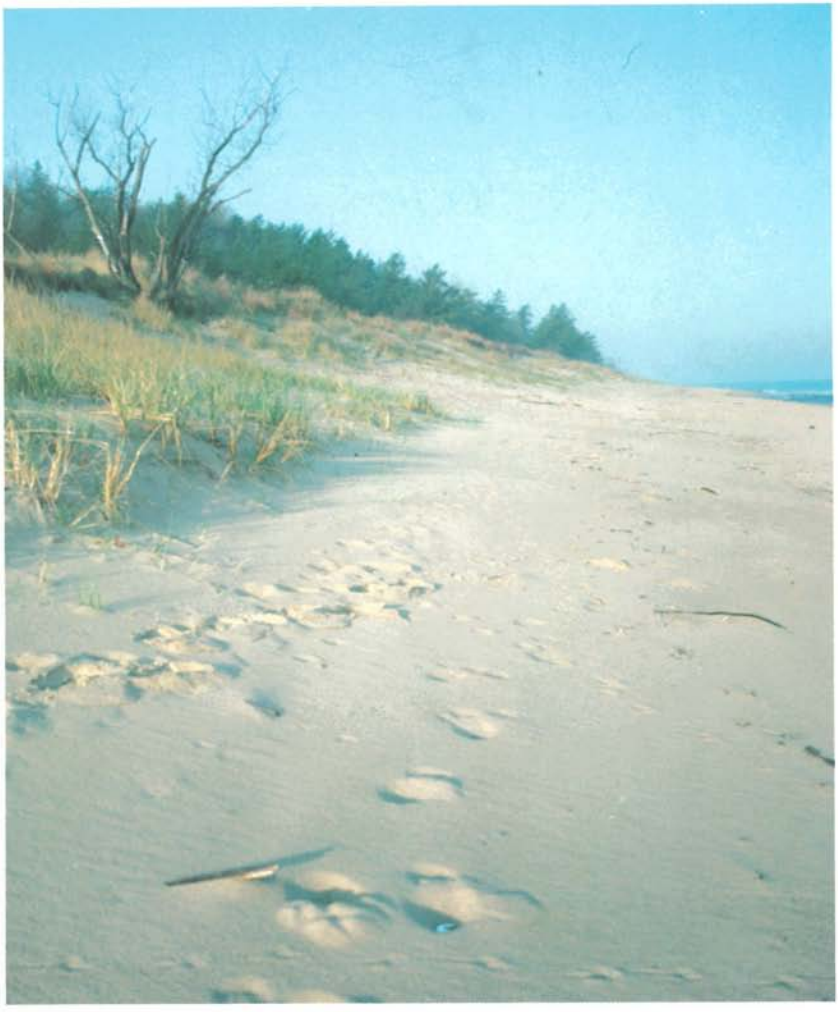
Mammals of Indiana Dunes National Lakeshore



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Contents

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Abstract. Thirty-seven species of mammals have been documented at the Indiana Dunes National Lakeshore—1 marsupial (Order Didelphimorphia): the Virginia opossum (*Didelphis virginiana*); 4 insectivores (Order Insectivora): the masked shrew (*Sorex cinereus*), the northern short-tailed shrew (*Blarina brevicauda*), the least shrew (*Cryptotis parva*), and the eastern mole (*Scalopus aquaticus*); 4 bats (Order Chiroptera): the little brown myotis (*Myotis lucifugus*), the eastern red bat (*Lasiurus borealis*), the silver-haired bat (*Lasionycteris noctivagans*), and the big brown bat (*Eptesicus fuscus*); 1 lagomorph (Order Lagomorpha): the eastern cottontail (*Sylvilagus floridanus*); 17 rodents (Order Rodentia): the eastern chipmunk (*Tamias striatus*), the woodchuck (*Marmota monax*), the thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*), the eastern gray squirrel (*Sciurus carolinensis*), the eastern fox squirrel (*S. niger*), the red squirrel (*Tamiasciurus hudsonicus*), the southern flying squirrel (*Glaucomys volans*), the American beaver (*Castor canadensis*), the white-footed mouse (*Peromyscus leucopus*), the prairie deer mouse (*Peromyscus maniculatus bairdii*), the Norway rat (*Rattus norvegicus*), the house mouse (*Mus musculus*), the prairie vole (*Microtus ochrogaster*), the meadow vole (*M. pennsylvanicus*), the woodland vole (*M. pinetorum*), the common muskrat (*Ondatra zibethicus*), and the meadow jumping mouse (*Zapus hudsonius*); 9 carnivores (Order Carnivora): the coyote (*Canis latrans*), the red fox (*Vulpes vulpes*), the common gray fox (*Urocyon cinereoargenteus*), the common raccoon (*Procyon lotor*), the long-tailed weasel (*Mustela frenata*), the least weasel (*M. nivalis*), the mink (*M. vison*), the American badger (*Taxidea taxus*), and the striped skunk (*Mephitis mephitis*);

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and 1 artiodactyl (Order Artiodactyla), the white-tailed deer (*Odocoileus virginianus*). Four additional species, the northern myotis (*Myotis septentrionalis*), the Indiana myotis (*M. sodalis*), the hoary bat (*Lasiurus cinereus*), and the southern bog lemming (*Synaptomys cooperi*) probably are present but have not been documented. Some of the most abundant mammals are the eastern cottontail, the eastern fox squirrel, the white-footed mouse, the white-tailed deer, and the meadow vole. Extirpated species are the common porcupine (*Erethizon dorsatum*), the gray wolf (*Canis lupus*), the red wolf (*C. rufus*), the black bear (*Ursus americanus*), the fisher (*Martes pennanti*), the northern river otter (*Lutra canadensis*), the mountain lion (*Felis concolor*), the lynx (*Lynx lynx*), the bobcat (*L. rufus*), the elk (*Cervus elaphus*), and the bison (*Bos bison*). The only threatened or endangered species known to be present is the American badger (state threatened list), but the Indiana myotis (federal endangered list) is likely present.

Key words: Bats, carnivores, dunes, habitats, insectivores, mammals, rodents.

Classic studies on plant and animal succession were conducted in the Indiana Dunes region by Cowles (1899) and by Shelford (1912a, 1912b). The dunes continue to attract historic and scientific interest.

The Indiana Dunes National Lakeshore encompasses about 5,260 ha on the southern tip of Lake Michigan in northern Indiana (Fig. 1). The lakeshore extends east along the lake from Gary, Indiana, nearly to Michigan City, Indiana, and is near Chicago in one of the most populated regions of the United States. The lakeshore was established in 1966 to preserve the nationally significant cultural and natural features along Lake Michigan's shoreline. The flora and fauna of the lakeshore are distinct and diverse. The National Park Service is mandated to preserve or restore these resources. The vascular flora of the lakeshore has been intensively studied (Cowles 1899). The plant communities as used in this monograph were classified in 1990 by Eric Kjellmark and plotted on computer by National Park Service personnel.

The flora of the lakeshore includes nearly 1,400 vascular plant species (Wilhelm 1990; Pavlovic and Bowles 1994) in a variety of natural habitats including, but not restricted to, open sand of the beaches, the grassy foredunes, shrubland, savanna, various types of forest, and aquatic habitats including marsh, bog, aquatic shrubland, and swamp. A number of human-caused or human-influenced habitats such as farmland, rights-of-way, and pine plantations are also present.

Presettlement records of mammals of the dunes area are scant and exist mainly as diary entries of explorers such as Father Marquette and LaSalle and records of furs sold at various trading posts. Virginia opossum (*Didelphis virginiana*), American beaver (*Castor canadensis*), and bison (*Bos bison*) were reported for the area in the 1600's. Panther (*Felis concolor*, or possibly bobcat,

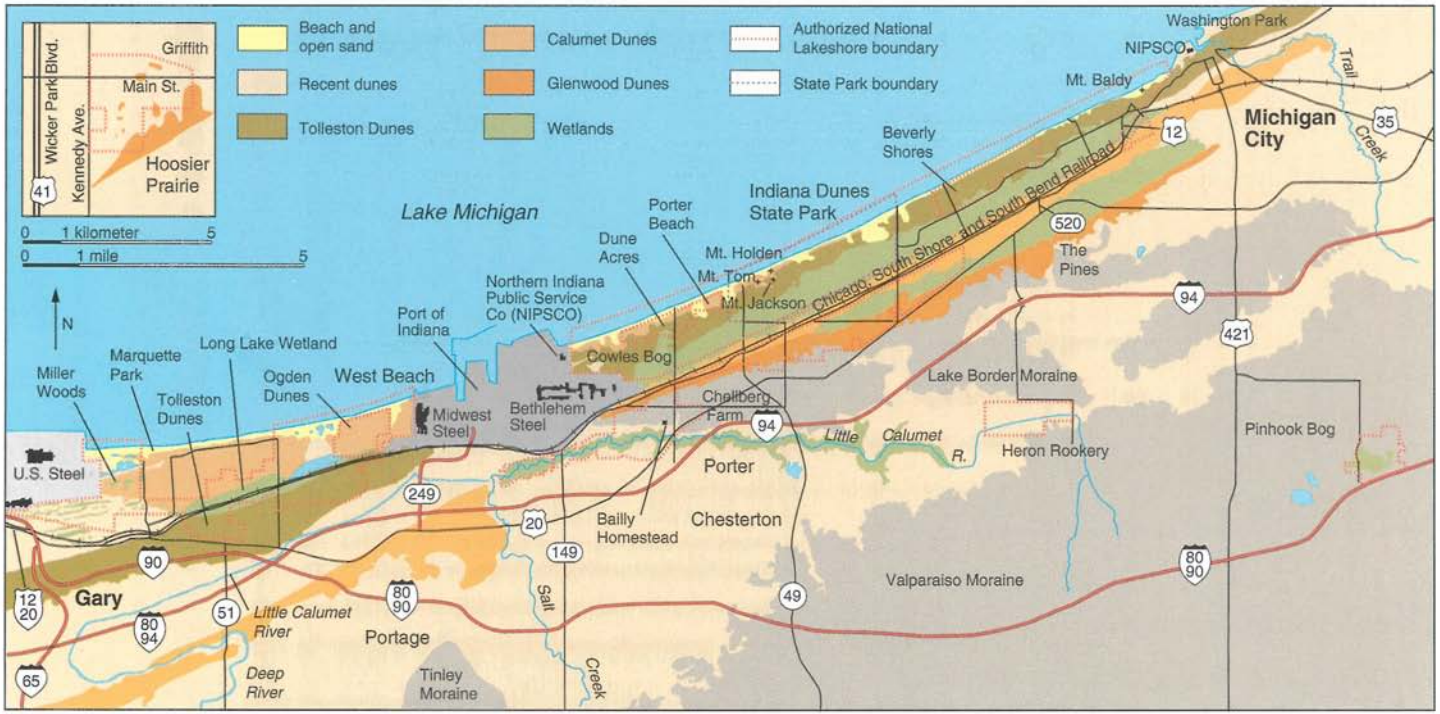

Fig. 1. The Indiana Dunes National Lakeshore.

Lynx rufus) was reported in the 1830's. White-tailed deer (*Odocoileus virginianus*) were plentiful until the 1870's but were probably extirpated from the state by 1900 (Mumford and Whitaker 1982). Reintroduction of deer began in the 1930's. An estimated 900 white-tailed deer existed in Indiana by 1943, 5,000 by 1951, and deer were probably in all counties of the state by 1966. They are presently abundant at the Indiana Dunes. Wolves (*Canis lupus*, or possibly coyotes, *Canis latrans*) were reported as late as 1914 (Lyon 1923). Black bears (*Ursus americanus*) were seen in the area until about 1870 (Brennan 1923). Brennan (1923) cited many records of wildlife including common gray and red foxes (*Urocyon cinereoargenteus* and *Vulpes vulpes*) and American badgers (*Taxidea taxus*).

The first significant publication on the mammals of the dunes was by Lyon (1923). Lyon recognized 22 species as present (Table 1). The only bat included was the eastern red bat (*Lasiurus borealis*). Lyon did not see any eastern moles (*Scalopus aquaticus*), muskrats (*Ondatra zibethicus*), Norway rats (*Rattus norvegicus*), common raccoons (*Procyon lotor*—a few were taken for fur each year), or long-tailed weasels (*Mustela frenata*), but he believed these records to be reliable. That he did not see raccoons probably indicates that they were uncommon at that time. Lyon reported that white-tailed deer had been extirpated for many years but had been fairly numerous about 1875. Lyon (1923) camped "north of the Mineral Spring Station of the Chicago, Lake Shore [*sic*] and South Bend Railway" and set traps in this area and westward to "opposite Oak Hill Station." He reported the white-footed mouse (*Peromyscus leucopus)* as the most abundant mammal at the lakeshore. The species was abundant in the most extensive habitat—the wooded dunes—and was the most common mammal in subdunal swamps and marshes. In the foredune area, Lyon reported the prairie deer mouse (*Peromyscus maniculatus bairdii*) and the house mouse (*Mus musculus*). From the area of the interdunal meadows and ponds, he reported the northern short-tailed shrew (*Blarina brevicauda*), the white-footed mouse, the prairie deer mouse, the prairie vole (*Microtus ochrogaster*), and the woodland vole (*M. pinetorum*). Lyon did not take the masked shrew (*Sorex cinereus*), the meadow vole (*M. pennsylvanicus*), or the meadow jumping mouse (*Zapus hudsonius*).

In addition to the 22 species listed as present, Lyon (1923) listed the following 9 species as almost certain to be found: the little brown myotis (*Myotis lucifugus*), the northern myotis (*M. septentrionalis* = *M. keenii* until recently; see Van Zyll de Jong 1979), the hoary bat (*Lasiurus cinereus*), the silver-haired bat (*Lasionycteris noctivagans*), the big brown bat (*Eptesicus fuscus*), the eastern gray squirrel (*Sciurus carolinensis*), the southern flying squirrel (*Glaucomys volans*), the meadow vole, and the meadow jumping mouse.

Lyon listed the following six species as probably occurring: the masked shrew, the least shrew (*Cryptotis parva*), the star-nosed mole (*Condylura*

Table 1. Records of mammals reported from the Indiana Dunes National Lakeshore.[a]

Mammal	Lyon 1923	Lyon 1936	Rand & Rand 1951	Texas Instruments[b] 1975–80	Krekeler[c] 1981
Virginia opossum (*Didelphis virginiana*)	x(2)[d,e]		x	6	u
Least shrew (*Cryptotis parva*)		x			r[f]
Masked shrew (*Sorex cinereus*)		x	x	2	u
Northern short-tailed shrew (*Blarina brevicauda*)	x(5)		x	5	c
Eastern mole (*Scalopus aquaticus*)	x		x	7	c
Little brown myotis (*Myotis lucifugus*)				1	c
Eastern red bat (*Lasiurus borealis*)	x(1)		x		c
Silver-haired bat (*Lasionycteris noctivagans*)		x	x		u[f]
Big brown bat (*Eptesicus fuscus*)			x		c[f]
Eastern cottontail (*Sylvilagus floridanus*)	x[e]		x	8	c
Eastern chipmunk (*Tamias striatus*)	x(1)[e]		x	4	a
Woodchuck (*Marmota monax*)	x[e]		x	5	a
Franklin's ground squirrel (*Spermophilus franklinii*)		x	x		u[f]
Thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*)	x[e]		x	2	c
Eastern gray squirrel (*Sciurus carolinensis*)		x?		3	c[e]
Eastern fox squirrel (*Sciurus niger*)	x[e]		x	4	c
Red squirrel (*Tamiasciurus hudsonicus*)	x(4+)[e]		x	4	c
Southern flying squirrel (*Glaucomys volans*)			x	3	c
American beaver (*Castor canadensis*)					u[e]
White-footed mouse (*Peromyscus leucopus*)	x[e]		x	5	a
Prairie deer mouse (*Peromyscus maniculatus bairdii*)	x(11)[e]		x		a

Table 1. *Continued.*

Mammal	Lyon 1923	Lyon 1936	Rand & Rand 1951	Texas Instruments[b] 1975–80	Krekeler[c] 1981
Norway rat (*Rattus norvegicus*)	x		x		c
House mouse (*Mus musculus*)	x(2)[e]		x	1	c
Prairie vole (*Microtus ochrogaster*)	x(7)[e]				u
Meadow vole (*Microtus pennsylvanicus*)		x	x		a
Woodland vole (*Microtus pinetorum*)	x(2)[e]			1	u
Common muskrat (*Ondatra zibethicus*)	x		x	3	c
Southern bog lemming (*Synaptomys cooperi*)			x		u[f]
Meadow jumping mouse (*Zapus hudsonius*)		x		2	u
Red fox (*Vulpes vulpes*)	x[e]			6	c
Common raccoon (*Procyon lotor*)	x		x	8	c
Long-tailed weasel (*Mustela frenata*)	x		x		u
Least weasel (*Mustela nivalis*)			x	2	u
Mink (*Mustela vison*)	x(1)[e]		x	1	u
American badger (*Taxidea taxus*)		x			p[f]
Striped skunk (*Mephitis mephitis*)	x(2)[e]		x	4	u[e]
White-tailed deer (*Odocoileus virginianus*)				8	c[e]

[a]Additional species likely to be at Indiana Dunes National Lakeshore: northern myotis (*Myotis septentrionalis*), hoary bat (*Lasiurus cinereus*), and coyote (*Canis latrans*). Most of these records were included in Lyon 1936 but may actually refer to other papers. The Franklin's ground squirrels were taken in 1947 and 1949, but the records have not been published (see text).
[b]Number of habitats (of a total of eight) in which a species was collected.
[c]a = abundant; c = common; u = uncommon; r = rare.
[d]Number of specimens reported by Lyon (when given).
[e]Species personally seen by Lyon (1923).
[f]No actual evidence of occurrence.

cristata), the southern bog lemming (*Synaptomys cooperi*), the coyote, and the American badger.

