches.

Edge Effects. The increased edge habitat associated with forest fragmentation, such as that which has occurred in the vicinity of Bixby State Preserve, can alter habitat suitability and movement of a variety of organisms (Forman 1995). Neotropical migratory bird species, for instance, often experience lower nest success (Flaspohler et al. 2001) and higher rates of nest predation (Hartley and Hunter 1998) and nest parasitism by cowbirds (Brittingham and Temple 1983) in the vicinity of forest edges than in the interior of a forest.

As for plants, increased intensity of wind and solar radiation associated with forest edge can influence habitat suitability, productivity, competitive interactions, rates of invasion by plant propagules, and disturbance rates (Chapin et al. 2002). In deciduous forests, results of the above edge effects are often apparent in the skewed distribution of understory species relative to edge proximity (Burke and Nol 1998, Matlack 1994). For example, selected understory species in oak forests of southeastern Pennsylvania and northern Delaware had their peak occurrence within 5 m of forest edge (*Carex* spp., *Circaea lutetiana*, *Podophyllum peltatum*, *Polygonatum biflorum*, *Prunus serotina*, *Viola* spp.) while other species (*Arisaema triphyllum*, *Smilacina racemosa*) occurred most frequently at distances at least 20 m away from the edge (Matlack 1994) [note: all of the above species occur at Bixby]. Forest edge can also impose barriers to pollen, spore and seed movement (Burke and Nol 1998). For example, ant dispersal of seeds in bloodroot (*Sanguinaria canadensis*, a common forest herb at Bixby) in the direction of forest edge is rare in deciduous forests of north Georgia (Ness 2004). Given the frequency of forest edge at Bixby, one can only assume that many of the above edge effects are at play in this preserve.

Altered Ecosystem Functions. Human activities (e.g., timber harvest, agricultural activities) at Bixby and adjacent lands have likely affected one or more ecosystem processes (e.g., nutrient and hydrologic cycles, material flow, etc.). Clear-cutting, such as has occurred in forests adjacent to Bixby in the past decade, can result in increased nutrient loss and runoff (Qualls et al. 2000, Turner et al. 2001). Increased forest edge associated with forest fragmentation has been shown to trap airborne nutrients and pollutants from adjacent agricultural land and to concentrate nutrient fluxes beneath the canopy in fragmented forest landscapes in the eastern United States (Weathers et al. 2001). Finally, disturbance can cause temporary declines in nitrogen uptake by vascular plants with resultant increase in nitrification (i.e., nitrate production) by soil microorganisms (Turner et al. 2001).

Future Potential

Specific powers and duties of the Iowa State Preserves Advisory Board include identifying unique natural and cultural areas for possible inclusion in the preserve system, protecting natural and cultural areas through research, inventory, and best management practices, educating the public through interpretive programs, and strengthening partnerships with state, county, private and conservation organizations (State Preserves Advisory Board and Iowa Department of Natural Resources 2001). In a recent evaluation of the preserve system, the Preserves Board declared that the potential of the preserve system has not been fully realized due to insufficient staffing and funding, lack of public awareness and the need of a strategic plan (State Preserves Advisory Board and Iowa Department of Natural Resources 2001).

Although much work remains to be done to fulfill the potential of the preserve system, the Preserves Board can take pride in the success of Bixby State Preserve in measuring up to this potential. This preserve, in our estimation, receives high marks for all of the roles (species oriented, example oriented, process oriented, social values oriented) a vegetation remnant should play in conservation (Saunders et al. 1991). We offer the following suggestions for future research and management activities at Bixby.

The vascular plants, diatoms, fungi, amphibians, reptiles, birds and mammals of Bixby have been inventoried. Additional survey in the preserve of diatoms (personal communication, Mark Edlund, St. Croix Watershed Research Station, Science Museum of Minnesota), fungi (personal communications, Rosanne Healy and Lois Tiffany, Department of Ecology and Evolutionary Biology, Iowa State University) and amphibians, reptiles and mammals (personal communications, Bruce Ehresman and Daryl Howell, Iowa Department of Natural Resources) in the preserve would probably result in discovery of additional species in each group. Furthermore, the bryophytes (i.e., mosses, liverworts, hornworts) here have not received careful study despite their conspicuous occurrence in numerous habitats (boulders, tree trunks, vertical cliff faces, ice cave, algific talus slopes, submerged rocks in Bear Creek) in the preserve. We recommend that the Iowa State Preserves Advisory Board solicit researchers to conduct inventories of the above organisms.

The genetic diversity of four algific talus slopes species (golden saxifrage, sullivantia, northern monkshood, and Iowa Pleistocene snail) in northeast Iowa has been examined. Different levels of intra- and inter-population genetic variation were detected for each of these four species, indicating that different sets of mechanisms explain the genetic structure of each. Given the diverse biogeographic origins of "special plants" (Table 3) and other organisms in the Paleozoic Plateau, we recommend that the genetic structure of other isolated species occurring in this region (including Bixby) be studied for trends relating to their genetics and biology.

We see the potential for Bixby to be included (along with other northeast Iowa forest preserves) in research projects focused on the influence of forest condition (i.e., pastured/logged forests versus mature forests) and landscape (e.g., patch size, degree of isolation, amount of edge) on plant population dynamics including seed production and germination rates, dispersal rates, pollination biology, and introduction of exotics such as garlic mustard. Finally, resurvey of forest vegetation plots at Bixby (and other northeast Iowa forest preserves) established and surveyed in the mid-1990s would be an initial step towards monitoring vegetation change in northeast Iowa forests, especially the apparent replacement of oak species by sugar maple in upland terrain. [Note: William Norris and William Watson resurveyed woody vegetation in all permanent plots at Bixby during summer 2005, after submission of this paper].

We have three recommendations for resource management at Bixby. At the smallest scale, we see an immediate need for woody plant removal in the prairie opening on Steamboat Rock; failure to do so will undoubtedly result in loss of this small but diverse microhabitat within the next decade. [Note: William Watson initiated woody plant removal on the prairie remnant at Steamboat Rock during summer 2005, after submission of this paper]. We also recommend that the Iowa State Preserves Board initiate an effort to manually remove garlic mustard from this preserve annually each spring. Though conspicuous, garlic mustard numbers at Bixby are currently low enough that concerted efforts to keeps its population in check here are still feasible. At the largest scale of management, we propose acquisition of forest land adjacent to the preserve boundaries that would go a long way in restoring landscape processes that existed prior to reduction and fragmentation of historic forest land (Fig. 1a).

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Appendix A. Annotated catalogue of the Bixby flora. Voucher specimens are deposited in the Ada Hayden Herbarium (ISC) at Iowa State University, Ames, Iowa, unless otherwise noted. AQ = aquatic; AS = *Acer saccharum* forest; ASQB = *Acer saccharum/Quercus borealis* forest; ATS = algific talus slope; BA = *Betula alleghaniensis* forest; FF = floodplain forest; G = glade; PO = prairie opening; PS = *Pinus strobus* forest; QA(D) = *Quercus alba* (disturbed) forest; RIP = riparian; RUD = ruderal; VCF = vertical cliff face;

PTERIDOPHYTES

ADIANTACEAE
Adiantum pedatum L. (northern maidenhair fern) [AS, ASQB, ATS, FF, QA(D)]
Cryptogramma stelleri (Gmelin) Prantl (slender rockbrake fern) [ATS]
Pellaea glabella Mett. ex Kuhn (smooth cliff-brake) [ASQB, PO, VCF]
ASPLENIACEAE
Asplenium rhizophyllum L. (walking fern) [AS, ASQB, ATS, BA]
DRYOPTERIDACEAE
Athyrium filix-femina (L.) Roth var. *angustum* (Willd.) Moore (northern lady fern) [AS, ASQB, FF, QA(D)]
Cystopteris bulbifera (L.) Bernh. (bulblet bladder fern) [AS, ASQB, ATS, BA, VCF]
Cystopteris protrusa (Weath.) Blasdell (creeping fragile fern) [ASQB]
Deparia acrostichoides (Schwartz) M. Kato (silvery spleenwort) [AS]
Diplazium pycnocarpon (Sprengel) M. Broun (narrow-leaved spleenwort) [1]
Dryopteris carthusiana (Vill.) H. P. Fuchs (spinulose wood fern) [AS, ATS, QA(D)]
Dryopteris intermedia (Willd.) Gray (glandular wood fern) [AS]
Gymnocarpium dryopteris (L.) Newman (oak fern) [ATS]
Gymnocarpium × *brittonianum* (Sarvela) Pryer & Haufler [2]
Gymnocarpium × *intermedium* Sarvela [ATS]
Matteucia struthiopteris (L.) Todaro var. *pensylvanica* (Willd.) Morton (ostrich fern) [AS]
Onoclea sensibilis L. (sensitive fern) [AS]
Woodsia obtusa (Sprengel) Torrey (blunt-lobed woodsia) [ASQB]
EQUISETACEAE
Equisetum arvense L. (common horsetail) [RIP, FF]
Equisetum hyemale L. var. *affine* (Engelm.) A. A. Eaton (common scouring-rush) [FF]
Equisetum pratense Ehrh. (meadow horsetail) [AS]
Equisetum scirpoides Michx. (dwarf scouring-rush) [BA]
LYCOPODIACEAE
Huperzia lucidula (Michx.) Trevisan (shining clubmoss) [BA]
Lycopodium dendroideum Michx. (tree clubmoss) [1]
OPHIOGLOSSACEAE
Botrychium dissectum Sprengel f. (dissected grape fern) [1]
Botrychium virginianum (L.) Sw. (rattlesnake fern) [AS, ASQB, FF, QA(D)]
OSMUNDACEAE
Osmunda claytoniana L. (interrupted fern) [QA(D)]