Lyon considered the following 11 species as not now extant (but whose remains may possibly be found), as extinct,or as probably extinct: the snowshoe hare (*Lepus americanus*), the common porcupine (*Erethizon dorsatum*), the timber wolf (*Canis lupus*), the black bear, the fisher (*Martes pennanti*), the northern river otter (*Lutra canadensis*), the mountain lion (*Felis concolor*), the lynx (*Lynx lynx*), the bobcat, the elk (*Cervus elaphus*), and the bison (*Bos bison*).

Brennan (1923) presented a chapter on mammals, although much of the information is not well documented. He relates early reports of American beaver, porcupine, coyote, black bear, northern river otter, mountain lion, lynx, bobcat, elk, moose (*Alces alces*), white-tailed deer, and American bison. The American beaver has not been seen in the area in years. A dog attacked and was injured by a porcupine in 1918 at Furnessville. Brennan cited many reports of timber wolves, and stated that some remained between Dune Park and Michigan City until 1919, but we suspect that many (if not all) of these were actually coyotes. The last black bear seen in the dunes region was in 1871, but it was probably forced there from Michigan when the entire east shore of Lake Michigan was on fire. The northern river otter has long been gone from the dunes area. The last lynx seen in the dunes was killed by Hunter Green in 1873 at Tremont. White-tailed deer were common in the dunes area through the 1860's, but the last one shot was in the early 1870's.

Brennan reported fourteen species as still present in 1923: the Virginia opossum, the eastern mole, the eastern cottontail (*Sylvilagus floridanus*), the woodchuck (*Marmota monax*), the eastern gray squirrel, the eastern fox squirrel (*Sciurus niger*), the red squirrel (*Tamiasciurus hudsonicus*), the muskrat, the red fox, the common gray fox, the raccoon, the mink (*Mustela vison*), the American badger, and the eastern skunk (*Mephitis mephitis nigra*). Burrows indicated the eastern mole was very common. Thousands of woodchucks were reported to be present, as well as thousands of muskrats in the marshes. Brennan saw an eastern gray squirrel and an American badger near the Furnessville Blowout in November 1918. He reported a red fox family was near the Furnessville Blowout, and that neighbors still held raccoon hunts (because they were so common).

Lyon (1936) reported additional mammalian species from Porter and Lake counties. These are not necessarily from the lakeshore, although Necker (1939) and Krekeler (1981) treated them as though they were. These species are discussed below and are listed under Lyon (1936) in Table 1.

Lyon considered the masked shrew rare in Indiana but reported the first specimens from the lakeshore from "the quaking bog at the south end of the tamarack swamp opposite Mineral Springs Station," which would be Cowles Bog, Porter County (Lyon 1924, 1936). Four specimens from Porter County taken by Lyon from subdunal meadows are in the U.S. National Museum (USNM) at Washington, D.C. (240631, 240632, 239782, 239783).

Lyon took a least shrew at Tremont on 31 October 1924 (Sanborn 1925). The specimen is USNM 240630 and is the only record of this species from the lakeshore. A specimen taken from Chesterton by Grant Stafford on 6 December 1942, however, is preserved in alcohol at the Field Museum of Natural History (FMNH 37422), Chicago, Illinois.

Three silver-haired bats from Indiana Dunes State Park are in the Field Museum of Natural History (33778 taken 24 September 1928 and 44339 and 44340 taken 3 May 1936).

Lyon (1936) reported Franklin's ground squirrels (*Spermophilus franklinii*) from both Lake and Porter counties, but none of the records apply to the lakeshore proper. The only records we found of this species at the lakeshore were three individuals collected by Alex Bognar at Miller, Porter County—two on 7 September 1947 (FMNH 73872, 73873) and one taken 15 May 1949 (FMNH 73874). Miller is just outside the present lakeshore boundary—we have included it as a recent lakeshore inhabitant. Scott Johnson of the Indiana Department of Natural Resources was unsuccessful in finding this species at that locality in 1986. We believe that Franklin's ground squirrel is not present today.

Lyon (1923) indicated the gray squirrel probably was at the lakeshore, and Brennan (1923) reported seeing one near the Furnessville Blowout in November 1918. The first documented record was that of Texas Instruments personnel (Ecological Services of Texas Instruments, Inc., six annual reports [1975–80; about subject in the Bailly Nuclear-1 Site] prepared for Northern Indiana Public Service Co., Hammond, Indiana).

On 13 April 1930, Lyon (1930) found a pile of seven dead meadow voles in Indiana Dunes State Park. The voles perhaps had been killed by a weasel. This seems to be the first definite record of this species at the lakeshore. Two are specimens in the Field Museum of Natural History (34231, 34232).

Lyon (1936) listed the southern bog lemming from Porter County, but the record apparently refers to a specimen taken 26 August 1905 at Hebron by Walter L. Hahn (USNM 141767). The first record of this species at the lakeshore (based on skeletal material) was by Rand and Rand (1951).

Lyon (1924, 1936) took one meadow jumping mouse from Porter County. It came from the large subdunal meadow just south of the dunes between Port Chester and Mineral Springs Station of the Chicago, Lakeshore and South Bend Railway.

Lyon (1923) obtained no firsthand evidence that coyotes were in the area now included in the lakeshore. Brennan (1923) cites numerous early timber wolf reports from the dunes region, but we suspect most or all of them to be of coyotes. No coyote remains, however, were found by Rand and Rand (1951). The presence of the coyote at the lakeshore was first documented by our study.

Brennan (1923) saw a badger in November 1918 near Furnessville Blowout in what is now the west portion of the Indiana Dunes State Park. The eight

additional species included in Table 1, under the column designated Lyon (1936), brings the number of species known from the lakeshore to 30.

Necker (1939) listed 29 species of mammals presumably occurring at the dunes although no new information was included. He included the species listed by Lyon (1923) but also many of the additional species discussed above even though Lyon recorded them only from Lake or Porter counties, not necessarily from the dunes.

Rand and Rand (1951) reported mammal bones found in blowouts in the Indiana Dunes State Park. They listed 33 species of recent mammals for which they had personal records. They found skeletal remains of 21 species, including 6 not then present: beaver, porcupine, black bear, fisher, elk, and white-tailed deer. They recorded both the silver-haired bat and the big brown bat from the general area, but it is not clear whether these were actually from the lakeshore. New species records for the lakeshore were the big brown bat, the southern flying squirrel, the southern bog lemming, and the least weasel (*Mustela nivalis*), bringing the number of species known from the area to 34.

A team from Texas Instruments spent 6 years of study in the Cowles Bog area (1975–80) collecting or observing 25 species of mammals. Some interesting records include one little brown myotis, two least weasels, and two woodland voles. They failed to capture any prairie deer mice, prairie voles, or meadow voles. Mammals they collected or observed are indicated in Table 1. Species reported for the first time by Texas Instruments personnel were the little brown myotis and the white-tailed deer, bringing to 36 the number of species known from the lakeshore.

Krekeler (1981) presented an annotated list of mammals known to be present or possibly present in the lakeshore area (Table 1), apparently all from previous information. He listed 43 species, 5 for which there is no documented evidence. The five, not included in Table 1, are the northern myotis, the Indiana myotis, the hoary bat, the evening bat (*Nycticeius humeralis*), and the coyote. Krekeler (1981) presented new information on only four species (Table 1). He stated that the eastern gray squirrel had been "extirpated from the northern third of the state but has been reintroduced in certain localities" and is now common in certain parts of the lakeshore. He indicated that the American beaver had been extirpated but reintroduced and was causing high water problems at Dune Acres. His was the first definite recent record of the American beaver at the lakeshore. Krekeler (1981) stated that the striped skunk (*Mephitis mephitis*) forages on the beach and that tracks of white-tailed deer are now regularly seen at the lakeshore. He listed the common gray fox as rare at the lakeshore, but until this study there was no verified record of the species. This brings the number of species previously recorded at the lakeshore to 37, although the Franklin's ground squirrel is apparently no longer present. The northern myotis and the hoary bat probably are present.

Whitman et al. (1990) presented information on mammals of Miller Woods. The 16 species reported are the Virginia opossum, masked shrew, northern short-tailed shrew, eastern mole, eastern cottontail, thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*),eastern gray squirrel, eastern fox squirrel, red squirrel, common raccoon, long-tailed weasel, and white-tailed deer.

The diverse habitats of the lakeshore create a home for approximately 37 (38 including the common gray fox, which was documented during this study) of the 56 species of mammals presently in Indiana. Franklin's ground squirrel was probably there as recently as the 1940's but is apparently gone now. Feral dogs (*Canis familiaris*) and cats (*Felis catus*) are present and may partially fill the predator niche. Bobcat sign was reported in the Heron Rookery, but this record has not been verified. The bobcat is an endangered species in Indiana.

More recent studies include ongoing monitoring of white-tailed deer by park personnel, studies of the effects of fire on small mammals, and sampling of common raccoons for distemper and roundworm (*Baylisascaris procyonis*).

We here present the first comprehensive survey of the mammals of the Indiana Dunes National Lakeshore. Our purpose is to determine the species, communities, and distribution of mammals at the Indiana Dunes National Lakeshore and their habitat preferences and requirements. In addition, we will attempt to determine the probable effects on mammals of past and present perturbations such as habitat destruction and fragmentation, air pollution, visitor activities, and park operations. Finally, we will suggest recommendations for further research, monitoring, and management of the mammals of the lakeshore.

Study Area

Henry Cowles recognized the scientific value of the Indiana Dunes, described the plant communities, and pioneered in formulating ideas of plant succession on the area (Cowles 1899). Numerous plant species are present, many of them listed as threatened or endangered and many not found elsewhere in Indiana. The first director of the National Park Service, Stephen Mather, called the Indiana Dunes "admittedly wonderful and inherently distinctive" and recommended that "a large section of this dune region should be preserved for all time" (Waldron 1983). Senator Paul H. Douglas of Illinois led the struggle to get the lakeshore set aside. He was encouraged by poet Carl Sandburg who wrote in a letter to Douglas (Engel 1983), "Those dunes are to the Midwest what the Grand Canyon is to Arizona and the Yosemite to California. They constitute a signature of time and eternity; once lost, the loss would be irrevocable."

Indiana Dunes National Lakeshore presently encompasses about 5,260 ha on the south shore of Lake Michigan, primarily in Lake and Porter counties,

Indiana, but with three outlying areas: Hoosier Prairie, Heron Rookery, and Pinhook Bog (Fig. 1). Pinhook Bog is in LaPorte County. The lakeshore was formally established in 1966 and includes Indiana Dunes State Park, established in 1926 (Engel 1983).

The dominant features are the dunes, which have been forming for thousands of years, the newest closer to and the oldest farther back from Lake Michigan. A great diversity of habitats is present—pure sand on the beach through various grassy and shrubby dunes to wooded dunes farther inland. Much of the area is in wetlands. This includes part of the Little Calumet River; smaller streams, ponds, swamps, and marshes; and much of the Great Marsh. Wet and dry prairie and Pinhook Bog also add to this diversity. Much of the land farther from the lake had been developed as homesites and farmlands, but much of this is now being purchased and returned to its natural state.

Materials and Methods

Several methods of obtaining data were utilized because attempts were made to survey all species of mammals existing in the park. Previously published data and that obtained by lakeshore personnel were used extensively in addition to the new data collected during this study.

We took samples from 24 habitats previously designated by Indiana Dunes National Lakeshore personnel. In each of the 24 habitats, several 25- x 25-m plots were selected for study. The number of plots ranged from 3 to 18, generally with fewer plots in the less extensive habitats. We tried to take samples in each habitat during each season. The work was carried out from 1987 to 1989.

In each habitat, National Park Service personnel designated the general areas for study. We determined specific plots for study by using 1:200 map sections of the lakeshore overlaid with outline maps of the vegetation types (habitats). We then overlaid the vegetation association to be sampled with a 10- x 20-block grid of 1-cm blocks. Random numbers were selected to designate specific groups of grid blocks—the first number designated the horizontal row and the second designated the vertical row. The first selected block that fell wholly within the targeted habitat was marked as the plot in which animals were to be sampled. The plots were then identified in the field using paced distances from known topographical and vegetation features. We sampled animals on 173 plots in the 24 habitats (Table 2), although the total number of plots, in a few instances, includes more than one sampling of the same plot.

The animals in plots were sampled with several types of mammal traps in order to capture a variety of species. Twenty-five ordinary snap-back mouse

traps were set in a grid pattern in each plot with 5 m between each trap (Fig. 2). We used 25 Tomahawk mouse-sized live traps, 10 rat traps, and 5 large Tomahawk traps (3 raccoon-size and 2 squirrel-size; Fig. 2). Snap traps were baited with peanut butter and oatmeal, the squirrel traps with apple, and the raccoon traps with bacon. Finally, 10 1-L plastic beakers containing about 25 mm of water were sunk to ground level in each plot as pitfalls—primarily to capture shrews, woodland mice, and bog lemmings. Pitfalls were set in what seemed to be the best places in the plot for shrews but preferably in runways or along or under logs or other objects. The traps and beakers were examined each day for 4 days, then the traps were removed. The beakers were further examined at 3-day intervals and removed on the 21st day. Animals trapped live were usually released. Dead animals were frozen for later examination, and representative

Table 2. Distribution of study plots by habitat type, Indiana Dunes National Lakeshore.

Habitat	Spring	Summer	Fall	Winter	**Total**
Barrens	0	3	1	1	5
Dry prairie	2	5	2	2	11
Wet prairie	0	4	0	2	6
Lowland terrestrial shrubland	1	8	0	0	9
Upland terrestrial shrubland	0	3	0	1	4
Oak savanna	2	11	1	1	15
Coniferous savanna	1	3	0	0	4
Mixed deciduous savanna	0	1	2	0	3
Black oak forest	1	5	0	2	8
Coniferous forest	1	1	1	1	4
Mixed deciduous forest	1	8	2	2	13
Ephemeral lowland forest	1	6	2	0	9
Perennial lowland forest	5	9	2	2	18
Marsh	1	7	2	2	12
Aquatic shrublands	1	2	0	2	5
Swamp	1	2	0	1	4
Pinhook Bog	1	2	0	1	4
Pannes	1	1	0	1	3
Aquatic area	1	3	0	0	4
Agricultural areas	1	7	0	1	9
Pine plantations	2	1	0	0	3
Razed residential areas	4	1	3	3	11
Rights-of-way	3	1	0	2	6
Disturbed sand areas	0	3	0	0	3
Total	31	97	18	27	173

specimens were preserved as study skins and deposited at the Indiana Dunes National Lakeshore. In each plot, the plant species were recorded and data were collected on herbaceous and woody cover and on mammal sign (tracks, burrows, runways, cuttings, and droppings). We list the mammals in taxonomic order (Jones et al. 1992) throughout to facilitate those interested in a single or a few species.

Plot Numbering System

The Indiana Dunes National Lakeshore includes five major disjunct tracts: a western tract extending from Miller Woods to West Beach; an eastern tract extending from Cowles Bog to Mount Baldy; Hoosier Prairie; the Heron Rookery; and Pinhook Bog. The National Park Service mapped these areas with a 1:200 topographical format. Three numbers were assigned to each plot—the first designating the specific plot, the second the map section, and the third one of the five areas.

Moles, bats, larger carnivores, and white-tailed deer were sampled poorly or not at all, using the above methods. We were able, for some species, to get an

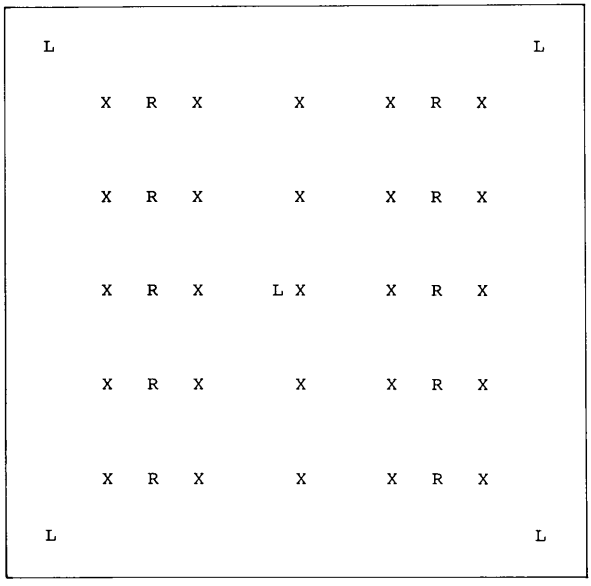

Fig. 2. Outline of standard study plot showing relation of various traps and sunken beakers. *X* = mouse traps (snap and live); *L* = large live traps; *R* = rat traps. Sunken cans were set in best places in plot, primarily along or under cover.

indication of relative abundance by using tracks, feces, or other sign. In addition, it was recognized that some expected species, particularly woodland voles and bog lemmings, were not being taken in the randomly selected plots. Therefore, additional traps, including pitfalls, were placed in lines for them in selected areas as follows: 160 traps and 50 pitfalls in upland and lowland forest near Cowles Bog (traps were in place from 7 to 9 April 1989; the pitfalls from 7 April to 5 May), 200 pitfalls in upland woods on north side of U.S. Highway 20 just east of State Route 300E (between 2 September and 24 November 1989).

To gather data on bats, mist nets were placed over streams and other flyways at nine different sites on seven nights. Locations netted were along Dunes Creek (four sites), along an abandoned road east of the Kemil Road Railroad Station, along the edge of the woods at West Beach, along the stream just north of Bailly Homestead, and along the trail near Cowles Bog (two sites). Requests were made of all park personnel for leads to bats, and posters were placed at strategic locations in the vicinity of the lakeshore.

Lakeshore personnel have collected data on deer (winter aerial counts) and on raccoons. These data are included in the report. Records were kept of animals killed on the road and of miscellaneous observations made on mammals as we traveled through and around the Indiana Dunes National Lakeshore.

Formation of Habitats

As the wind blows off Lake Michigan, sand collects along the lakeshore, allowing dune formation to begin—this action leads directly or indirectly to the various habitats discussed later. The lower beach is the area from the water line to the line reached by summer storms. In its pure state the lower beach hosts no permanent plant or animal communities (Cowles 1899), although organisms visit this environment to obtain food or water. It is too rigorous an environment for plants to become established. Above where summer storms reach—the middle beach—the environment is less rigorous and some annuals can grow. The upper edge of the middle beach is where the most severe of the winter storms reach—storms that eliminate the plants. Sea rocket (*Cakile edentula*), common bugseed (*Corispermum hyssopifolium*), and seaside spurge (*Euphorbia polygonifolia*) are some of the prominent plants here.

The area between where the winter storms reach and the first line of dunes is known as the upper beach. Annual and perennial plants that can grow in sand can exist in this less rigorous area. Dune-forming plants take root here, giving rise to the first line of dunes. Chief among the dune formers are marram grass (beach grass; *Ammophila breviligulata*) and sand reed (*Calamovilfa longifolia*), although other plants may act as dune formers. Good dune formers must be

hardy perennial xerophytics that won't die after their first season. They must send out shoots both laterally and downwards, and the roots must exist as stems and the stems must serve as roots. Dunes inhabited by plants with these characteristics grow both wider and taller.

After marram grass, sand reed, or other dune-forming plants have caused a dune to form, a number of other plant species become established. Little bluestem grass (*Andropogon scoparius*) is often prominent and forms thick stands of grass in the area just behind the marram grass unless woody plants immediately become dominant. The two major types of habitats listed as dry prairie here are those dominated by marram grass or little bluestem grass and are principally found on the front dunes.

Prominent along the first lines of dunes are eastern cottonwoods (*Populus deltoides*). Eastern cottonwood is a dune former also, even though it does not send its roots laterally. Cottonwood can continue to grow when almost completely buried; thus it can help to build rather high dunes.

After the dry prairie or grass stage, the next successional (seral) stage occurs on the second row of dunes. In the area of southern Lake Michigan it is a conifer–basswood stage, with conifers more prominent to the north and basswood (*Tilia americana*) more abundant in the immediate area of the Indiana Dunes National Lakeshore. The conifer–basswood is a relatively brief stage. One can find an occasional conifer or basswood along the third line of dunes, but these have normally been replaced before reaching that row.

Oak forest begins at the third row of dunes and includes much of the area covered by the lakeshore. Black oaks (*Quercus velutina*) predominate on the ridges and in the drier areas. Red oaks (*Q. rubra*—usually known as *Q. borealis*) predominate in the lower, more moist areas, although some white oaks (*Q. alba*) also occupy the lower areas. Local light, soil, moisture, and slope conditions determine which of a variety of herb and shrub species exist with this stage.

The final or climax stage seems to be the maple or beach maple forest, but it is not clear how much of this habitat originally existed. This stage was the farthest from the beach and most has been obliterated by human development.

We have presented the way classic succession occurs on the dunes if other factors do not intercede. Other factors do intercede, however—both natural and those produced by humans—and cause the situation to be more complicated.

The major natural factor is the occasional interruption of the seral process when a local area reverts to open sand and succession repeats. These interruptions are generally caused by either blowouts, areas of open sand, or wandering dunes—dunes that are moved inland by the wind. Blowouts and wandering dunes can be caused by anything that reexposes open sand on areas that were once vegetated or captured. Old dunes sometimes become undermined, and loss of vegetation may then occur. Wandering dunes sometimes occur at the end of the life of dune formers, especially eastern cottonwoods. If the sand becomes

exposed in these or other ways, it will be moved over the top of the dune by the wind and come to rest when the wind is broken on the back side. The entire dune may begin moving inland, covering everything in its path. One may stand on a wandering dune in a late fall storm and feel and see the sand coming over the top and covering the trees behind. Wandering dunes can move great distances inland until they are recaptured by dune-forming plants, especially marram grass and sand reed.

The Indiana Dunes National Lakeshore also has a great amount of aquatic habitat. Aquatic succession begins with open water in interdunal ponds. If the drainage is poor, the pond may grow over with heaths and other bog-forming plants. This occurred at Pinhook Bog and at Cowles Bog, although the latter does not look like a bog because its dominant plants are cattails.

If drainage is good and the ponds are not too deep, cattails and various graminiform plants may become established and form a marsh. The Great Marsh once covered many square kilometers of this area, and major sections of it still exist. Many smaller marshes also occur. Shrubs such as buttonbush (*Cephalanthus occidentalis*), willow (*Salix* sp.), and alder (*Alnus rugosa*) can invade the marshes, forming aquatic shrubland. Last, seedlings of trees such as elm (*Ulmus* sp.), silver (*Acer saccharinum*) and red maple (*A. rubrum*), and ash (*Fraxinus* sp.) may become established in the aquatic shrubland, and as they mature they outcompete the aquatic shrubs and the area becomes swamp, the final aquatic stage.

Man has altered the southern shore of Lake Michigan. The building of roads, railroads, houses, factories, and other structures and the likely contamination of soil, water, and air with pollutants are examples (Reshkin 1990).

We present the various habitats in the approximate order of the seral stages and developments. The beach and near-beach habitats are dynamic, ever-changing, and intergrading from one to another. The naming and describing of specific habitats does not imply the absence of variation and intergradation.

Habitats

Barren Ground

Natural barren ground at the Indiana Dunes National Lakeshore consists of open sand on the beaches (Fig. 3) and in the blowouts (Fig. 4). Open sandy beaches occur all along the shore, and blowouts are scattered throughout the lakeshore. Barren ground comprises about 4% of the area—most of it in beaches. Minimal plant life occurs on the barrens proper.

No permanent assemblage of mammals inhabits the bare sand, although many animals visit at night. Clumps of vegetation may be inhabited, especially

Fig. 3. Barren ground in an open sandy beach at West Beach.

Fig. 4. Barren ground in a blowout in the state park.

ontheblowouts.Therewerethreeplotsonbeachesandtwoinblowouts(Fig. 5). Tracks of Virginia opossum, raccoon, and prairie deer mice were seen at all three beach plots; tracks of white-tailed deer were seen at two. These animals apparently visit the beaches at night to feed or drink or both. The mammals found in blowouts were mostly in and around an occasional clump of grass. The clumps consisted primarily of marram grass and sea rocket. Only three species of mammals were taken in blowouts—one masked shrew, one prairie vole, and three meadow voles. Voles were expected in this habitat when the clumps of grass were large enough, but the presence of the masked shrew was somewhat surprising. We suspect the shrew of being a transient or of dispersing to a new location.

Prairie

Prairie comprises about 4.4% of the total area of the Indiana Dunes National Lakeshore—about 75% is in dry prairie, the rest is in wet prairie.

Dry Prairie

Most of the dry prairie is on the front line of dunes and consists primarily of pure stands of marram grass and sand reed, the major dune-forming species. Cover in this habitat provides ample hiding spots for small mammals. Sometimes little bluestem grass is present, or it may form dense stands in dunes behind the foredunes. Dry prairie is shown on the foredunes (Fig. 6) and on sandy areas away from the shore (Fig. 7). Six of 11 plots in which mammals were sampled in dry prairie were primarily of marram grass or sand reed; little bluestem grass predominated in the remainder of the plots (Fig. 8). The plots with little bluestem grass often had a greater variety of plant species, especially when away from the lakeshore.

The small mammals taken in traps in dry prairie were 31 prairie deer mice, 10 white-footed mice, 5 meadow voles, 4 thirteen-lined ground squirrels, 3 northern short-tailed shrews, and 3 eastern cottontails. All five prairie voles were taken in one plot. The generally sparse cover in many of the plots in which mammals were taken probably accounted for both the abundance of prairie deer mice and the low number of prairie voles. The prairie deer mouse is the only small mammal of Indiana that increases with decreased vegetative cover. Voles, however, thrive only in good plant cover. A study of the relation of prairie deer mice to prairie voles in this habitat and of the relation between white-footed mice and prairie deer mice would be valuable. We hypothesize that white-footed mice should increase with increased vegetative and woody cover, whereas prairie deer mice should decrease with increased vegetative cover and essentially never occur in areas with woody cover. Short-tailed

Fig. 6. Dry prairie on the foredunes (early dunes) at West Beach.

Fig. 7. Dry prairie inland at West Beach.

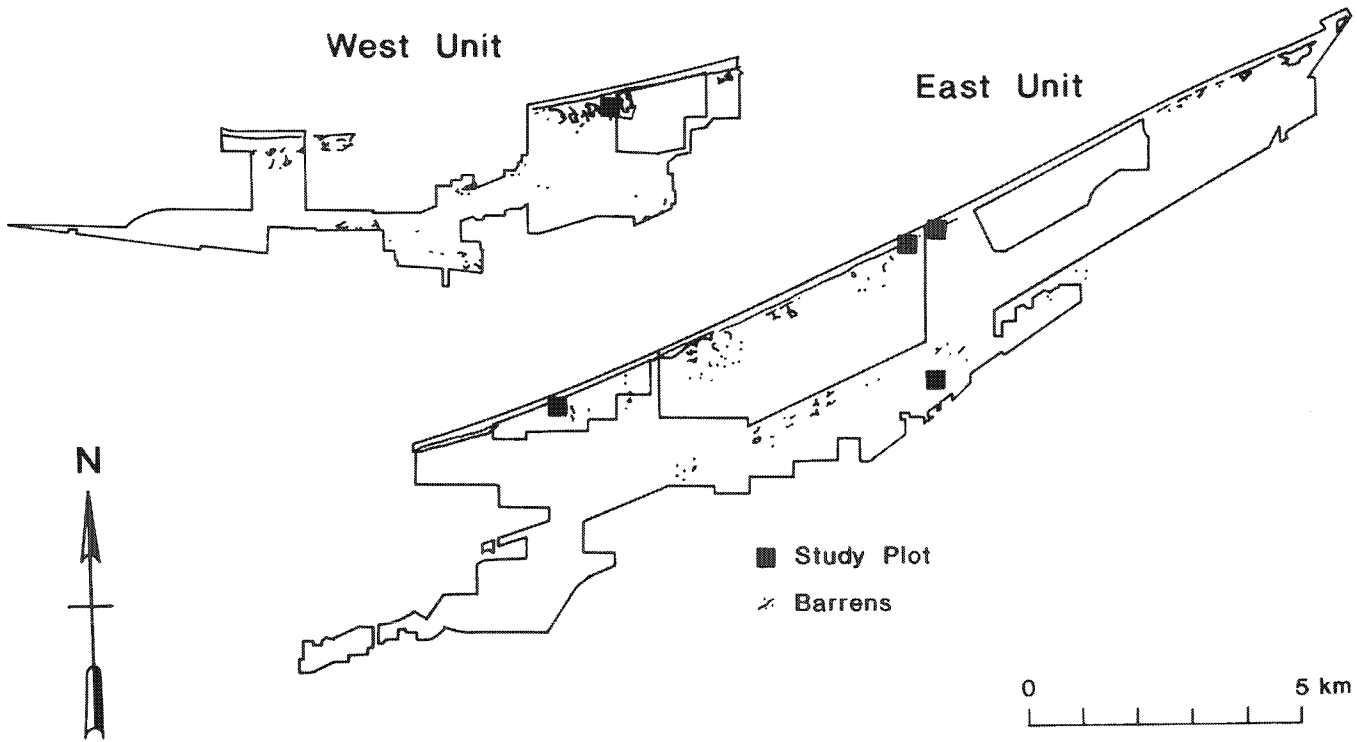

Fig. 5. Distribution of five plots in barrens at Indiana Dunes National Lakeshore.

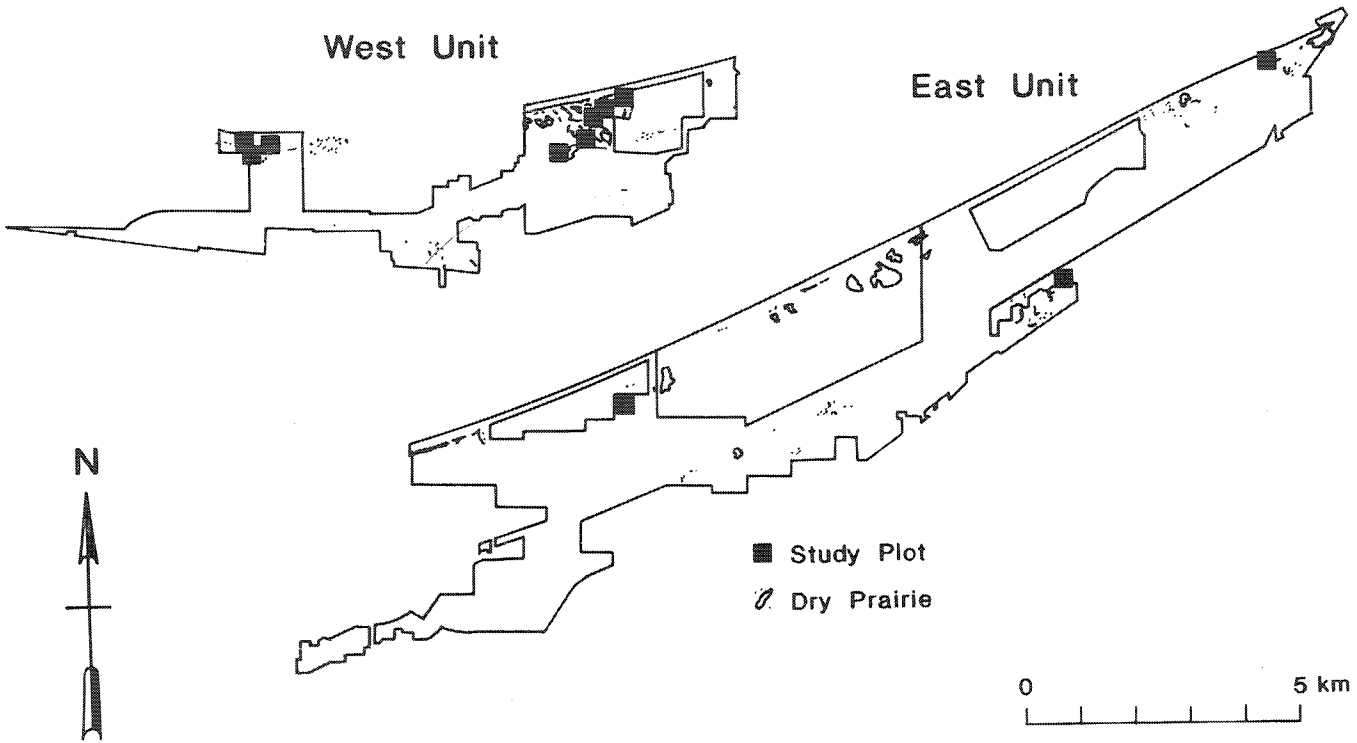

Fig. 8. Distribution of 11 plots in dry prairie at Indiana Dunes National Lakeshore.

shrews were taken in two plots, which indicated that the plots graded into wetter areas.