GYMNOSPERMS

CUPRESSACEAE
Juniperus virginiana L. (red cedar) [PO]
PINACEAE
Pinus strobus L. (eastern white pine) [ASQB, PS]
TAXACEAE
Taxus canadensis Marsh. (American yew) [AS, ASQB, ATS]

ANGIOSPERMS (DICOTYLEDONS)

ACERACEAE
Acer negundo L. (box elder) [FF, RIP]
Acer nigrum Michx. f. (black maple) [ASQB]
Acer saccharinum L. (silver maple) [FF]
Acer saccharum Marsh. (sugar maple) [AS, ASQB]
ADOXACEAE
Adoxa moschatellina L. (moschatel) [ATS]
AMARANTHACEAE
!*Amaranthus retroflexus* L. (pigweed) [RUD]
ANACARDIACEAE
Rhus glabra L. (smooth sumac) [RIP]
Rhus typhina L. (staghorn sumac) [RUD, PO]
Toxicodendron radicans (L.) Kuntze ssp. *negundo* (Greene) Gillis (poison ivy) [ASQB]

Appendix A. Continued.

APIACEAE
Cryptotaenia canadensis (L.) DC. (honewort) [AS, ASQB, FF, RIP]
!*Daucus carota* L. (Queen Anne's lace) [RIP, RUD]
Heracleum lanatum Michx. (cow parsnip) [FF]
Osmorhiza claytonii (Michx.) C. B. Clarke (sweet cicely) [AS, ASQB, BA]
Osmorhiza longistylis (Torrey) DC. (anise root) [ASQB]
!*Pastinaca sativa* L. (wild parsnip) [RUD]
Sanicula canadensis L. (black snakeroot) [AS, ASQB]
Sanicula gregaria Bickn. (common snakeroot) [AS, ASQB, FF, G]
Sanicula marilandica L. (black snakeroot) [AS, ASQB]
Sanicula trifoliata Bickn. (large-fruited black snakeroot) [AS, ASQB]
Taenidia integerrima (yellow pimpernel) (L.) Drude [ASQB, G]
Zizia aurea (L.) Koch (golden alexanders) [AS, ASQB, RUD]
APOCYNACEAE
Apocynum androsaemifolium L. (spreading dogbane) [AS, ASQB, G]
ARALIACEAE
Aralia nudicaulis L. (wild sarsaparilla) [AS, ASQB, BA, QA(D)]
Aralia racemosa L. (spikenard) [AS, ASQB, ATS, BA]
Panax quinquefolium L. (ginseng) [AS, ASQB, QA(D)]
ARISTOLOCHIACEAE
Asarum canadense L. (wild ginger) [AS, ASQB, ATS, BA, FF]
ASCLEPIADACEAE
Asclepias exaltata L. (poke milkweed) [ASQB]
Asclepias syriaca L. (common milkweed) [RIP, RUD]
Asclepias verticillata L. (whorled milkweed) [PO]
ASTERACEAE
Achillea millefolium L. ssp. *lanulosa* (Nutt.) Piper (western yarrow) [AS, RIP, RUD]
Ambrosia artemisiifolia L. (common ragweed) [RIP, RUD]
Ambrosia trifida L. (giant ragweed) [RIP, RUD]
Antennaria plantaginifolia (L.) Richardson (ladies' tobacco) [ASQB, G, PO]
!*Anthemis cotula* L. (dog fennel) [RUD]
!*Arctium minus* Bernh. (common burdock) [AS, ASQB, FF, QA(D), RIP, RUD]
Aster cordifolius L. (blue wood aster) [AS, ASQB, ATS, BA, QA(D), RUD, VCF]
Aster lateriflorus (L.) Britton (side-flowered aster) [AS, ASQB, RIP, RUD]
Aster pilosus Willd. (hairy aster) [RUD]
Aster prenanthoides Muhl. ex Willd. (crooked stem aster) [AS, FF, RIP]
Aster sagittifolius Willd. (arrow-leaved aster) [AS]
Aster sericeus Vent. (silky aster) [PO]
Aster shortii Lindley [AS, ASQB]
Bidens cernua L. (nodding bur marigold) [FF, RUD]
Bidens connata Muhl. ex Willd. (swamp beggar-ticks) [FF, RUD]
Bidens frondosa L. (beggar-ticks) [RUD]
Bidens tripartita L. (trifid beggar-ticks) [RUD]
Cacalia muhlenbergii (Sch.-Bip.) Fern. (great Indian plantain) [AS, FF]
!*Cichorium intybus* L. (chicory) [RUD]
Cirsium altissimum (L.) Sprengel (tall thistle) [ASQB]
!*Cirsium arvense* (L.) Scop. (Canada thistle) [RIP]
Cirsium discolor (Muhl. ex Willd.) Sprengel (field thistle) [AS, ASQB, RUD] [6]
!*Cirsium vulgare* (Savi) Tenore (bull thistle) [RUD]
Conyza canadensis (L.) Cronq. (horseweed) [RUD] [6]
Coreopsis palmata Nutt. (tickseed) [PO]
Erigeron annuus (L.) Pers. (annual fleabane) [AS, ASQB, FF, RUD, RIP]
Erigeron strigosus Muhl. ex Willd. (rough fleabane) [PO]
Eupatorium purpureum L. (purple Joe-pye-weed) [AS, ASQB, RIP, RUD]
Eupatorium rugosum Houtt. (white snakeroot) [AS, ASQB, ATS, BA, FF, RUD]
!*Galinsoga quadriradiata* Ruiz & Pavon (Peruvian daisy) [RIP]
Helenium autumnale L. (sneezeweed) [RIP]
Helianthus strumosus L. (pale-leaved sunflower) [ASQB]
Helianthus tuberosus L. (Jerusalem artichoke) [RUD]
Heliopsis helianthoides (L.) Sweet (ox-eye) [AS, ASQB]
Krigia biflora (Walter) Blake (false dandelion) [ASQB] [6]

Appendix A. Continued.