Sign was observed of the eastern cottontail, the red fox, and the white-tailed deer in two plots and of the domestic dog and the long-tailed weasel in one. In addition, sign was observed here that could have been of the southern bog lemming. No bog lemmings have been taken at the lakeshore, but they undoubtedly occur there. The bog lemming is not primarily in, limited to, or even often found in bogs or even in wet areas. It has a broad range of habitats from woods to rank meadows to dry *Andropogon* fields.

The thirteen-lined ground squirrel now exists primarily in mowed areas such as on golf courses, lawns, pastures, and roadsides. Its presence in this habitat might indicate that dry prairie had been the ancestral habitat for this species before the country was settled.

The six plots with marram grass–sand reed harbored all six species (26 individuals) of mammals taken in this habitat in traps: 11 prairie deer mice, 5 white-footed mice, 5 prairie voles, 2 ground squirrels, 2 eastern cottontails, and 1 northern short-tailed shrew. The five plots with little bluestem grass as the dominant species harbored five species (30 individuals), including 21 prairie deer mice, 4 white-footed mice, 2 northern short-tailed shrews, 2 thirteen-lined ground squirrels, and 1 eastern cottontail. The marram grass plots were generally in the foredunes area, whereas many of the bluestem plots were far from the front line of dunes. Cover was generally better in the marram grass plots, probably the reason for the prairie voles and fewer prairie deer mice being there as compared with the bluestem plots.

Wet Prairie

Six plots were studied in wet prairie (Fig. 9). These plots had various grasses and forbs as the dominant plants, but four of them had a shrub layer containing significant amounts of willow, aspen, and oak. Some of the major grasses were *Panicum*, reed canarygrass *(Phalaris arundinaceae)*, *Aristida* sp., *Agrostis* sp., and blue joint grass (*Calamagrostis canadensis*). Cattails and rushes were also dominant in one plot. On these plots, cover ranged from fair (ground not 100% covered, animals able to hide in clumps but cannot move about freely without being seen from above) to excellent (ground 100% covered, animals able to move about freely without being seen from above). A photograph of the drier part of Hoosier Prairie is shown (Fig. 10).

The most abundant mammal species in wet prairie was the masked shrew. We expected the meadow vole to be predominant because earlier the meadow vole was taken in large numbers by Mumford and Whitaker (1982) along the edge of wet areas at Hoosier Prairie. Voles are cyclic and perhaps they were at a population low during our work. We took 11 masked shrews in three of the six plots studied. The white-footed mouse (nine) and the northern

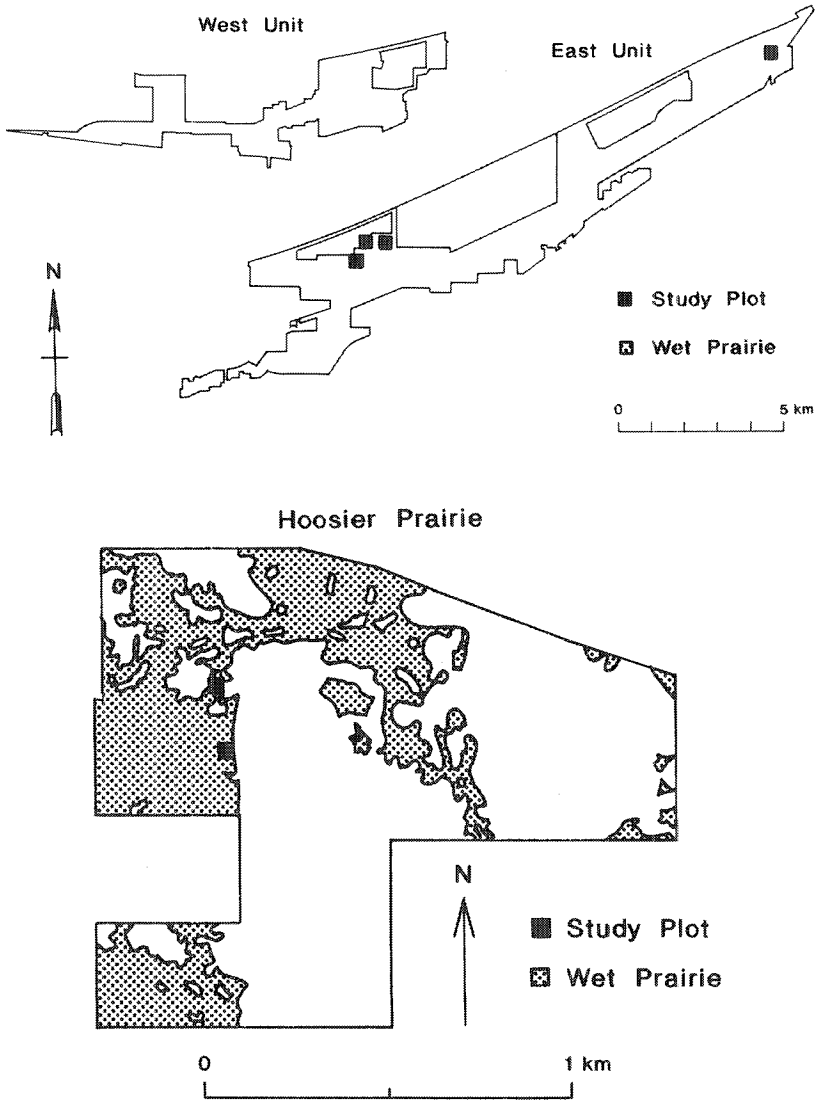

Fig. 9. Distribution of six plots in wet prairie at Indiana Dunes National Lakeshore.

short-tailed shrew (eight) were second and third in abundance. Other mammals taken in traps were four prairie deer mice, two common raccoons, one meadow vole, and one meadow jumping mouse. Sign of the eastern mole, the woodchuck, the common raccoon, and the white-tailed deer were each seen in one plot. The shrew, the meadow vole, and the jumping mouse reflect the generally moist environment with ample herbaceous vegetation. The presence of the prairie deer mouse in two of the plots indicated that some dry, open area was present.

Trapping was carried out by J. O. Whitaker and R. E. Mumford at Hoosier Prairie (27–28 April 1977) using 1,508 snap traps for 2 nights for a total of 3,016 trap nights. They took 60 meadow voles, 22 masked shrews, and 10 northern short-tailed shrews. The masked shrews and voles were in the wetter areas of grasses and sedges, the northern short-tailed shrews were in mixed moist areas, and the white-footed mice were mostly taken where there was brush or woods. Most of the traps were in grass sedge meadow, which included clumps of willows.

The meadow voles were feeding extensively on the willow fruits. The fruiting twigs were 0.5–1 m high. The voles cut off the twigs, pulled them down, and recut them until the heads were reached. Cuttings 4–15 cm long

Fig. 10. Wet prairie on Hoosier Prairie.

were left in piles with the fruiting leaflets and parts of the fruits on top of the piles of twigs. The stomachs of the mice were full of the cuttings.

Terrestrial Shrubland

No major lasting terrestrial shrubland stage exists in the successional sequence at the lakeshore. Rather, the front dunes rapidly give way to forest—although there is a brief shrubby stage at the interface between the front grass-covered dunes and the forested dunes. The shrub stage consists of saplings of oaks, conifers, basswood; other trees soon to populate; and sometimes other species such as grape and cherry. Bearberry (*Arctostaphylus uva-ursi*) is often found at this interface. While not a lasting habitat in the dune succession series, it is an important habitat at the lakeshore that exists mostly in areas farther away from the lakeshore. The habitat includes about 4.3% of the lakeshore and is divided into lowland and upland components.

Lowland Terrestrial Shrubland

Samples were taken from nine plots in lowland terrestrial shrubland (Figs. 11 and 12). Two of the plots in this habitat were in willow thickets, one was in a red maple thicket, and one was in an aspen thicket. Two were in a former sand mine area that was growing back to dry prairie, with clumps of little bluestem grass, and one was in a thicket where red osier dogwood (*Cornus stolonifera*) and *Lonicera* sp. formed a dense shrub layer, while grasses and other herbs formed a dense layer of ground cover.

No species of mammal was dominant or even abundant in this habitat. Six white-footed mice, five northern short-tailed shrews, four thirteen-lined ground squirrels, two Virginia opossums, two common raccoons, one woodchuck, one red squirrel, and one meadow vole were taken in traps. Sign of eastern cottontail, woodchuck, and white-tailed deer each occurred in three plots; common raccoon in two; and eastern mole, thirteen-lined ground squirrel, red squirrel, and meadow vole each in one. We suspect that mammal use of this habitat is transitory. Thirteen-lined ground squirrels appeared in three of these plots—two of the plots were in the former sand mine with clumps of little bluestem grass and formed good habitat for this species; the third was in the dense *Cornus stolonifera–Lonicera* thicket. The thicket did not seem to be good habitat for this species, but two males were taken.

Upland Terrestrial Shrubland

Four plots in upland terrestrial shrubland (Figs. 13 and 14) were highly disturbed transition stages between grassy old field or savanna and wooded habitats. Sampling in summer was highly productive in one plot, yielding 44 individuals of four species of mammals in the traps. The 33 meadow voles and 9 shrews taken there reflect the former field habitat rather than the

present transitional shrub stage. We predict that these forms will disappear as the transition towards more woody vegetation continues in this plot. Small numbers of 14 species (including the domestic dog) were found in this habitat. We suspect that the lack of a well-developed mammal community in shrubland is because of the ephemeral nature of the habitat.

Mammals trapped here were 34 meadow voles, 9 short-tailed shrews, 4 white-footed mice, 2 raccoons, 1 masked shrew, 1 prairie deer mouse, 1 prairie vole, and 1 meadow jumping mouse. Sign of white-tailed deer was in two plots; sign of eastern cottontail, eastern chipmunk (*Tamias striatus*), eastern fox squirrel, domestic dog, and red fox was in one plot each.

Fig. 11. Lowland terrestrial shrubland at Inland Marsh.

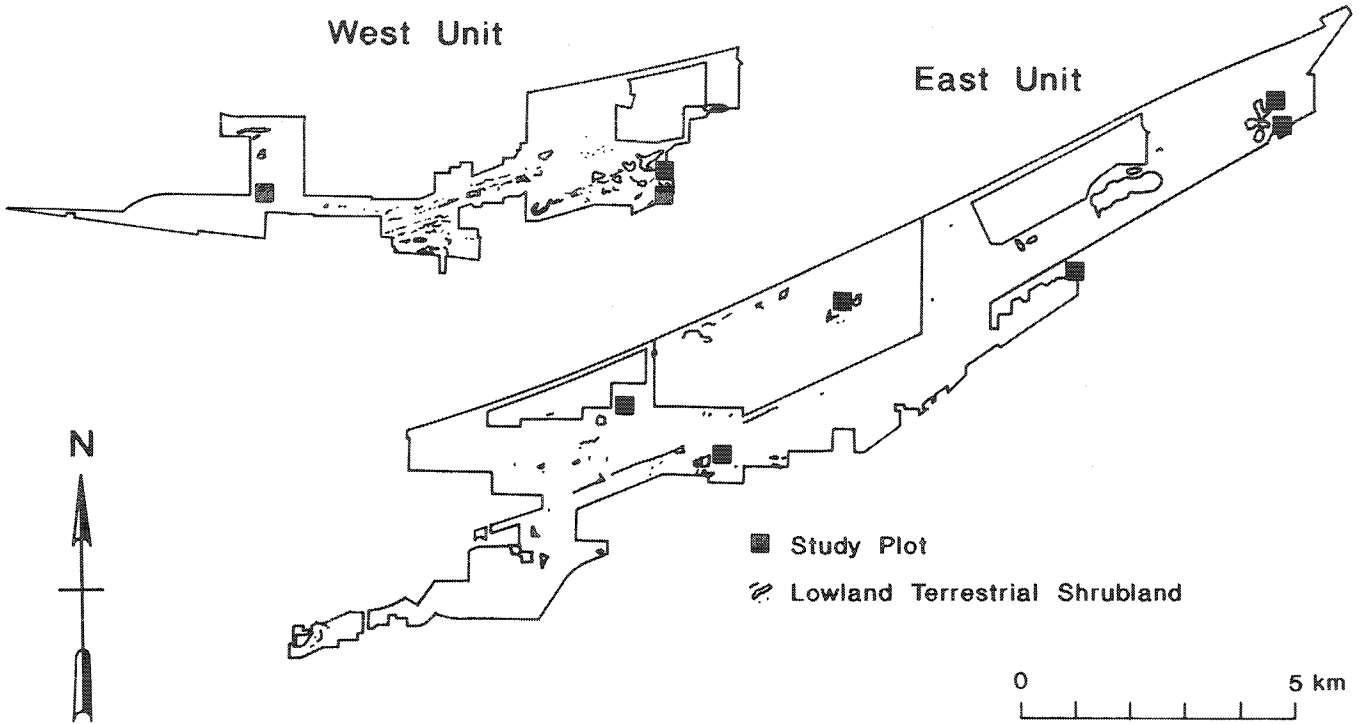

Fig. 12. Distribution of nine plots in lowland terrestrial shrubland at Indiana Dunes National Lakeshore.

Savanna

The lakeshore includes three types of savanna. Oak savanna constitutes about 3% of the area, coniferous savanna about 0.1%, and mixed deciduous savanna about 1.0%.

Oak Savanna

Oak savanna consisted of grassy areas with scattered black oaks (Fig. 15). This habitat was prominent at the lakeshore, grading into black oak forest in such a way that it was often difficult to decide whether an area was black oak forest or black oak savanna. Fifteen plots were studied in this habitat (Fig. 16), and all had a canopy of nearly pure black oak, usually thin. Both the shrub and herb layers varied considerably. Some of the more important shrubs, besides

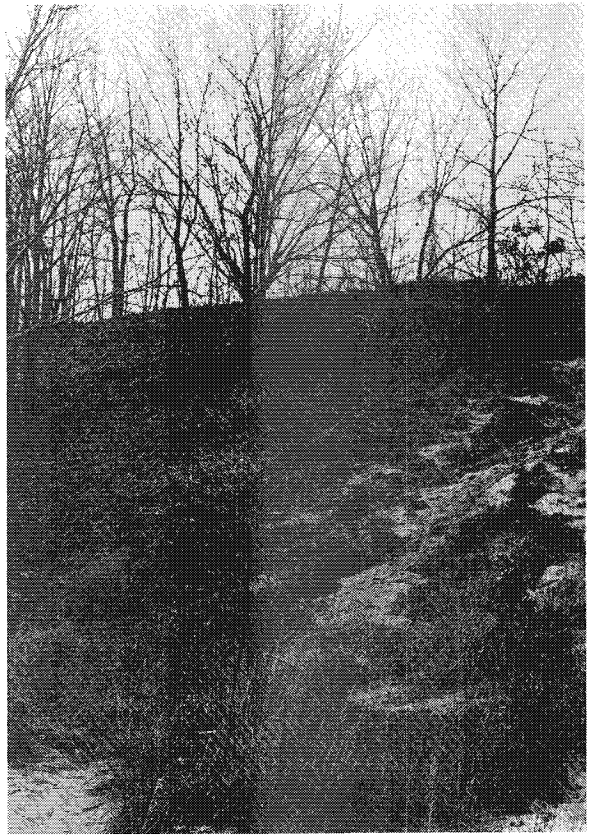

Fig. 13. Upland terrestrial shrubland at Miller Woods.