Lactuca biennis (Moench) Fern. (tall blue lettuce) [AS, RUD]
Lactuca canadensis L. (wild lettuce) [RUD]
Liatris aspera Michx. (blazing star) [PO]
Polymnia canadensis L. (leafcup) [AS, ASQB, ATS, BA]
Prenanthes alba L. (rattlesnake-root) [AS, ASQB, QA(D)]
Rudbeckia hirta L. (black-eyed Susan) [RUD] [6]
Rudbeckia laciniata L. (tall coneflower) [AS, ATS, BA, FF, RUD]
Senecio aureus L. (golden ragwort) [RIP]
Senecio plattensis Nutt. (prairie ragwort) [RIP]
Silphium perfoliatum L. (cup plant) [FF, RIP, RUD]
Solidago canadensis L. (tall goldenrod) [RUD]
Solidago flexicaulis L. (zig-zag goldenrod) [AS, ASQB, BA, QA(D), RUD]
Solidago gigantea Aiton (smooth goldenrod) [FF, RUD] [6]
Solidago nemoralis Aiton (field goldenrod) [PO]
Solidago sciaphila Steele (cliff goldenrod) [ASQB, VCF]
Solidago ulmifolia Muhl. ex Willd. (elm-leaved goldenrod) [ASQB, AS, FF, QA(D), RUD]
!*Taraxacum officinale* Weber (common dandelion) [AS, ASQB, FF, RIP, RUD]
!*Xanthium strumarium* L. (cocklebur) [1]

BALSAMINACEAE
Impatiens capensis Meerb. (spotted touch-me-not) [FF, RIP, RUD]
Impatiens pallida Nutt. (pale touch-me-not) [ASQB, FF, RIP, RUD]

BERBERIDACEAE
!*Berberis thunbergii* DC. (Japanese barberry) [ASQB, QA(D)]
Caulophyllum thalictroides (L.) Michx. (blue cohosh) [AS, ASQB, ATS, BA, FF]
Podophyllum peltatum L. (mayapple) [AS, ASQB, ATS, FF, QA(D)]

BETULACEAE
Betula alleghaniensis Britton (yellow birch) [AS, ATS, BA]
Betula papyrifera Marsh (paper birch) [AS, ASQB] [6]
Carpinus caroliniana Walter (blue beech) [AS, BA]
Corylus americana Walter (hazelnut) [AS, ASQB]
Corylus cornuta Marsh. (beaked hazelnut) [AS, ATS, BA]
Ostrya virginiana (P. Miller) K. Koch (ironwood) [AS, ASQB, QA(D)]

BORAGINACEAE
Hackelia virginiana (L.) I. M. Johnston (stickseed) [AS, ASQB, G]
Lithospermum canescens (Michx.) Lehm. (hoary puccoon) [G, PO]

BRASSICACEAE
!*Alliaria petiolata* (Bieb.) Cavara & Grande (garlic mustard) [FF]
Arabis canadensis L. (sickle pod) [1]
Arabis hirsuta (L.) Scop. [ASQB, ATS]
Arabis laevigata (Muhl. ex Willd.) Poiret [AS, ASQB, VCF]
!*Barbarea vulgaris* R. Br. (yellow rocket) [AS, FF, RIP, RUD, VCF]
!*Brassica* L. sp. [RIP]
!*Capsella bursa-pastoris* (L.) Medicus [RUD, RIP]
Cardamine bulbosa (Schreber) BSP. [RIP]
Dentaria laciniata Muhl. ex Willd. (toothwort) [AS, ASQB, ATS, FF]
Lepidium L. sp. (peppergrass) [RUD]
Rorippa palustris L. Besser (marsh cress) [RIP]

CAMPANULACEAE
Campanula americana L. (tall bellflower) [AS, ASQB, FF, RIP, RUD]
Campanula rotundifolia L. (harebell) [AS, ASQB, PO, VCF]
Lobelia inflata L. (Indian tobacco) [AS, QA(D)]
Lobelia siphilitica L. (great lobelia) [RUD]

CAPRIFOLIACEAE
Diervilla lonicera Miller (bush honeysuckle) [AS, ATS, BA]
Lonicera dioica L. var. *glaucescens* (Rydb.) Butters (wild honeysuckle) [AS, ASQB, ATS, BA]
!*Lonicera maackii* (Rupr.) Herder [G]
Lonicera prolifera (Kirchner) Rehder (wild honeysuckle) [ASQB] [6]
!*Lonicera tatarica* L. (Tartarian honeysuckle) [ASQB, RIP, RUD]
Sambucus canadensis L. (elderberry) [FF, RIP, RUD]
Sambucus racemosa L. ssp. *pubens* (Michx.) House (red-berried elderberry) [1]
Triosteum aurantiacum Bickn. [ASQB]

Appendix A. Continued.

Triosteum perfoliatum L. (horse gentian) [ASQB, G]
Viburnum lentago L. (nannyberry) [AS, ASQB, BA, FF, PO, QA(D)]
Viburnum rafinesquianum Schultes (downy arrowwood) [AS, ASQB, BA, G, PO, QA(D)]
Viburnum trilobum Marsh. (highbush cranberry) [ATS]

CARYOPHYLLACEAE
Cerastium nutans Raf. (nodding chickweed) [RIP, RUD]
!*Cerastium vulgatum* L. (mouse-ear chickweed) [FF]
Moehringia lateriflora (L.) Fenzl (sandwort) [AS, ASQB]
!*Myosoton aquaticum* (L.) Moench (giant chickweed) [RIP]
!*Saponaria officinalis* L. (bouncing bet) [RIP, RUD]
!*Silene pratensis* (Rafn) Gren. & Godron (white campion) [RIP, RUD]
Stellaria longifolia Muhl. ex Willd. (stitchwort) [RUD]
!*Stellaria media* (L.) Vill. (common chickweed) [AS, RIP, RUD]

CELASTRACEAE
Celastrus scandens L. (bittersweet) [AS, ASQB]
Euonymous atropurpureus Jacq. (wahoo) [AS, ASQB, ATS, PO, FF]

CHENOPODIACEAE
!*Chenopodium album* L. (lamb's quarters) [RUD] [6]
Chenopodium standleyanum Aellen (woodland goosefoot) [RUD]

CONVOLVULACEAE
Calystegia sepium (L.) R. Br. (hedge bindweed)[1]
Calystegia spithamaea (L.) Pursh (low bindweed) [ASQB]
Cuscuta cephalanthii Engelm. (buttonbush dodder) [FF]

CORNACEAE
Cornus alternifolia L. f. (alternate-leaved dogwood) [AS, ASQB, BA, FF]
Cornus drummondii C. A. Meyer (rough-leaved dogwood) [ASQB]
Cornus foemina P. Miller ssp. *racemosa* (Lam.) J.S. Wilson (gray dogwood) [RUD]
Cornus rugosa Lam. (speckled dogwood) [AS, BA]

CUCURBITACEAE
!*Cucurbita pepo* L. (striped gourd) [RIP]
Echinocystis lobata (Michx.) T. & G. (wild balsam apple) [FF]

ERICACEAE
Monotropa uniflora L. (Indian pipe) [QA(D)] [6]
Pyrola elliptica Nutt. (shinleaf) [PS]

EUPHORBIACEAE
Acalypha rhomboidea Raf. (three-seeded mercury) [FF, RUD]
Acalypha virginica L. [RUD]
Euphorbia corollata L. (flowering spurge) [PO]
!*Euphorbia esula* L. (leafy spurge) [RUD]
Euphorbia maculata L. (carpet spurge) [5]
Euphorbia nutans Lag. (nodding spurge) [RUD]

FABACEAE
Amphicarpaea bracteata (L.) Fern. (hog peanut) [AS, ASQB]
Desmodium glutinosum (Muhl. ex Willd.) Wood (pointed tick-trefoil) [AS, ASQB, G]
Desmodium nudiflorum (L.) DC. (bare-stemmed tick-trefoil) [AS, ASQB, G]
Lathyrus ochroleucus Hooker (wild pea) 1
!*Lotus corniculatus* L. (bird's-foot trefoil) [RUD] [6]
!*Medicago lupulina* L. (black medic) [RIP, RUD]
!*Melilotus alba* Medicus (white sweet clover) [RIP]
!*Melilotus officinalis* (L.) Pallas (yellow sweet clover) [RIP]
!*Trifolium hybridum* L. (alsike clover) [RUD]
!*Trifolium pratense* L. (red clover) [RUD]
!*Trifolium repens* L. (white clover) [RIP, RUD]

FAGACEAE
Quercus alba L. (white oak) [ASQB, QA(D)]
Quercus borealis Michx. f. var. *maxima* (Marsh.) Ashe (northern red oak) [ASQB, PO]
Quercus ellipsoidalis E.J. Hill (northern pin oak) [ASQB]
Quercus macrocarpa Michx. (bur oak) [ASQB] [6]
Quercus muhlenbergii Engelm. (chinquapin oak) [AS, ASQB, G]

Appendix A. Continued.