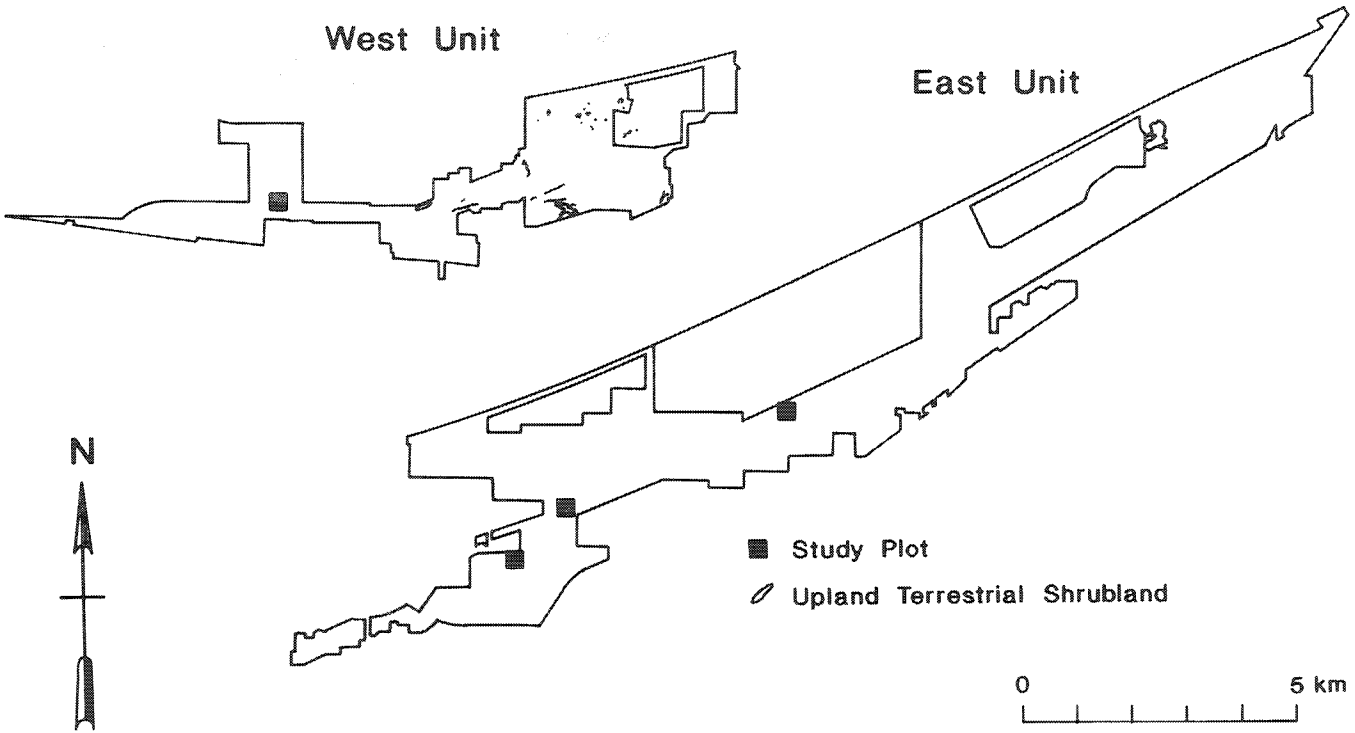

Fig. 14. Distribution of four plots in upland terrestrial shrubland, Indiana Dunes National Lakeshore.

Fig. 15. Black oak savanna at Miller Woods.

oak saplings, were blackberry (*Rubus* sp.), blueberry (*Vaccinium* sp.), rose (*Rosa* sp.), and Japanese honeysuckle (*Lonicera japonica*). The herb layer was diverse, but most of the areas contained a major grass or sedge (often *Andropogon*, *Panicum* sp., or *Carex* sp.). Bracken fern (*Pteridium aquilinum*) and goldenrod (*Solidago* sp.) were important on some of the plots.

The white-footed mouse was the most abundant mammal in this habitat—18 were taken in 10 plots. Three prairie deer mice were also taken. The prairie deer mouse occurs in sparsely vegetated, dry areas without woody vegetation. The white-footed mouse is primarily a species of the woods but is present in a variety of habitats, becoming less common with decreased woody vegetation. Savanna is primarily a thinly wooded habitat that tends to favor the white-footed mouse over the prairie deer mouse. The prairie deer mouse is favored as the canopy becomes thinner and especially when the undergrowth is thin. The plots with the prairie deer mice had thin canopy layers and sparse shrub and herb layers that provided poor cover (not 100% covered, difficult for animals to hide, cannot move around freely without being seen from above). The diversity of this habitat seems to have had a positive effect on the diversity of the mammal fauna because 14 species of mammals were recorded. Besides the white-footed and the prairie deer mice, three masked shrews, three thirteen-lined ground squirrels, two

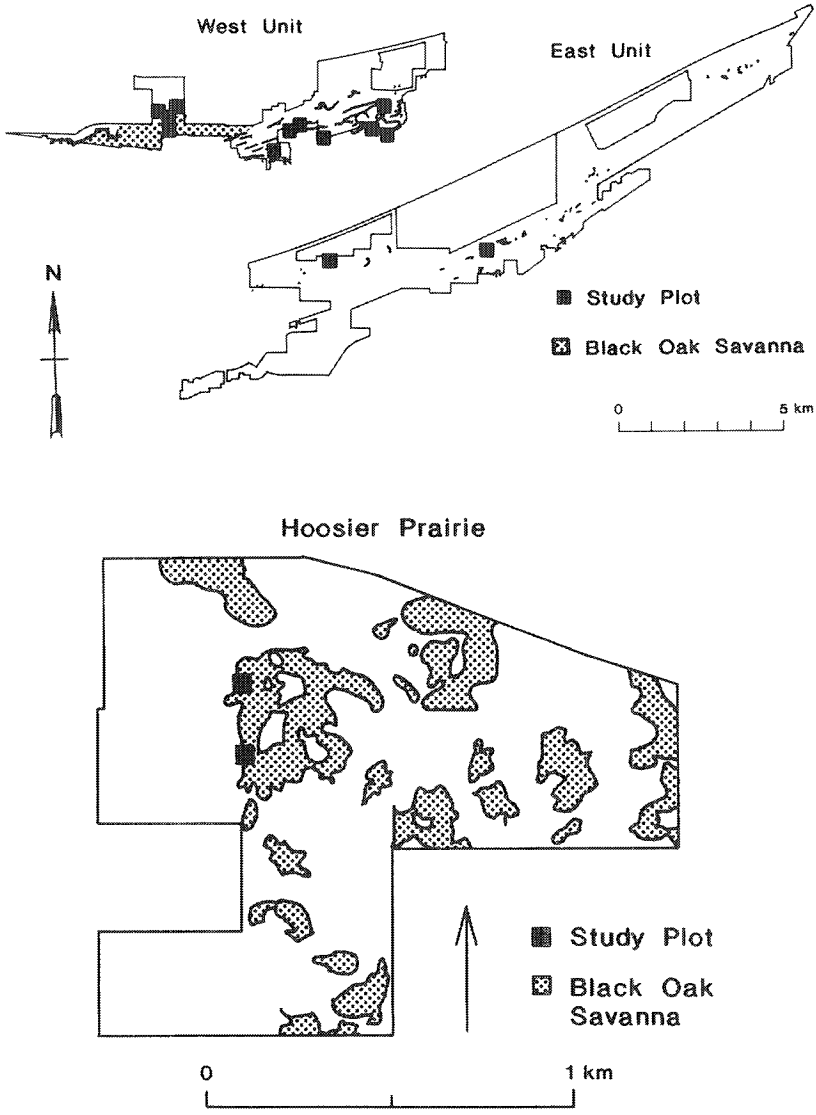

Fig. 16. Distribution of 15 plots in black oak savanna, Indiana Dunes National Lakeshore.

eastern chipmunks, one southern flying squirrel, and one common raccoon were taken in traps. Sign or sightings of white-tailed deer were recorded in seven plots; eastern mole, woodchuck, and eastern fox squirrel in five plots; eastern cottontail, eastern chipmunk, and red fox in two plots; and eastern gray squirrel in one.

Coniferous Savanna

Little coniferous savanna occurs at the lakeshore, so only four plots were placed there (Figs. 17 and 18). The plots were along the interface between the front grassy dunes and the black oak dunes behind. All had a sparse canopy layer of jack pine (*Pinus banksiana*), sometimes with a few black oaks. The shrub and herb layers were usually dense, forming fair to excellent cover. Bearberry was a major shrub species. Little bluestem grass or *Panicum* sp. were the dominant herbs. A diversity of other shrub and herb species was also present.

Ten species of mammals were recorded from this habitat. The white-footed mouse was the most abundant—15 were captured in three of the four plots. Virginia opossum, thirteen-lined ground squirrel (four trapped), muskrat, and white-tailed deer were each recorded in two plots. Eastern cottontail, prairie deer mouse (seven trapped), meadow vole, red fox, and raccoon were each recorded from one plot. This habitat, like oak savanna, ranges from very open

Fig. 17. Coniferous savanna at Miller Woods.

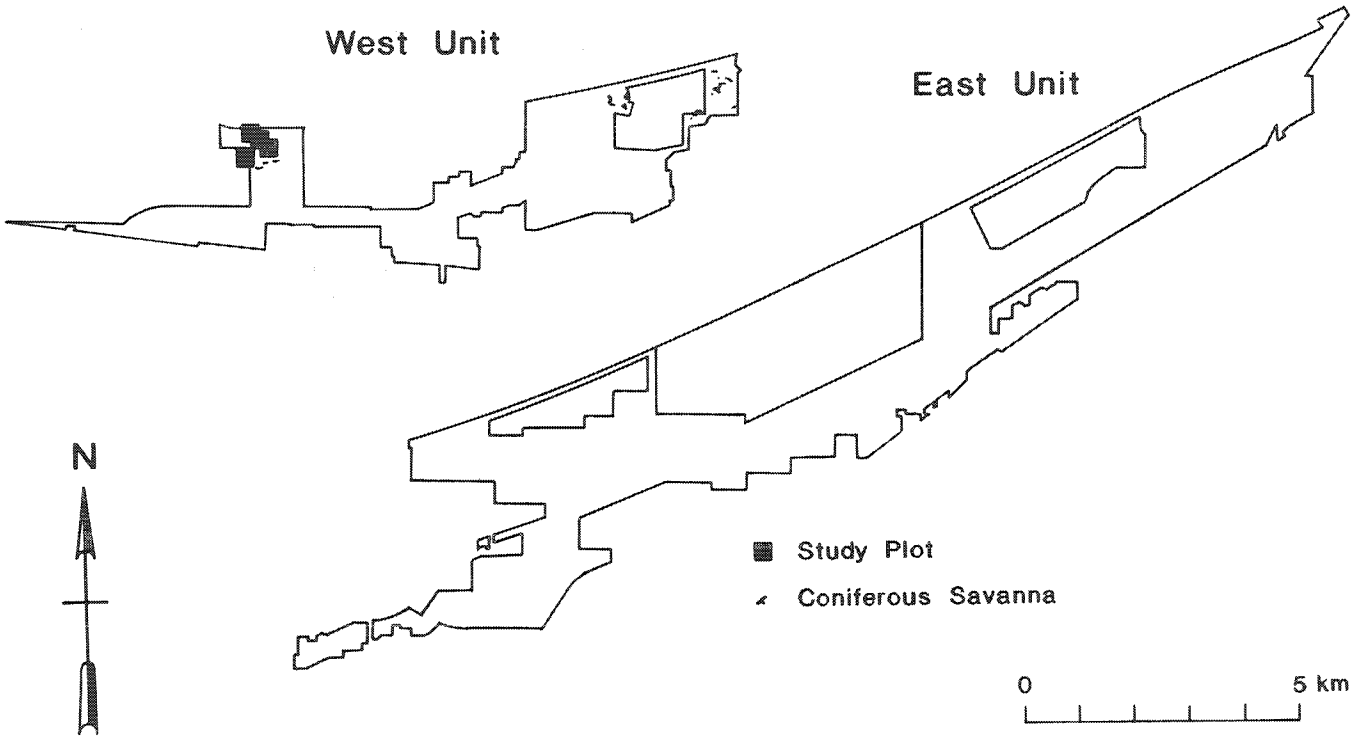

Fig. 18. Distribution of four plots in coniferous savanna, Indiana Dunes National Lakeshore.

to a canopy approaching that of oak forest. The white-footed mouse was favored in wooded plots, whereas the prairie deer mouse was favored in open areas. The occurrence of meadow voles and muskrats indicated a moist environment with good cover (near 100% ground cover, animal can move about freely without being seen from above) in some plots (two were along interdunal ponds); the presence of the thirteen-lined ground squirrel and the prairie deer mouse indicated dry, sparsely vegetated habitat in others.

Mixed Deciduous Savanna

There were only three plots in mixed deciduous savanna (Figs. 19 and 20). All had scattered eastern cottonwoods with little bluestem grass as the principal herbaceous species. Other major grasses were old witch grass (*Panicum capillare*) and brome grass (*Bromus* sp.). The shrub layer was mixed, but grape, aromatic sumac, and bearberry were some of the more abundant species. Grass provided fair to good cover in these plots.

Five species of mammals were taken in this habitat. The white-footed mouse was most abundant—it was taken in all three plots and totaled 20 individuals. Other mammals taken were four northern short-tailed shrews, one prairie deer mouse, one meadow mole, and one raccoon.

Fig. 19. Mixed deciduous savanna at West Beach.

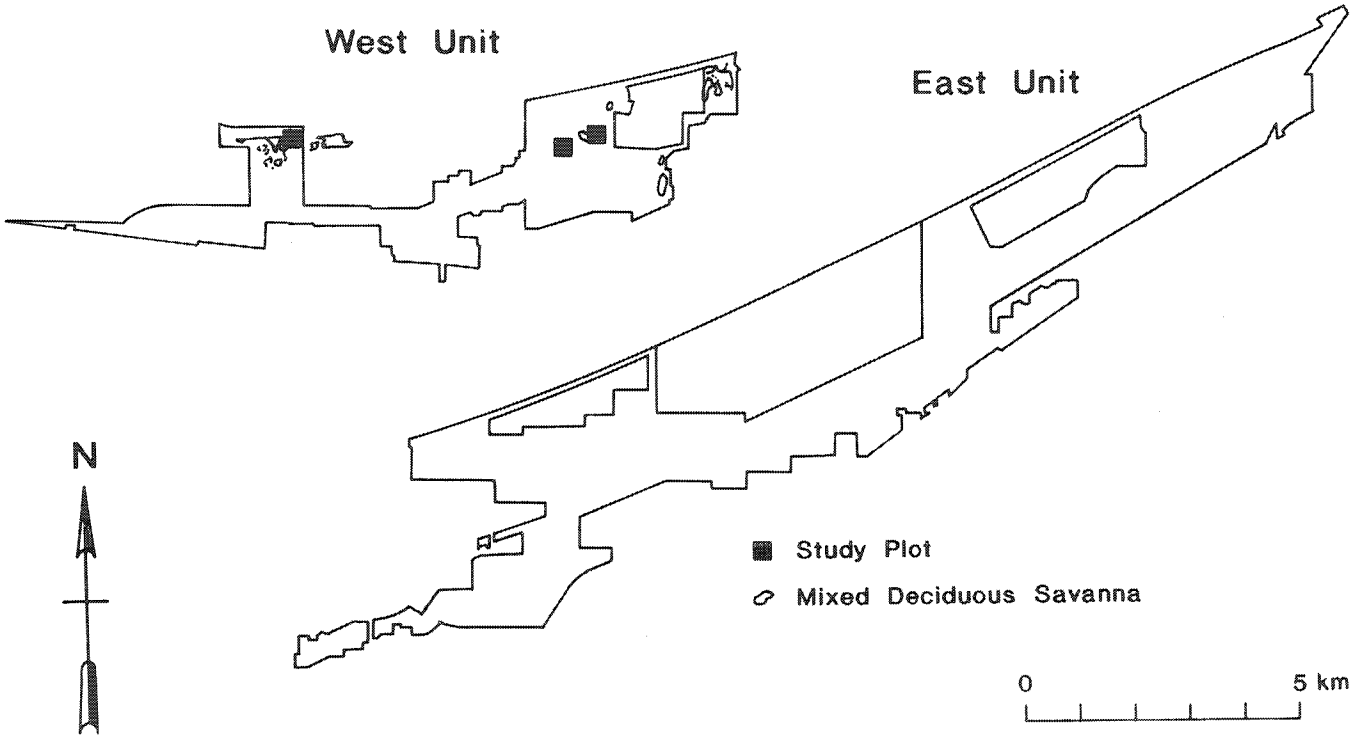

Fig. 20. Distribution of three plots in mixed deciduous savanna, Indiana Dunes National Lakeshore.

Upland Forest

Upland forest—about 30% of the entire area—is the most widespread habitat type in the lakeshore. Upland oak forest makes up 24.7% of the total lakeshore. Mixed deciduous forest makes up 5.4%, and coniferous forest constitutes 0.7%.

Upland Oak Forest

Oak forest graded into oak savanna, and together the two habitats made up a major proportion of the area of the lakeshore. Black oak predominates on the higher drier areas and red oak in the lower interdunal areas of the many rows of oak dunes at the lakeshore. Eight plots were included in upland oak forest (Figs. 21 and 22).