GENTIANACEAE
Gentiana alba Muhl. (pale gentian) [GL]
Gentianella quinquefolia (L.) Small ssp. *occidentalis* (A. Gray) J. Gillett (stiff gentian) [G] [1]
GERANIACEAE
Geranium maculatum L. (wild geranium) [AS, ASQB, ATS, FF, QA(D), RUD, VCF]
HAMAMELIDACEAE
Hamamelis virginiana L. (witch hazel) [AS]
HYDROPHYLLACEAE
Ellisia nyctelea L. (wild tomato) [AS, ASQB, ATS, RIP]
Hydrophyllum appendiculatum Michx. (appendaged waterleaf) [AS]
Hydrophyllum virginianum L. (Virginia waterleaf) [AS, ASQB, ATS, FF, RIP, RUD]
HYPERICACEAE
Hypericum punctatum Lam. (spotted St. John's wort) [AS]
JUGLANDACEAE
Carya cordiformis (Wang.) K. Koch (bitternut hickory) [AS, ASQB, FF]
Carya ovata (P. Miller) K. Koch (shagbark hickory) [ASQB]
Juglans cinerea L. (butternut) [QA(D)]
Juglans nigra L. (black walnut) [FF, RIP]
LAMIACEAE
Agastache scrophulariifolia (Willd.) Kuntze (purple giant hyssop) [FF]
Blephilia hirsuta (Pursh) Bentham (wood mint) [AS, FF, RUD]
!*Glechoma hederacea* L. var. *micrantha* Moric. (creeping Charlie) [RUD]
!*Leonurus cardiaca* L. (motherwort) [FF, RIP, RUD]
Lycopus americanus Muhl. ex Barton (water horehound) [RIP]
Mentha arvensis L. (wild mint) [RIP]
Monarda fistulosa L. (wild bergamot) [RIP, RUD]
!*Nepeta cataria* L. (catnip) [RIP, RUD]
Prunella vulgaris L. (self heal) [ASQB, RIP, RUD]
Scutellaria lateriflora L. (mad-dog skullcap) [FF, RIP]
Scutellaria ovata Hill (forest skullcap)[1]
Scutellaria parvula Michx. (little skullcap) [1, 5]
Teucrium canadense L. (American germander) [FF, RIP, RUD]
MALVACEAE
!*Abutilon theophrasti* Medicus (velvet leaf) [RIP]
Malva sp. [RIP, RUD]
MENISPERMACEAE
Menispermum canadense L. (moonseed) [AS, ASQB, RUD]
MORACEAE
!*Morus alba* L. (white mulberry) [RIP]
OLEACEAE
Fraxinus americana L. (white ash) [ASQB, QA(D)] [6]
Fraxinus nigra Marsh. (black ash) [ATS, RIP]
Fraxinus pennsylvanica Marsh. (green ash) [ASQB]
ONAGRACEAE
Circaea alpina L. (dwarf enchanter's nightshade) [ATS]
Circaea × *intermedia* Ehrh [3]
Circaea lutetiana L. ssp. *canadensis* (L.) Ascherson & Magnus (enchanter's nightshade) [AS, ASQB, FF, QA(D), RUD]
Epilobium coloratum Biehler (cinnamon willowherb) [RIP]
Oenothera biennis L. complex (evening primrose) [RIP, RUD]
OXALIDACEAE
Oxalis dillenii Jacq. (yellow wood sorrel) [1]
Oxalis stricta L. (yellow wood sorrel) [RIP, RUD]
Oxalis violacea L. (violet wood sorrel) [ASQB, G]
PAPAVERACEAE
Dicentra canadensis (Goldie) Walp. (squirrel corn) [AS]
Dicentra cucullaria (L.) Bernh. (Dutchman's breeches) [AS, ASQB, ATS, FF, RUD]
Sanguinaria canadensis L. (bloodroot) [AS, ASQB, ATS, BA, FF, RUD]
PHRYMACEAE
Phryma leptostachya L. (lopseed) [AS, ASQB, BA]
PLANTAGINACEAE
Plantago rugelii Dcne. (common plantain) [RIP, RUD]

Appendix A. Continued.

POLEMONIACEAE
Phlox divaricata L. (blue phlox) [AS, ASQB, FF, RUD]
Polemonium reptans L. (Jacob's ladder) [AS, ASQB, ATS, FF]
POLYGALACEAE
Polygala senega L. (Seneca snakeroot) [ASQB, G, PO]
POLYGONACEAE
!*Polygonum aviculare* L. (prostrate knotweed) [RUD]
Polygonum erectum L. (erect knotweed) [RUD]
Polygonum pensylvanicum L. var. *laevigatum* Fern. [RIP]
!*Polygonum persicaria* L. (lady's thumb) [FF, RIP]
Polygonum sagittatum L. (tearthumb) [RUD]
Polygonum scandens L. (climbing false buckwheat) [RUD]
Polygonum virginianum L. (jumpseed) [ASQB, RUD]
!*Rumex acetosella* L. (red sorrel) [1]
Rumex altissimus Wood (pale dock) [RUD]
!*Rumex crispus* L. (curly dock) [RIP]
PORTULACACEAE
Claytonia virginica L. (spring beauty) [AS, ASQB, ATS, FF, RUD]
RANUNCULACEAE
Aconitum noveboracense Gray (northern wild monkshood) [AS, ATS]
Actaea pachypoda Ell. (white baneberry) [AS, ASQB]
Actaea rubra (Aiton) Willd. (red baneberry) [AS, ASQB, ATS, BA, FF]
Anemone canadensis L. (Canada anemone) [RUD] [6]
Anemone quinquefolia L. (wood anemone) [AS, ASQB, ATS, BA, FF, VCF]
Anemone virginiana L. (tall anemone) [AS, ASQB, G, RUD]
Aquilegia canadensis L. var. *coccinea* (Small) Munz (columbine) [AS, ASQB, ATS, BA, VCF]
Clematis virginiana L. (virgin's bower) [RIP, RUD]
Hepatica nobilis P. Miller var. *acuta* (Pursh) Steyerm. (liverleaf) [AS, ASQB, ATS, BA, FF]
Hydrastis canadensis L. (golden seal) [1]
Isopyrum biternatum (Raf.) T. & G. (false rue anemone) [AS, ASQB, ATS, FF, RUD]
Ranunculus abortivus L. (small-flowered crowfoot) [AS, ASQB, ATS, FF, QA(D), VCF]
Ranunculus recurvatus Poiret (hooked buttercup) [AS, ASQB, ATS, BA, FF, RUD]
Ranunculus septentrionalis Poiret (swamp buttercup) [AS, ASQB, FF, QR]
Thalictrum dasycarpum Fischer & Ave-Lall. (purple meadow-rue) [ASQB, FF, RIP, RUD]
Thalictrum dioicum L. (early meadow-rue) [AS, ASQB, FF]
RHAMNACEAE
Rhamnus alnifolia L'Her. (alder buckthorn) [ATS]
!*Rhamnus cathartica* L. (common buckthorn) [FF]
ROSACEAE
Agrimonia gryposepala Wallr. (tall agrimony) [AS]
Agrimonia pubescens Wallr. (soft agrimony) [ASQB]
Agrimonia striata Michx. [AS, RIP, RUD]
Amelanchier arborea (Michx. f.) Fern. (downy serviceberry) [AS, PO]
Amelanchier sanguinea (Pursh) DC. (New England serviceberry)[1]
Crataegus coccinea L. (scarlet hawthorn)[1]
Fragaria vesca L. var. *americana* Porter (woodland strawberry) [AS]
Fragaria virginiana Duchesne (wild strawberry) [AS, FF, G, RIP, RUD]
Geum canadense Jacq. (white avens) [AS, ASQB, ATS, FF, QA(D), RUD]
Malus sylvestris (L.) P. Miller (wild apple) [ASQB]
Physocarpus opulifolius (L.) Maxim. (ninebark) [ASQB, RUD]
Potentilla norvegica L. (Norwegian cinquefoil) [G, RUD]
!*Potentilla recta* L. (sulphur cinquefoil) [RUD] [6]
Potentilla simplex Michx. (common cinquefoil) [ASQB, PO]
Prunus americana Marsh. (wild plum) [G]
Prunus serotina Ehrh. (wild black cherry) [ASQB, QA(D)]
Prunus virginiana L. (choke cherry) [ASQB, BA, FF, QA(D)]
Rosa blanda Aiton (meadow rose) [PO]
!*Rosa multiflora* Thunb. ex Murray (multiflora rose) [AS, ASQB, FF, G, PO, QA(D), RUD]
Rubus allegheniensis Porter ex Bailey (blackberry) [RUD]
Rubus idaeus L. var. *strigosus* (Michx.) Maxim. (wild red raspberry) [ATS]
Rubus occidentalis L. (black raspberry) [AS, ASQB, ATS, FF, RUD]

Appendix A. Continued.