Vegetation was studied in six of the eight plots. One was predominantly red oak. Black oak was dominant in the remainder. Black oak forest consisted primarily of rather low scrubby black oaks, with relatively little undergrowth. The shrub layer was often dense and diverse in this habitat, often containing black oak sprouts and blueberry (*Vaccinium vacillans*). The herbaceous layer was often diverse, although it most often provided poor to fair cover. The

Fig. 21. Black oak forest near Cowles Bog.

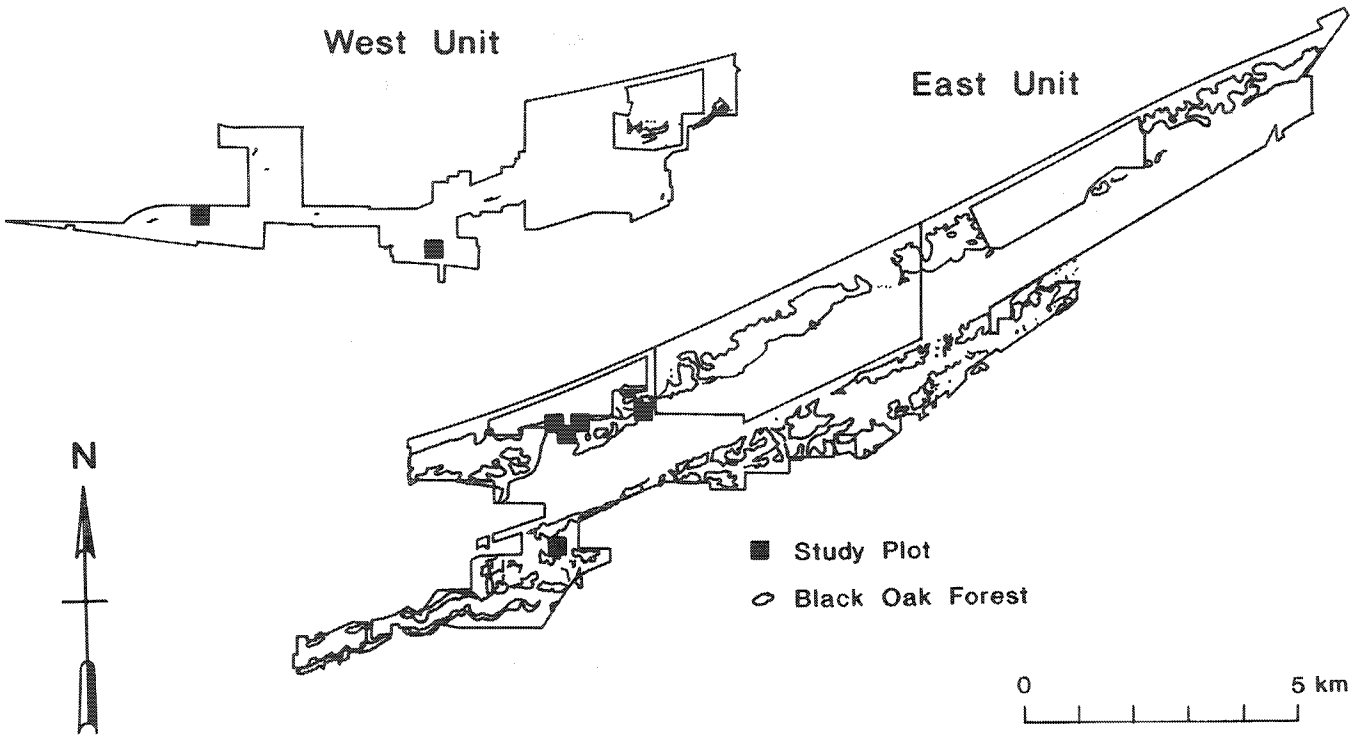

Fig. 22. Distribution of seven plots in upland (black) oak forest, Indiana Dunes National Lakeshore.

dominant herbaceous plants were most often Pennsylvania sedge (*Carex pennsylvanicus*) and bracken fern.

Twelve species of mammals were taken in this habitat. The white-footed mouse occurred in all 8 plots with 59 animals being taken. Five northern short-tailed shrews, two eastern gray squirrels, one eastern chipmunk, and one southern flying squirrel were also taken in traps. Sign or sightings of white-tailed deer were recorded in three plots; eastern chipmunk and eastern fox squirrel in two; and eastern mole, eastern gray squirrel, gray fox, long-tailed weasel, and eastern skunk in one each.

Upland Coniferous Forest

Upland coniferous forest makes up only 0.7% of the Indiana Dunes National Lakeshore (Figs. 23 and 24). Coniferous forest, particularly jack pine, often occurs on the front side of the second row of dunes. The coniferous forest replaces the briefly occurring shrub seral stage before being replaced by oak forest. This habitat is difficult to locate, and only four plots were studied. The plots differed. One studied in spring had a fairly dense canopy of white pine, black oak, and sassafras (*Sassafras albidum*) and a herbaceous layer of scattered sedges and bracken fern. The one plot studied in summer was in a red pine plantation in the state park near the beach house. It had a dense canopy, a sparse

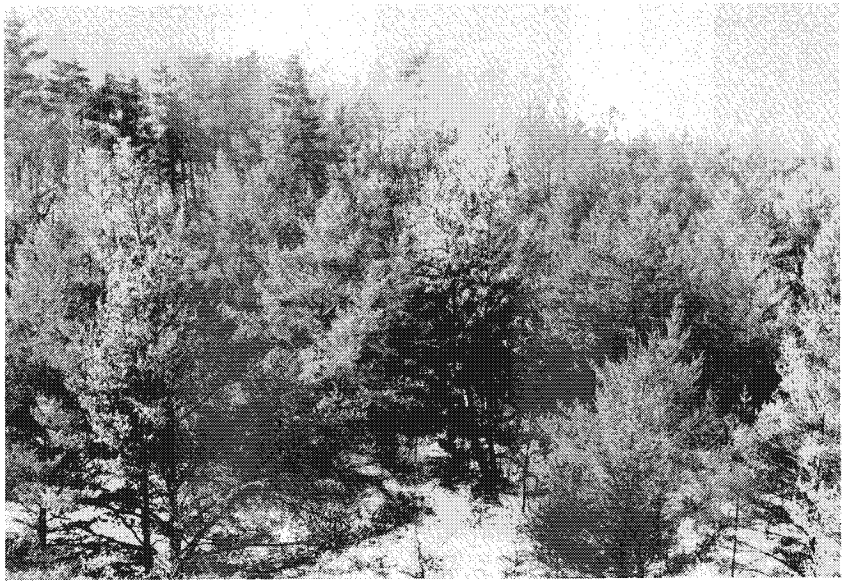

Fig. 23. Upland coniferous forest east of Dune Acres.

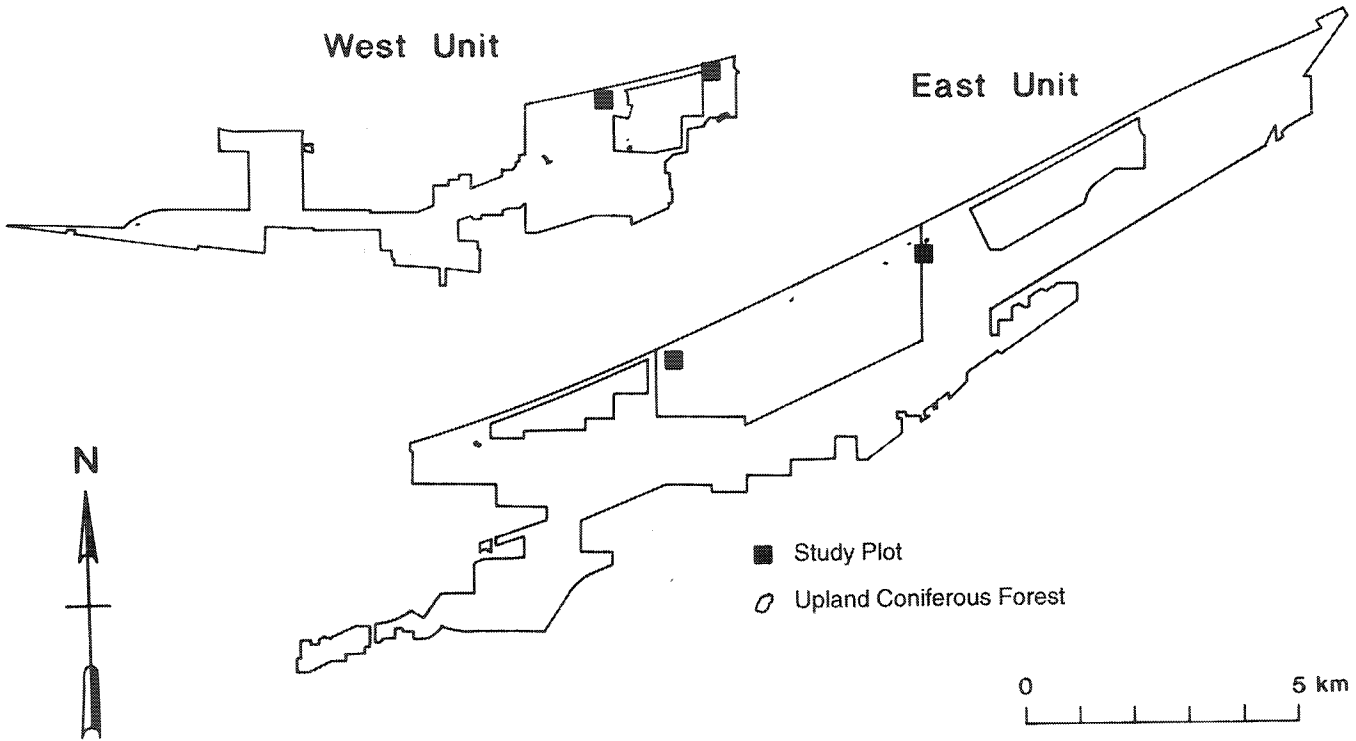

Fig. 24. Distribution of four plots in upland coniferous forest, Indiana Dunes National Lakeshore.

shrub layer with wild black cherry (*Prunus serotina*) the only common species other than the pine and a depauperate herb layer with some aster (*Aster*) and wild columbine (*Aquilegia canadensis*). The plots studied in fall and winter were the more typical low jack pine forest with scattered shrubs and very poor herbaceous cover. Bearberry was present in both and was common in the winter plot. Common juniper (*Juniperus communis*) and red osier dogwood were in the plot studied in fall.

Seven species were recorded in this habitat. The white-footed mouse was most abundant and occurred in all four plots (16 individuals were taken). No other species was trapped in more than one plot, but sign of the Virginia opossum and the white-tailed deer were each seen in one. Other mammals trapped were seven red squirrels, two eastern chipmunks, two common raccoons, and one eastern cottontail.

Upland Mixed Deciduous Forest

Mixed deciduous forest made up 5.4% of the lakeshore, and 13 study plots were located there (Figs. 25 and 26). Plots classed as upland mixed deciduous forest had a variety of dominant tree species, but oak (black, red, white, and pin [*Quercus palustris*]) and maple (red and silver) were the most common. One plot trapped in winter was a typical (presumably for the dunes area) climax beech–maple forest.

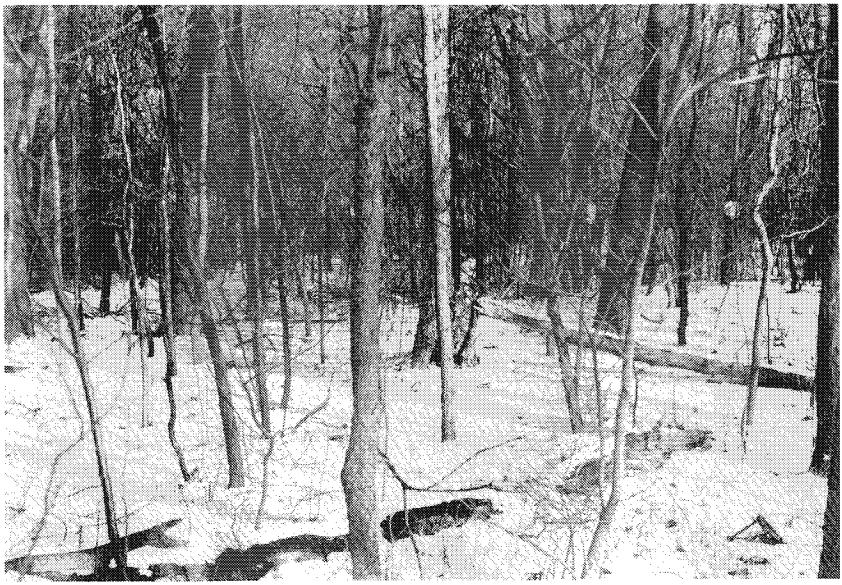

Fig. 25. Upland mixed deciduous forest near Lakeshore Headquarters.

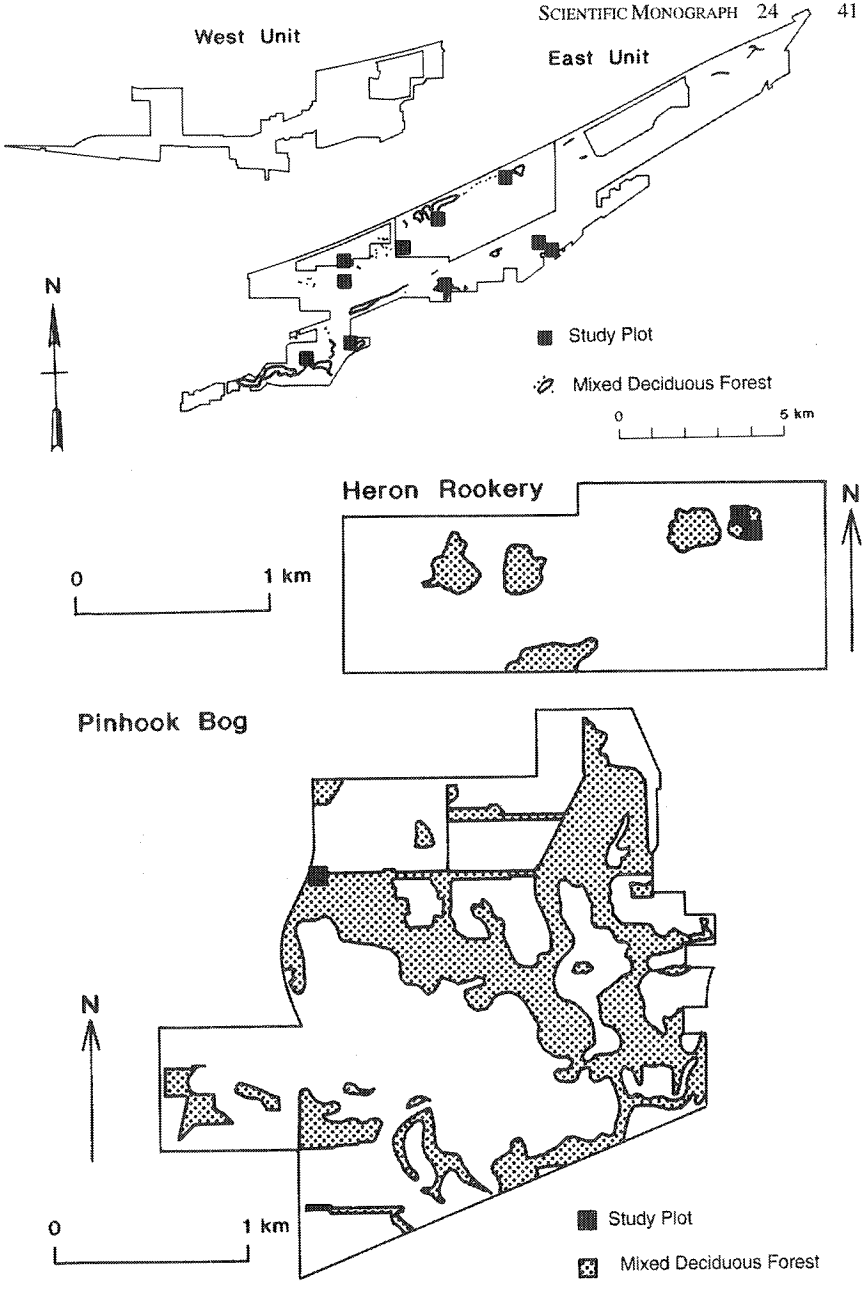

Fig. 26. Distribution of 13 plots in upland mixed deciduous forest, Indiana Dunes National Lakeshore.

Cherry, ash, and elm were other dominant species in a few plots. The species of the shrub layer varied, but witch hazel, Japanese honeysuckle, blueberry, spicebush (*Lindera benzoin*), and saplings of several tree species were prominent. Cover of the shrub layer ranged from sparse to dense. The herb layer was listed as sparse in most plots. Several herbaceous species were present, but some of the more common ones in these plots were *Poa*, *Carex*, *Agrimonia*, and *Osmorhiza*.

The most abundant species of mammal at the lakeshore and in this habitat was the white-footed mouse—81 individuals were taken in 12 of the 13 plots. The second most abundant species was the common raccoon (nine taken), followed by northern short-tailed shrews (six), Virginia opossum (two), woodchuck (one), and red squirrel (one). Eastern moles, eastern fox squirrels, and white-tailed deer (or sign) were observed in three plots. Ten species were recorded in this habitat.

Lowland Forest

Lowland forest is the second largest habitat in the lakeshore after upland forest. It was divided into perennial (23% of the area) and ephemeral wet lowland forest (67% of the area).

Ephemeral Lowland Forest

Nine plots were in ephemeral lowland forest (Figs. 27 and 28). Plant data were collected in seven of the nine plots. The canopy was usually quite dense but varied in species composition. Silver or red maple were present in six plots, followed by oak and ash each in two plots and aspen and sassafras each in one. The shrub layer varied from sparse to dense and consisted mostly of seedlings of the trees previously mentioned plus spicebush, *Viburnum*, *Cornus*, and others. Ground cover varied from fair to excellent, and species composition varied greatly between plots.

Twelve species of mammals were recorded in this habitat. Seventy white-footed mice were taken in traps in seven of the nine plots. Twelve northern short-tailed shrews and four eastern chipmunks were taken in four plots; six common raccoons were taken in five plots; three long-tailed weasels were taken in two plots; and two red squirrels, one masked shrew, one eastern cottontail, one meadow vole, and one woodchuck were each taken in one plot. White-tailed deer (or sign) were observed in four plots; eastern mole and eastern cottontail in one.

Perennial Lowland Forest

Perennial lowland forest retains water more than 6 months of the year. Mammals were sampled from 18 plots in the perennial lowland forest (Figs. 29 and 30). Vegetation varied greatly in this habitat. Maple was most often a dominant tree (seven plots) followed by oak (pin oak in four, black oak in one), aspen in four, elm in three, and birch and wild black cherry each in two. These same tree species were common in the shrub layer, along with many others,

including blueberries, winterberry (*Ilex verticillata*), and *Rubus*. The herb layer varied even more, although graminoids and ferns were common. Most plots had a large number of species, and ground cover varied from excellent in some plots to almost entirely absent in others. The herb and shrub layers were often clumped in hummocks.

The white-footed mouse (53 individuals) was taken in 13 of the 18 plots in this habitat. Seven common raccoons; six northern short-tailed shrews; five eastern chipmunks; and one each Virginia opossum, masked shrew, woodchuck, and eastern fox squirrel were taken in traps. White-tailed deer sign was recorded in 11 plots, raccoon were taken or sign seen in 7, and chipmunks in 6. Fifteen species were recorded in this habitat, including red squirrels observed or sign in three plots, eastern moles (two), domestic dog (two), and eastern cottontail, woodchuck, and meadow vole (each one).

Burrows in two plots could have been of the star-nosed mole, but no individuals were taken. The star-nose mole has not been taken at the lakeshore, and additional work is needed to determine if it is present. The westernmost record for that species in the state is at Trail Creek at the southern edge of Michigan City, or just east of Indiana Dunes State Park.

Fig. 27. Ephemeral lowland forest near Lakeshore Headquarters.

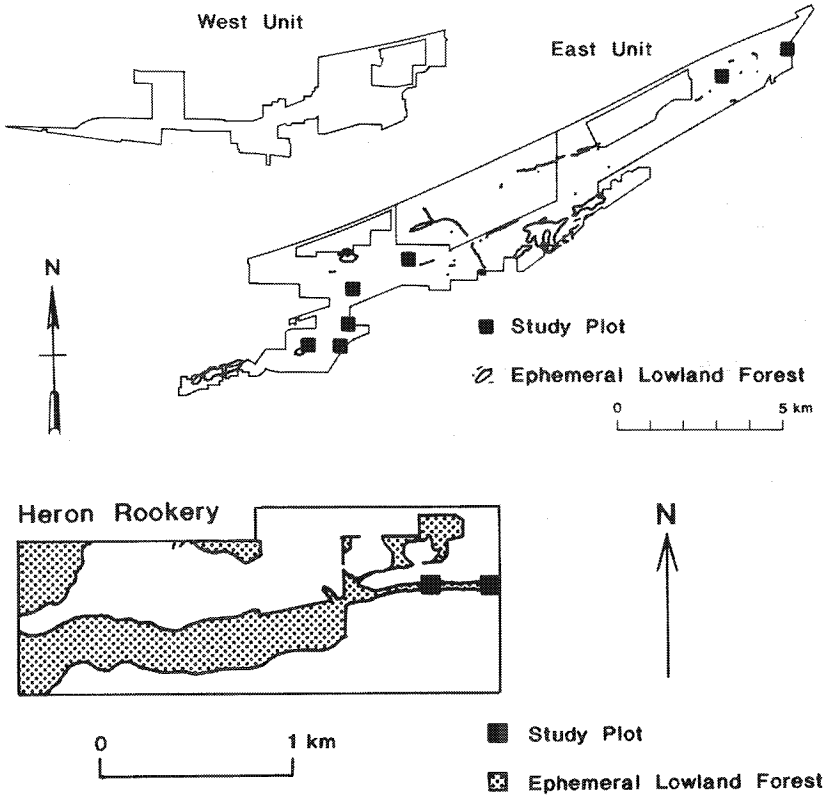

Fig. 28. Distribution of nine plots in ephemeral lowland forest, Indiana Dunes National Lakeshore.

We feel that shrews were under-sampled in this habitat. Numerous shrews should have been taken in the sunken can traps here. Low catch could have been due to the dry conditions, especially in the extreme-drought summer of 1988.

Wetlands

A variety of types of wetlands exists in the lakeshore. The largest in area is marsh (6%) followed by 1% each in aquatic shrubland, swamp, and bog, 0.5% in panne (depressions behind the foredunes), and 3% in open water.

Fig. 29. Perennial lowland forest near Lakeshore Headquarters.

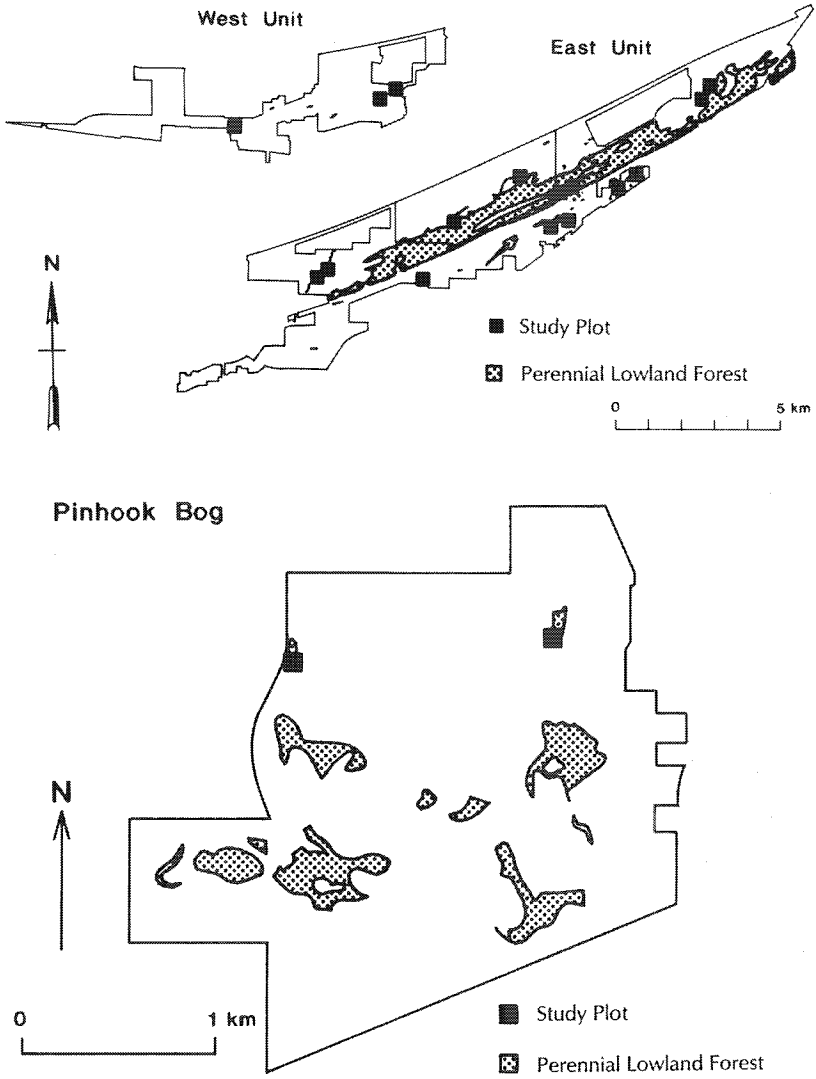

Fig. 30. Distribution of 18 plots in perennial lowland forest, Indiana Dunes National Lakeshore.

Marsh

Marsh habitat on the area (Figs. 31 and 32) includes the Grand Marsh or, currently, the Great Marsh. Many common muskrats occur in these marshes, but marsh trapping was more along the edges of the marshes than within them. Much of the marsh is cattail (*Typha*), but many other species such as bulrushes, sedges, and sometimes buttonbush occur there.

Cowles Bog, in many senses, is a marsh rather than a bog because cattail is the dominant plant species. However, it is a floating mat of vegetation more typical of bogs, and it does have some of the typical bog species—grass-of-parnassus (*Parnassia glauca*) and pitcher plant (*Sarrecenia purpurea*).

Vegetation was studied in seven plots in marsh. Canopy was absent in most but consisted of scattered willows or elms in a few. The shrub layer consisted

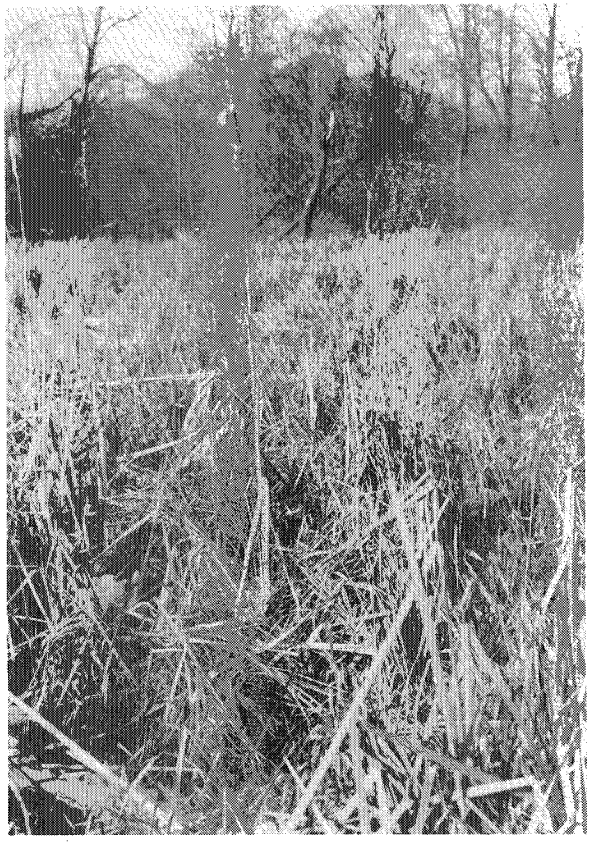

Fig. 31. Marsh; remnant of Great Marsh near Dune Acres.

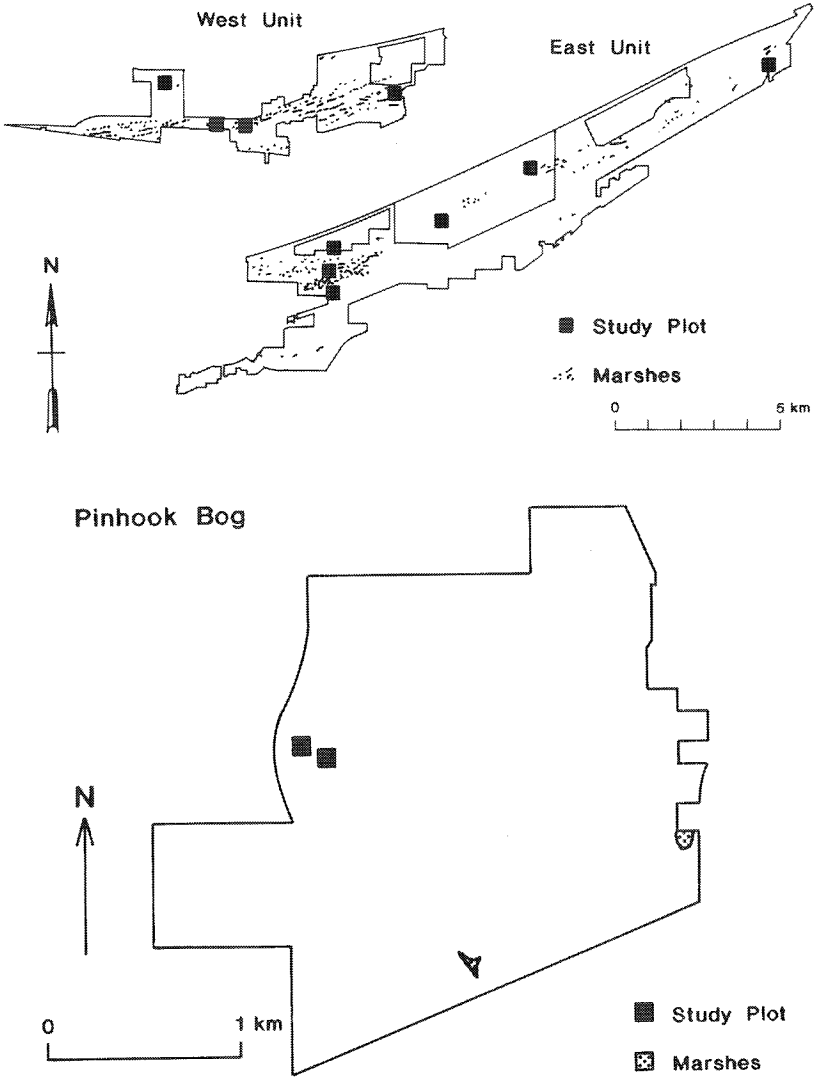

Fig. 32. Distribution of 12 plots in marshes, Indiana Dunes National Lakeshore.

of thick buttonbush in five of the plots, was absent in one, contained willow in one, and *Ribes* in one. The herb layer was most often of cattail, sedges, or blue joint grass, although false nettle (*Boehmeria cylindrica*) was a dominant in two plots and *Juncus* in one plot.

Twelve species of mammals were recorded from marsh habitat. Three species were of near equal importance—the masked shrew, the white-footed mouse, and the meadow vole—followed by the northern short-tailed shrew, the common raccoon, and the white-tailed deer. Other species recorded in lower numbers were the eastern cottontail, the eastern chipmunk, the woodchuck, the prairie vole, the common muskrat, and the long-tailed weasel.

The muskrat is a major species in the marshes, lakes, and ditches of the area but did not show up extensively in the marsh plots. The plots were not out in the water, nor were muskrat traps used. Common muskrats are abundant at the lakeshore (see common muskrat species account).

Aquatic Shrublands

Aquatic shrublands made up about 1% of the total lakeshore (Figs. 33 and 34). Vegetation was studied in three plots. The canopy was absent in two plots and consisted of open oaks in one. The shrub layer was of aspens, willows, or oaks, and the herb layer was of blue joint grass or cattails.

Eight mammal species were recorded in this habitat. The northern short-tailed shrew, the white-footed mouse, and the meadow vole were the mammals with the most widespread occurrence in plots in this habitat, although only four, three, and three individuals were taken in the plots involved. The greatest number of one species taken was of the meadow jumping mouse (13, all in one plot). The eastern cottontail, the prairie vole, the common raccoon, and the white-tailed deer were each recorded in one plot.

Swamp

About 1% of the lakeshore is in swamp, and four study plots were established there (Figs. 35 and 36). Three of the four plots were assessed for vegetation. The canopy in each instance was of eastern cottonwood or black willow (Salix *nigra*). The willow was a dominant in the shrub layer along with blackberry in one plot and grape in another. The excellent ground cover was mainly of grasses (blue joint grass or *Phalaris*), sedges, and cattails.

Much of the swamp habitat was covered with water, but eight meadow voles were taken in two of the plots and nine white-footed mice were taken in one. Also, two common raccoons and one fox squirrel were taken in traps, and eastern cottontail sign was seen in one plot.