Rubus pubescens Raf. (dwarf raspberry) [ATS]
Rubus rosa Bailey [RIP]
RUBIACEAE
Galium aparine L. (cleavers) [AS, ASQB, ATS, FF, RUD]
Galium boreale L. (northern bedstraw) [AS, ASQB, ATS, BA, G, QA(D), PO]
Galium circaezans Michx. (wild licorice) [ASQB]
Galium concinnum T. & G. (shining bedstraw) [AS, ASQB, ATS, AS, FF, QA(D)]
Galium triflorum Michx. (sweet-scented bedstraw) [AS, ASQB, ATS, BA, FF, RIP]
RUTACEAE
Zanthoxylum americanum P. Miller (prickly ash) [[AS, ASQB, BA, FF, QA(D)]
SALICACEAE
Populus deltoides Bartram ex Marsh. (cottonwood) [FF] [6]
Populus grandidentata Michx. (big-toothed aspen) [QA(D)] [6]
Populus tremuloides Michx. (quaking aspen) [PO]
Salix amygdaloides Andersson (peach-leaved willow) [FF, RIP]
Salix bebbiana Sarg. (beaked willow) [1]
Salix exigua Nutt. ssp. *interior* (Rowlee) Cronq. [RIP]
Salix nigra Marsh. (black willow) [FF]
Salix rigida Muhl. [RIP]
SANTALACEAE
Comandra umbellata (L.) Nutt. (bastard toadflax) [PO]
SAXIFRAGACEAE
Chrysosplenium iowense Rydb. (golden saxifrage) [ATS]
Heuchera richardsonii R. Br. (alumroot) [ASQB, G, PO, PS, VCF]
Mitella diphylla L. (bishop's cap) [AS, ASQB, ATS, BA, FF]
Penthorum sedoides L. (ditch stonecrop) [RIP]
Ribes cynosbati L. (prickly gooseberry) [AS, ASQB, VCF]
Ribes hudsonianum Richardson (northern currant) [ATS]
Ribes missouriense Nutt. ex T. & G. (wild gooseberry) [ASQB, FF, QA(D)]
Saxifraga forbesii Vasey (Forbes' saxifrage) [ATS]
Sullivantia sullivantii (T. & G.) Britton [ATS]
SCROPHULARIACEAE
Aureolaria grandiflora (Bentham) Pennell (yellow false foxglove) [G]
Mimulus ringens L. (monkey flower) [RIP] [6]
Pedicularis canadensis L. (lousewort) [ASQB, G, PO, QA(D)]
Scrophularia lanceolata Pursh (figwort)[ASQB, FF]
Scrophularia marilandica L. (figwort) [FF, RIP, RUD]
!*Verbascum thapsus* L. (common mullein) [RIP, RUD]
!*Veronica arvensis* L. (corn speedwell) [RUD]
Veronica peregrina L. [RIP]
!*Veronica serpyllifolia* L. [RIP]
Veronicastrum virginicum (L.) Farw. [ASQB, FF, PO]
SOLANACEAE
!*Lycium halimifolium* P. Miller (matrimony vine) [RUD]
Physalis heterophylla Nees [RUD]
Solanum americanum P. Miller (black nightshade) [RUD]
!*Solanum dulcamara* L. (European bittersweet) [FF, RIP]
STAPHYLEACEAE
Staphylea trifolia L. (bladdernut) [AS, ASQB, FF]
THYMELAEACEAE
Dirca palustris L. (leatherwood) [AS, ASQB, BA]
TILIACEAE
Tilia americana L. (basswood) [AS, FF, QA(D)]
ULMACEAE
Celtis occidentalis L. (hackberry) [FF] [6]
Ulmus americana L. (American elm) [FF]
Ulmus rubra Muhl. (red elm) [ASQB, FF]
Ulmus thomasii Sarg. (rock elm) [1]
URTICACEAE
Laportea canadensis (L.) Wedd. [AS, ASQB, ATS, FF, RIP]
Parietaria pensylvanica Muhl. ex Willd. (pellitory) [AS, ASQB]

Appendix A. Continued.

Pilea pumila (L.) Gray (clearweed) [AS, ASQB, FF, G, RIP, VCF]
Urtica dioica L. (stinging nettle) [ATS, BA, FF, RUD, VCF]
VERBENACEAE
Verbena bracteata Lag. & Rodr. (creeping vervain) [1]
Verbena hastata L. (blue vervain) [RIP]
Verbena urticifolia L. (white vervain) [RIP]
VIOLACEAE
Hybanthus concolor (T. F. Forster) Sprengel (green violet) [AS]
Viola nephrophylla Greene (bog violet) [FF]
Viola sororia Willd. (hairy blue violet) [AS, ASQB, ATS, FF, QA(D), RUD]
Viola pubescens Aiton (downy yellow violet) [AS, ASQB]
VITACEAE
Parthenocissus quinquefolia (L.) Planchon (Virginia creeper) [ASQB, FF]
Parthenocissus vitacea (Knerr) A. S. Hitchc. (woodbine) [ASQB, BA, QA(D), RIP, RUD]
Vitis vulpina L. (frost grape) [VCF]
Vitis riparia Michx. (riverbank grape) [ASQB, FF, QA(D), RIP, RUD]

(MONOCOTYLEDONS)

ARACEAE
Arisaema dracontium (L.) Schott (green dragon) [1]
Arisaema triphyllum (L.) Schott (jack-in-the-pulpit) [AS, ASQB, ATS, BA, FF, QA(D)]
CYPERACEAE
Carex albursina Sheldon (blunt-scaled wood sedge) [AS, ASQB, FF]
Carex blanda Dewey (common wood sedge) [AS, ASQB, RIP, RUD, VCF]
Carex careyana Dewey (Carey's wood sedge) [1]
Carex cephalophora Willd. (short-headed bracted sedge) [ASQB, QA(D)]
Carex communis Bailey (common beach sedge) [AS, BA]
Carex conjuncta Boott (soft fox sedge) [ATS, RIP]
Carex deweyana Schwein. (Dewey's hummock sedge) [ATS]
Carex eburnea Boott (ivory sedge) [AS, PO]
Carex grisea Wahl. (gray wood sedge) [ASQB, FF, RIP, RUD]
Carex hirtifolia Mack. (hairy wood sedge) [AS, ASQB, FF, QA(D)]
Carex hitchcockiana Dewey (hairy gray sedge) [AS, ASQB]
Carex jamesii Schwein. (grass sedge) [AS, ASQB]
Carex laxiculmis Schw. var. *copulata* (L.H. Bailey) Fern. (weak-stemmed wood sedge) [AS, ASQB]
Carex normalis Mack. (spreading oval sedge) [ASQB]
Carex oligocarpa Willd. (sparse-fruited sedge) [ASQB]
Carex peckii Howe (Peck's sedge)[ATS]
Carex pedunculata Muhl. ex Willd. (long-stalked hummock sedge) [AS, ASQB]
Carex pensylvanica Lam. (common oak sedge) [AS, ASQB, QA(D)]
Carex radiata (Wahl.) Small (straight-styled wood sedge) [AS]
Carex rosea Schk. ex Willd. (curly-styled wood sedge) [AS, ASQB, QA(D)]
Carex sparganioides Muhl. ex Willd. (loose-headed bracted sedge) [AS, ASQB]
Carex sprengelii Dewey ex Sprengel (long-beaked sedge) [AS]
Carex stipata Muhl. ex Willd. (common fox sedge) [AS, FF, RIP]
Carex vulpinoidea Michx. (brown fox sedge) [RIP]
Carex woodii Dewey (Wood's stiff sedge)[AS]
Cyperus squarrosus L. (awned flat sedge) [RIP]
Eleocharis R. Br. sp. (spikerush) [RIP] [6]
Scirpus atrovirens Willd. (dark green bulrush) [RIP, RUD]
DIOSCOREACEAE
Dioscorea villosa L. (wild yam) [AS, ASQB, FF]
IRIDACEAE
Sisyrinchium campestre Bickn. (blue-eyed grass) [PO]
JUNCACEAE
Juncus tenuis Willd. (path rush) [PO, RIP, RUD]
Luzula acuminata Raf. (wood rush) [BA]
Luzula multiflora (Retz.) Lej. (wood rush) [1]
LEMNACEAE
Lemna minor L. (duckweed) [AQ] [6]

Appendix A. Continued.

LILIACEAE
Allium cernuum Roth (nodding wild onion) [AS]
Allium tricoccum Aiton (wild leek) [AS, ASQB, ATS, FF, QA(D)]
Erythronium albidum Nutt. (white trout-lily) [AS, ASQB, FF, RUD]
!*Hemerocallus fulva* (L.) L. (day lily) [RIP, RUD]
Hypoxis hirsuta (L.) Cov. (yellow stargrass) [G, PO]
Maianthemum canadense Desf. (Canada mayflower) [AS, ASQB, ATS, BA]
!*Ornithogalum umbellatum* L. (Star of Bethlehem) [RIP]
Polygonatum biflorum (Walter) Ell. (Solomon's seal) [AS, ASQB, PO]
Smilacina racemosa (L.) Desf. (false Solomon's seal) [AS, ASQB, ATS, BA, QA(D), VCF]
Smilax ecirrhata (Engelm. ex Kunth) S. Watson (carrion flower) [AS, ASQB, BA]
Smilax herbacea L. (carrion flower) [AS, ASQB]
Smilax hispida Muhl. (greenbriar) [AS, ASQB]
Streptopus roseus Michx. (rosy twisted stalk) [AS, ATS]
Trillium nivale Riddell (snow trillium) [1]
Trillium flexipes Raf. (nodding trillium) [AS, ASQB, ATS, BA, FF]
Uvularia grandiflora Small (bellwort) [AS, ASQB, BA, QA(D)]
ORCHIDACEAE
Aplectrum hyemale (Muhl. ex Willd.) Torrey (putty-root) [1]
Coeloglossum viride (L.) Hartman var. *virescens* (Muhl. ex Willd.) Luer (bracted orchid) [ASQB]
Corallorhiza odontorhiza (Willd.) Nutt. (fall coral-root orchid) [QA(D)]
Cypripedium calceolus L. var. *pubescens* (Willd.) Correll (yellow lady's slipper orchid) [AS, ASQB, ATS, BA]
Galearis spectabilis (L.) Raf. [AS, ASQB] [6]
Goodyera pubescens R. Br. (rattlesnake plantain) [1]
POACEAE
!*Agrostis gigantea* Roth (tedtop) [RIP, RUD]
Andropogon gerardii Vitman (big bluestem) [PO]
Brachyeleytrum erectum (Schreber) Beauv. [AS, ASQB]
!*Bromus inermis* Leysser (smooth brome) [RIP]
Bromus latiglumis (Shear) A. S. Hitchc. [RUD]
Bromus pubescens Muhl. ex Willd. (Canada brome) [AS, ASQB, QA(D)]
Cinna arundinacea L. (common wood reed) [ASQB, RUD]
Cinna latifolia (Trevir.) Griseb. (drooping wood reed) [AS]
!*Dactylis glomerata* L. (orchard grass) [RIP, RUD]
Danthonia spicata (L.) Beauv. ex R. & S. (poverty oat grass) [G, PO]
Dichanthelium acuminatum (Sw.) Gould & Clark var. *implicatum* (Scribner) Gould & Clark [G]
Dichanthelium latifolium (L.) Gould & Clark (broad-leaved panic grass) [ASQB, G]
Dichanthelium perlongum (Nash) Freckm. [G]
!*Digitaria ischaemum* (Schreber ex Schweigger) Schreber ex Muhl. (smooth crabgrass) [RUD]
!*Echinochloa crus-galli* (L.) Beauv. (barnyard grass) [FF]
Elymus canadensis L. (Canada wild rye) [PO] [6]
Elymus hystrix L. (bottlebrush grass) [AS, ASQB]
!*Elymus repens* (L.) Gould (quack grass) [RUD]
Elymus riparius Wieg. (streambank wild rye) [FF, RUD]
Elymus villosus Muhl. ex Willd. (slender wild rye) [ASQB, FF, RUD]
Eragrostis pectinacea (Michx.) Nees [RUD]
Festuca subvertillata (Pers.) Alexeev (nodding fescue) [AS, ASQB, QA(D)]
Glyceria striata (Lam.) A. S. Hitchc. (fowl manna grass) [AS, FF, RIP]
Hesperostipa spartea (Trinius) Barkworth (porcupine grass) [PO]
Leersia virginica Willd. (whitegrass) [AS, ASQB, FF, RIP, RUD] [6]
!*Lolium perenne* L. (English ryegrass) [RUD]
Muhlenbergia frondosa (Poiret) Fern. (wirestem muhly) [QA(D), PO, RUD]
Muhlenbergia racemosa (Michx.) BSP. (marsh muhly) [PO]
Muhlenbergia schreberi J. F. Gmelin (nimblewill) [ASQB, RUD]
Muhlenbergia sobolifera (Muhl. ex Willd.) Trin. (rock muhly) [ASQB]
Muhlenbergia sylvatica (Torrey) Torrey ex Gray (forest muhly) [4]
Muhlenbergia tenuiflora (Willd.) BSP. [AS, ASQB]
Oryzopsis asperifolia Michx. (rough-leaved rice-grass) [1]
Panicum capillare L. (witchgrass) [RUD]
Panicum dichotomiflorum Michx. (knee grass) [RUD]
Phalaris arundinacea L. (reed canary grass) [FF, RIP]

Appendix A. Continued.

!*Phleum pratense* L. (timothy) [RIP, RUD]
Piptatherum racemosum Ricker ex A.S. Hitchc.(black-seeded rice-grass) [AS, ASQB, QA(D)]
!*Poa annua* L. (annual bluegrass) [FF, RIP]
!*Poa compressa* L. (Canadian bluegrass) [PO]
!*Poa pratensis* (Kentucky bluegrass) [ASQB, PO, RIP, RUD]
Poa sylvestris Gray (woodland bluegrass) [ASQB]
!*Poa trivialis* L. (meadow grass) [AQ]
Poa wolfii Scribner (meadow bluegrass) [ASQB]
!*Schedonorus phoenix* (Schreber) Roemer & Schultes (alta fescue) [RUD]
Schizachne purpurascens (Torrey) Swallen (false medic) [AS, ATS]
!*Setaria faberi* Herrm. (giant foxtail) [RIP]
!*Setaria pumila* (Poir.) Roem. & Schult. (yellow foxtail) [RUD]
!*Setaria viridis* (L.) Beav. (green foxtail) [RUD]
Sphenopholis intermedia (Rydb.) Rydb. (slender wedgegrass) [ASQB, ATS, G]
Sporobolus vaginiflorus (Torrey ex Gray) Wood (poverty grass) [PO]

[1]Plants reported by D. M. Roosa in the "Resource Inventory and Management Plan for Bixby State Preserve" (IDNR, 1990); unverified by authors.
[2]Reported by J.H. Peck et al. (Jour. Iowa Acad. Sci. 1997 104:77–81); unverified by authors.
[3]Reported by J. C. Nekola (Jour. Iowa Acad. Sci. 1990 97:37–45); unverified by authors.
[4]ISC record (1963); unobserved by authors.
[5]ISC record (pre-1945); unobserved by authors.
[6]Observed by authors; no specimen collected.

Appendix B. List of fungi known to occur at Bixby State Preserve, compiled by Rosanne Healy and Lois Tiffany. All taxa represented by at least one specimen collected at Bixby since 1923 and deposited in the Ada Hayden Herbarium (ISC) at Iowa State University. Habitat information given in brackets (when available). + = taxon known from only 2–4 records in Iowa; * = taxon known only from Bixby in Iowa.

ASCOMYCOTA

Subclass Discomycetes - Inoperculate

Order Helotiales

Bisporella citrina (Batsch: Fr.) Korf & Carpenter [on down wood]
Chlorosplenium aeruginascens (Nylander) Karsten [on down wood]
**Helotium naviculisporium* Ellis
Hymenoscyphus fructigenus (Bull.: Merat) S.F. Gray [on acorn cap]
Leotia lubrica Persoon [on soil]
Rutstroemia firma (Pers.) Karst. [on overwintered petioles]
Rutstroemia macrospora (Pk.) Kanouse [on overwintered petioles]

Subclass Discomycetes - Operculate

Cyathipodia villosa (Hedwig ex O. Kuntze) Boudier [on soil]
Gyromitra brunnea Underw. [on soil]
Helvella crispa Scop.: Fr. [on soil]
Humaria hemisphaerica (Wiggers ex Fries) Fuckel [on soil]
Morchella deliciosa Fr.: Fr. [on soil]
Morchella esculenta Fr. [on soil]
Peziza succosa Berk. [on soil]
Peziza L. sp.
Sarcoscypha dudleyi (Peck) Baral [on down branch]
Sarcoscypha occidentalis (Schwein.) Sacc. [on down branch]
Scutellinia scutellata (L.: St. Amans) Lamb. [on down wood, damp soil]
Urnula craterium (Schwein.: Fr.) Fr. [on decaying oak branches]

Subclass Loculoascomycetes

Order Pleosporales

Apiosporina morbosa (Schwein.:Fr.) Arx [*Prunus virginiana* L.]

Subclass Pyrenomycetes

Order Xylariales

Camarops petersii (Berk. & Curt.) Nannfeldt [on down wood]
Daldinia concentrica (Bolton: Fr.) Cesati & de Not. [on down wood]
Diatrype stigma (Hoff.) de Not.
Hypoxylon sp. [on fallen branches of white birch; on wood]
Xylaria hypoxylon (L.) Grev. [on down wood]
Xylaria polymorpha (Persoon: Merat) Greville [on down wood]
Xylaria sp.

BASIDIOMYCOTA

Order Agaricales

(mushrooms)

Agaricus placomyces Peck [on ground]
Armillaria mellea (Vahl.: Fr.) Karst. group [on wood]
Crepidotus sp. [on down wood]
+*Hohenbuehelia angustatua* (Berkeley) Singer [on wood]
Hygrophorus puniceus (Fr.) Fr. [on ground]
Hypsizygus ulmarius (Bull.) Redhead [on wood]
Inocybe fastigiata (Schaeff.) Quel. [on soil]
Laccaria laccata (Fr.) Berk. & Br. [on soil]
Lactarius subvellarius Pk. [on soil]
Marasmiellus nigripes (Schweintz) Singer [on down twigs]
Marasmius rotula (Scopoli:Fries) Fries [on soil at base of tree]
Marasmius siccus (Schw.) Fr. [on leaf, twig litter]
Mycena hematopus (Pers.: Fr.) Kummer [on down wood]
Mycena leaiana (Berk.) Sacc. [on down wood]
Pleurotus ostreatus (Jacq.: Fr.) Kummer [on down wood]
Pluteus cervinus (Schaeffer:Fries) Kummer [on down wood]

Appendix B. Continued.

Xerula megalospora (Clements) Redhead, Ginns & Shoemaker [on soil, rooting]

(boletes)

Tylopilus felleus (Bull.:Fr.) Karst. [on soil]

Order Aphyllophorales

(cantharelloid)

Cantharellus cibarius Fr.: Fr. [ground]
Craterellus cornucopoides (L.: Fr.) Pers. [ground]

(clavarioid)

Clavaria sp. [ground]

(merulioid)

Phlebia tremellosus (Schrad:Fr.) Nak. & Burds. [on down wood]
+*Phlebia radiata* Fr. [on cherry birch]

(poroid)

Ganoderma applanatum (Pers.:S.F. Gray) Pat. [wood]
Irpex sp. [on wood]
Ischnoderma resinosum (Schrad.: Fr.) Karst. [on down wood]
Laetiporus sulphureus (Bull.: Fr.) Murr. [on wood]
Phellinus gilvus (Schw.) Pat. [on wood]
Polyporus alveolaris (DC.: Fr.) Bord. & Sing. [on down wood]
Polyporus badius (Pers.: SF Gray) Schw. [on down wood]
Polyporus elegans Bull.: Fr. [on down wood]
Polyporus squamosus Huds.: Fr. [on down wood]
Trichaptum biforme (Fr.:Kl.) Ryv. [on wood]

(schizophylloid)

Schizophyllum commune Fr. [on wood]

(thelephoroid)

Cyphellopsis anomala (Pers.) Fckl. [on Betula alba log]
Stereum gausapatum Fries [on wood]
Stereum hirsutum Willd.:Fr. complex [on wood]
Stereum sanguinolentum (Alb. & Schwein.:Fr.) Fr. [on wood]

Order Tremellales

(jelly fungi)

Tremella mesenterica Fries [on down wood]
Tremellodendron schweinitzii (Pk.) Atkinson [on soil]

Order Uredinales

Cerotelium dicentrae Mains & H.W. Anderson in Mains [*Dicentra cucullaria* (L.) Bernh.]
Coleosporium asterum (Diet.) Syd. [Solidago sp.]
Cronartium ribicola J.C. Fischer:Rabenh. [*Ribes hudsonianum* Rich.]
Gymnconia nitens (Schw.) Kern & Thurston [*Rubus occidentalis* L.]
Melampsora medusae Thuem. [*Populus deltoides* J. Burtram:Marsh.]
Puccinia coronata Corda
Puccinia cyperi Arth. [Erigeron annuus (L.) Pers.]
Puccinia dioicae P. Magn. [*Aster sagittifolius*; *Solidago ulmifolia*]
Puccinia grindeliae Pk. [*Aster* sp.]
Puccinia pimpinellae (Strauss) Mart. [*Osmorhiza longistylus* (Torr.) DC.]
Puccinia plumbaria Peck [Phlox divaricata L.]
Puccinia podophylli Schwein. [Podophyllum peltatum L.]
Puccinia polygoni-amphibii Pers.:Pers. [*Geranium maculatum* L.]
Puccinia recondita Rob. ex Desm. [*Impatiens capensis* Merb.; *Hydrophyllum virginianum* L.; *Ranunculus septontrionalis* Poir; *R. sceleratus* L.]
Puccinia violae (Schrum.) Berk. in Sm. [Viola L. sp.]
Uromyces ari-triphylli (Schwein.) Seeler [*Arisaema triphyllum* (L.) Torr.]

DEUTEROMYCOTA

Order Melanconiales

Colletotrichum dematium (Pers.) Grove [on *Smilaceina racemosa* (L.) Desf.]

Order Moniliales

Cercospora heucherae Ell. & G. Martin [on *Heuchera richardsonii* R. Br.]

Appendix B. Continued.

Order Sphaeropsidales
+*Septoria viridi-tingens* M.A. Curtis in Peck [on *Allium tricoccum* Aiton]

LICHENS
* *Anaptychia hypoleuca* (Muhl.) Mass. [on wood]
+*Anaptychia palmatula* (Michx.) Vain [old *Ulmus* L. bark]
Collema bachmanianum (Fink) Degel. [on soil]
Collema subflaccidum Degel. [moss on old wood]
Heterodermia speciosa (Wulf.) Trevis. [on old bark; on *Ulmus* L., on *Betula alleghaniensis* Britton bark]
Leptogium lichenoides (L.) Zahlbr. [over moss on boulder in stream]
Parmelia aurulenta Tuck. [on old wood; on trees]
Parmelia borreri (Sm.) Turn. [on *Ulmus* L. bark; on *Betula alleghaniensis* Britton bark]
Parmelia margaritata Hue [on trunk of *Ulmus* L.]
+*Parmelia saxatilis* (L.) Ach. [on *Betula alleghaniensis* Britton]
Parmelia subrudecta Nyl. [*Ulmus* L.]
Parmelia subtinctoria Zahlbr. [on trunk of *Ulmus* L.; at base of *Ulmus* L.]
Parmelia sulcata Tayl. [on dead branches in outdraft of ice cave]
Peltigera evansiana Gyel. [on dead *Betula alleghaniensis* Britton bark]
**Peltigera rufescens* (Weiss) Hymb. [on sunny rock in stream, over moss]
Phaeophyscia imbricata (Vain.) Essl. [on trunk of tree in parking lot]
+*Phaeophyscia orbicularis* (Neck.) Moberg. [on old Betula alleghaniensis Britton bark]
+*Physcia adscendens* (Th. Fr.) Oliv. [on low shrubs and rock tops]
Physcia aipolia (Ehrh.) Hampe [on Carpinus caroliniana Walter]
Physcia stellaris (L.) Nyl. [on *Carpinus caroliniana* Walter]
Physconia detersa (Nyl.) Poelt [old *Betula alleghaniensis* Britton bark]
Pyxine sorediata (Ach.) Mont. [on *Populus deltoides* Marsh.; on trunk of *Ulmus* L.]
+*Ramalina fastigiata* (Pers.) Ach. [at base of *Ulmus* L.]

MYXOMYCOTA

Order Liceales
Reticularia splendens Morgan [on log of *Tilia americana* L.]

Order Physarales
Diderma globosum Persoon [conifer needles]
Didymium sp.
Fuligo septica (L.) Wiggers
Physarum melleum (Berk. & Br.) Mass.

Order Trichiales
Hemitrichia stipitata (Mass.) MacBr.
Metatrichia vesparium (Batsch) Nann-Brem.

OOMYCOTA

Order Peronosporales
Peronospora parasitica (Pers.:Fr.) Fr. [on *Dentaria laciniata* Muhl.]
+*Peronospora phlogina* D & H [on *Phlox divericata* L.]

Appendix C. Bird species detected at Bixby State Preserve between late May and mid-July, 1995 and 1996. The point count method (Ralph et al. 1993) was used to census birds. Waterfowl, raptors and nightjars were not recorded during this study, and hence are not included in this list. Nomenclature follows American Ornithologists' Union 1998 Checklist of North American Birds, 7th edition. Cowbird host: Susceptibility to cowbird parasitism (Best et al. 1996). Area Sensitivity: tendency for abundance, frequency of occurrence and/or nest success to be greater with either increasing (positive area sensitivity) or decreasing (negative area sensitivity) patch size (Best et al. 1996). PIF Prioritization: Index developed by Fish and Wildlife Service that ranges from 5 (high management concern) to 1 (low management concern); scores for each species are based on means of seven criterion values (Thompson et al. 1993).

Order	Family	Common Name	Scientific Name	Cowbird Host[1]	Area Sensitivity[2]	PIF Prioritization[3]
Cuculiformes	Cuculidae	Yellow-billed cuckoo	*Coccyzus americanus* L.	Ra	+	3.29
Trochliiformes	Trochliidae	Ruby-throated hummingbird	*Archilochus colubris* L.	N	(+)	2.57
Coraciiformes	Alcedinidae	Belted kingfisher	*Ceryle alcyon* L.	N	+	—
Piciformes	Picidae	Hairy woodpecker	*Picoides villosus* L.	N	+	—
Piciformes	Picidae	Downy woodpecker	*Picoides pubescens* L.	N	+	—
Piciformes	Picidae	Red-bellied Woodpecker	*Melanerpes carolinus* L.	N	+	—
Piciformes	Picidae	Pileated woodpecker	*Drycopus pileatus* L.	N	+	—
Passeriformes	Tyrannidae	Acadian flycatcher	*Empidonax virescens* Vieillot	U	++	3.43
Passeriformes	Tyrannidae	Eastern wood-pewee	*Contopus virens* L.	U	+	3.29
Passeriformes	Tyrannidae	Great crested flycatcher	*Myarchus crinitus* L.	U	+	3.29
Passeriformes	Vireonidae	Yellow-throated Vireo	*Vireo flavifrons* Vieillot	F	+	3.00
Passeriformes	Vireonidae	Warbling vireo	*Vireo gilvus* Vieillot	F	+	2.57
Passeriformes	Vireonidae	Red-eyed Vireo	*Vireo olivaceus* L.	Re	+	2.14
Passeriformes	Corvidae	Blue jay	*Cyanocitta cristata* L.	Ra	(+)	—
Passeriformes	Corvidae	American crow	*Corvus brachrhynchos* Brehm.	Ra	(+)	—
Passeriformes	Paridae	Eastern titmouse	*Baeolophus bicolor* L.	Ra	+	—
Passeriformes	Sittidae	White-breasted nuthatch	*Sitta caroliniensis* Latham.	Ra	+	—
Passeriformes	Troglodytidae	House wren	*Troglodytes aedon* Vieillot	Ra	(?)	1.57
Passeriformes	Sylviidae	Blue-gray gnatcatcher	*Polioptila caerulea* L.	F	++	2.43
Passeriformes	Turdidae	Veery	*Catharus fuscescens* Stephens	F	++	3.29
Passeriformes	Turdidae	Wood thrush	*Hylocichla mustelina* Gmelin	Re	++	3.57
Passeriformes	Turdidae	American robin	*Turdus migratorius* L.	U	(-)	—
Passeriformes	Mimidae	Gray catbird	*Dumetella caroliniensis* L.	U	(-)	2.86
Passeriformes	Parulidae	Yellow warbler	*Dendroica petechia* L.	Re	(+)	1.57
Passeriformes	Parulidae	Cerulean warbler	*Dendroica cerulea* Wilson	U	++	4.29
Passeriformes	Parulidae	American redstart	*Setophaga ruticilla* L.	F	+	2.86
Passeriformes	Parulidae	Ovenbird	*Seiurus aurocapillus* L.	Re	++	3.14
Passeriformes	Parulidae	Louisiana waterthrush	*Seiurus motacilla* Vieillot	F	++	3.00
Passeriformes	Parulidae	Common yellowthroat	*Geothlypis trichas* L.	Re	(?)	2.29
Passeriformes	Thraupidae	Scarlet tanager	*Piranga olivacea* Gmelin	Re	++	3.00
Passeriformes	Emberizidae	Eastern towhee	*Pipilo erythrophthalmus* L.	Re	-	—
Passeriformes	Emberizidae	Chipping sparrow	*Spizella passerina* Bechstein	Re	(-)	1.86
Passeriformes	Emberizidae	Song sparrow	*Melospiza melodia* Wilson	Re	(?)	—
Passeriformes	Cardinalidae	Northern cardinal	*Cardinalis cardinalis* L.	Re	(-)	—
Passeriformes	Cardinalidae	Rose-breasted grosbeak	*Pheucticus leudovicianus* L.	F	+	3.14
Passeriformes	Cardinalidae	Indigo bunting	*Passerina cyanea* L.	Re	(-)	2.86
Passeriformes	Icteridae	Common grackle	*Quiscalus quiscula* L.	Ra	0	—
Passeriformes	Icteridae	Brown-headed cowbird	*Molothrus ater* Boddaert	—	(+)	—
Passeriformes	Icteridae	Northern oriole	*Icterus galbula* L.	U	(+)	2.86
Passeriformes	Fringillidae	American goldfinch	*Carduelis tristis* L.	U	(?)	—

[1]Cowbird host: N = no, Ra = rare, U = uncommon, F = frequent, and Re = regular

[2]Area sensitivity: ++ = consistently positive area sensitivity; + = primarily positive area sensitivity but some studies detected none; (+) = primarily no area sensitivity but some studies detected positive area sensitivity; — = consistently negative area sensitivity; (-) = primarily no area sensitivity but some studies detected negative area sensitivity; 0 = consistently no area sensitivity; (?) = area sensitivity unknown because of contradictory results in different studies; and ? = area sensitivity unknown because it has not been studied.

Appendix D. Amphibians, reptiles, and mammals documented to occur at Bixby State Preserve (VanDeWalle 1997).

Common Name	Scientific Name	Abundance	Habitat
A) Amphibians			
Family Hylidae			
Spring Peeper	*Pseudacris crucifer* Wied-Neuwied	Abundant	Stream
Chorus Frog	*Pseudacris triseriata* Wied-Neuwied	Abundant	Stream
Gray Treefrog	*Hyla versicolor* LeConte	Abundant	Deciduous Forest
Family Ranidae			
Green Frog	*Rana clamitans* Latreille	Abundant	Stream
Northern Leopard Frog	*Rana pipiens* Schreber	Common	Stream
Pickerel Frog	*Rana palustris* LeConte	Common	Stream
Family Bufonidae			
American Toad	*Bufo americanus* Holbrook	Abundant	Deciduous Forest
B) Reptiles			
Family Emydidae			
Painted Turtle	*Chrysemys picta* Schneider	Rare	Stream
Family Colubridae			
Midland Brown Snake	*Storeria dekayi* Holbrook	Abundant	Streamside
Eastern Garter Snake	*Thamnophis sirtalis* L.	Common	Streamside
Red-Sided Garter Snake	*Thamnophis sirtalis* L. ssp. *parietalis*	Common	Streamside
C) Mammals			
Family Soricidae			
Short-Tailed Shrew	*Blarina brevicauda* Say	Common	Streamside
Family Talpidae			
Eastern Mole	*Scalopus aquaticus* L.	Common	Deciduous Forest
Family Vespertillidae			
Hoary Bat	*Lasiurus cinereus* Beauvios	Uncommon	Deciduous Forest
Family Muridae			
White-footed Mouse	*Peromyscus leucopus* Rafinesque	Abundant	Deciduous Forest; Streamside
Meadow Vole	*Microtus pennsylvanicus* Ord	Common	Streamside
Family Sciuridae			
Eastern Chipmunk	*Tamias striatus* L.	Common	Deciduous Forest
Fox Squirrel	*Sciurus niger* L.	Common	Deciduous Forest
Family Castoridae			
Beaver	*Castor canadensis* Kuhl	Common	Streamside
Family Procyonidae			
Raccoon	*Procyon lotor* L.	Common	Deciduous Forest; Streamside
Family Cervidae			
White-Tailed Deer	*Odocoileus virginianus* Zimmermann	Common	Deciduous Forest