Additional collections were made by J. O. Whitaker and R. E. Mumford in fall 1978 in the swamp just north of Cowles Bog. Three species were taken there, including 33 masked shrews, 10 white-footed mice, and 2 northern short-tailed

shrews. These data indicate high numbers of masked shrews in swamp at the lakeshore — in contrast to present data. We suspect that shrew populations were low during the time of the present study because few shrews were taken in any habitat.

Bogs

Two bogs, Pinhook Bog (Fig. 37) and Cowles Bog (Fig. 38), are in the Indiana Dunes National Lakeshore. Bogs are acidic or sometimes calcareous ponds with poor drainage that have become covered with mats of vegetation, particularly *Sphagnum*. They are often called sphagnum bogs. Some typical plants of bogs besides *Sphagnum* are pitcher plants, sundew (*Drosera* sp.), cotton grass (*Eriophorum* sp.), and poison sumac (*Rhus vernix*), with heaths (Ericaceae) such as leatherleaf (*Chamaedaphne calyculata*), blueberries, bog rosemary (*An-*

Fig. 33. Aquatic shrublands near Cowles Bog.

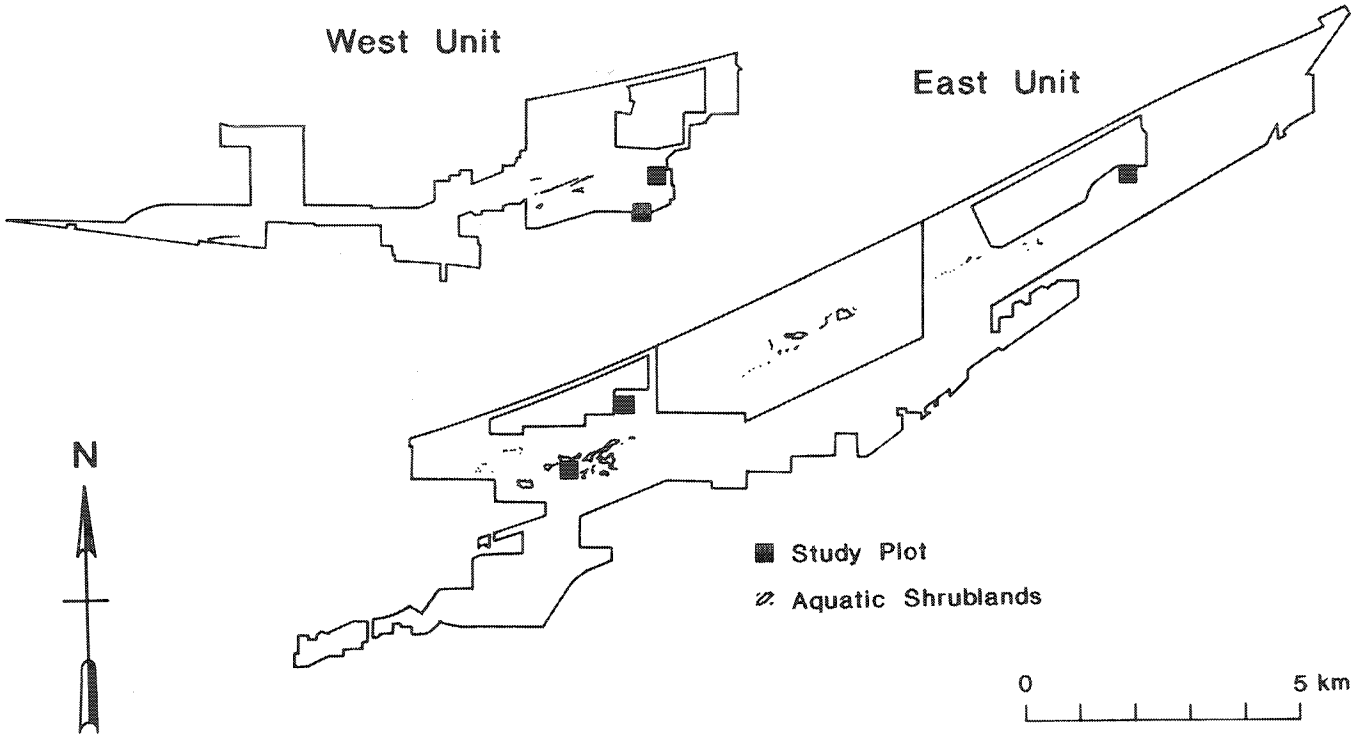

Fig. 34. Distribution of five plots in aquatic shrublands, Indiana Dunes National Lakeshore.

dromeda glaucophylla), and cranberries being dominant. Tamarack (*Larix laricina*) often occurs mostly at the perimeter.

Pinhook Bog is typical, probably the best example in Indiana, and is the only bog we trapped during the present survey. Cowles Bog is not a typical bog as exhibited by its vegetation. Rather than heaths, dominant herbaceous plants there are cattail, boneset, jewelweed, and other marsh or wet meadow plants, although tamarack and poison sumac are common.

Information on the mammals of bogs comes from the three plots at Pinhook Bog studied during the present survey (Fig. 39) and also from trapping at both Pinhook and Cowles bogs by J. O. Whitaker and R. E. Mumford in 1978.

Pinhook Bog. Three plots were trapped in summer, and one was trapped in both summer and winter to provide four data sets. The plot trapped in spring is

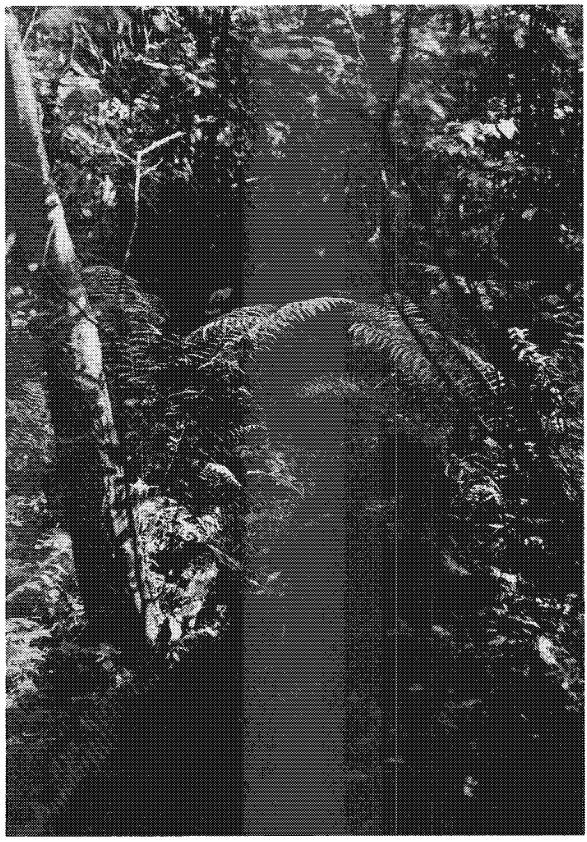

Fig. 35. Swamp at Cowles Bog.

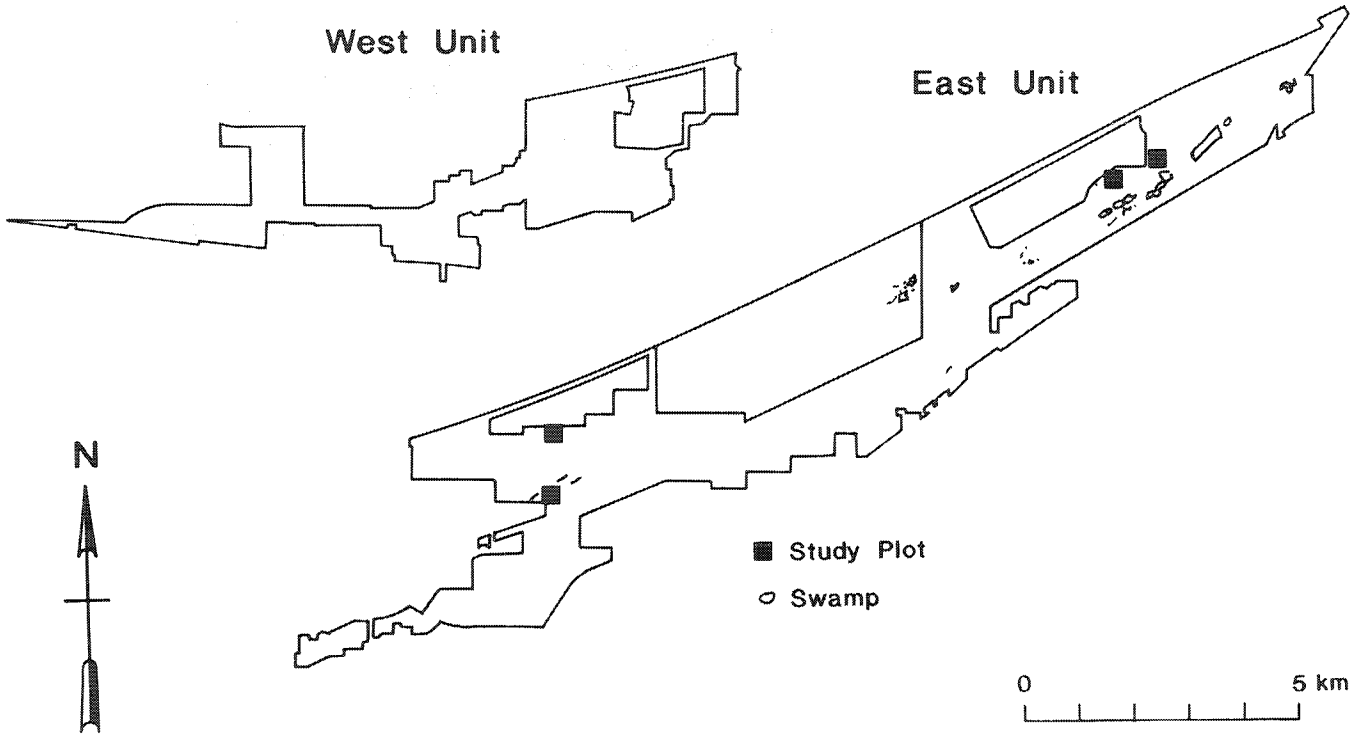

Fig. 36. Distribution of four plots in swamp, Indiana Dunes National Lakeshore.

best characterized as bog–perennial lowland forest. None of the typical bog plants were present. The dominant plant in the canopy was willow. The shrub layer had a number of species but included buttonbush, winterberry, poison ivy (*Rhus radicans*), wild rose, and other species, whereas the herb layer was dominated by blue joint grass and a smartweed—water heartsease (*Polygonum coccineum*). The other plots contained typical bog vegetation. The canopy was sparse but included tamarack and some pines and willows. The shrub layer was of typical bog species—bog rosemary, leatherleaf, blueberry, and huckleberry (*Gaylussacia baccata*). The herb layer contained sphagnum, sedges, and pitcherplant.

We took five species of mammals in the four plots in this habitat. The white-footed mouse was the only mammal taken in more than one plot (16 were

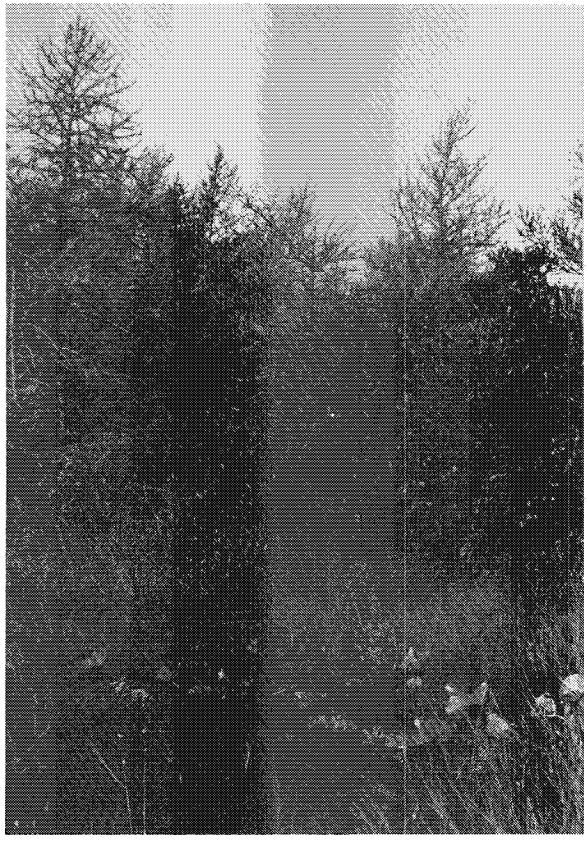

Fig. 37. Pinhook Bog.

taken in two plots). Other species taken were three northern short-tailed shrews, one eastern cottontail, one eastern chipmunk, and one common raccoon.

Mumford and Whitaker took 70 small mammals during their trapping (4,250 trap nights) of Pinhook Bog in 1978, the majority by sunken cans (pitfalls). Of these, 47 were masked shrews, 8 were northern short-tailed shrews, 5 were white-footed mice, 5 were meadow jumping mice, 3 were meadow voles, and 2 were house mice. We took no masked shrews in Pinhook, and only a few were taken during the present study. The house mouse is abundant in cultivated fields with ample ground cover in Indiana but is not often caught in native habitats. Few house mouse records exist from the dunes area. None were taken in the agricultural fields, but this was undoubtedly because of the low amount of herbaceous cover in the fields when trapped.

Fig. 38. Cowles Bog.

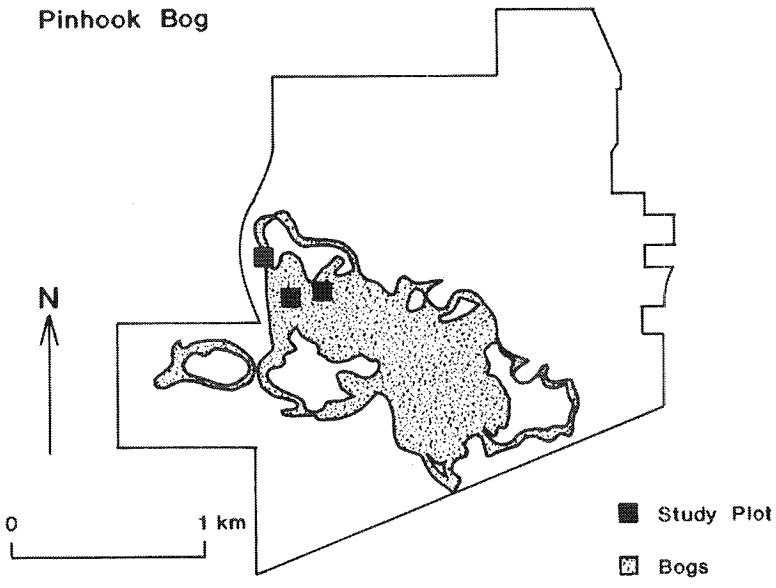

Fig. 39. Distribution of three plots in bogs, Indiana Dunes National Lakeshore.

Cowles Bog. Mumford and Whitaker (1982) trapped for small mammals in Cowles Bog in 1978. Another 32 masked shrews were taken there along with 5 northern short-tailed shrews, 4 meadow voles, and 1 meadow jumping mouse (400 trap nights).

Pannes

The pannes are shallow depressions behind the front line of dunes (Fig. 40). They contain water much of the time and are often surrounded by grassy areas and shrubs. Hiebert et al. (1986) presents more information on pannes.

Vegetation was studied in two of the three plots in pannes (Fig. 41). The canopy layer was absent and the shrub layer was dense in a plot trapped in summer containing red osier dogwood, willow, and Kalm's St. John's wort (*Hypericum kalmianum*) but was sparse and contained only the latter species in a single plot trapped in fall. The herb layer formed excellent cover in the plot trapped in summer and fair in the plot trapped in fall. A number of herbaceous species were present including several members of the family Cyperaceae, *Eleocharis*, twig rush (*Cladium mariscoides*), *Rhynchospora*,

Fig. 40. A panne near West Beach.

and lake shore rush (*Juncus balticus*), strawberry, mountain mint (*Pycnanthemum virginianum*), and others.

Five species of mammals were taken in the three plots in pannes. The meadow vole was the only regularly occurring species (13 taken in two of the three plots).

Three white-footed mice were taken in one of the plots, whereas three prairie deer mice were taken in another. The absence of overlap of these two species in this habitat further enhances the value of a study of the interrelations of these two species in the lakeshore area. Other species trapped in this habitat were one Virginia opossum and one northern short-tailed shrew.

Aquatic Areas

Aquatic habitat consisted of areas with standing water (Fig. 42) too deep for emergent vegetation such as cattails—fauna in that habitat could not be sampled. We did sample mammals from four plots on the edge of the aquatic community (Fig. 43).

The plots listed in this edge habitat varied. Three were studied for vegetation. One for which samples were taken in spring was a black oak–shrub marsh ecotone with a red maple, sweet gum, sassafras, and slippery elm (*Ulmus rubra*)

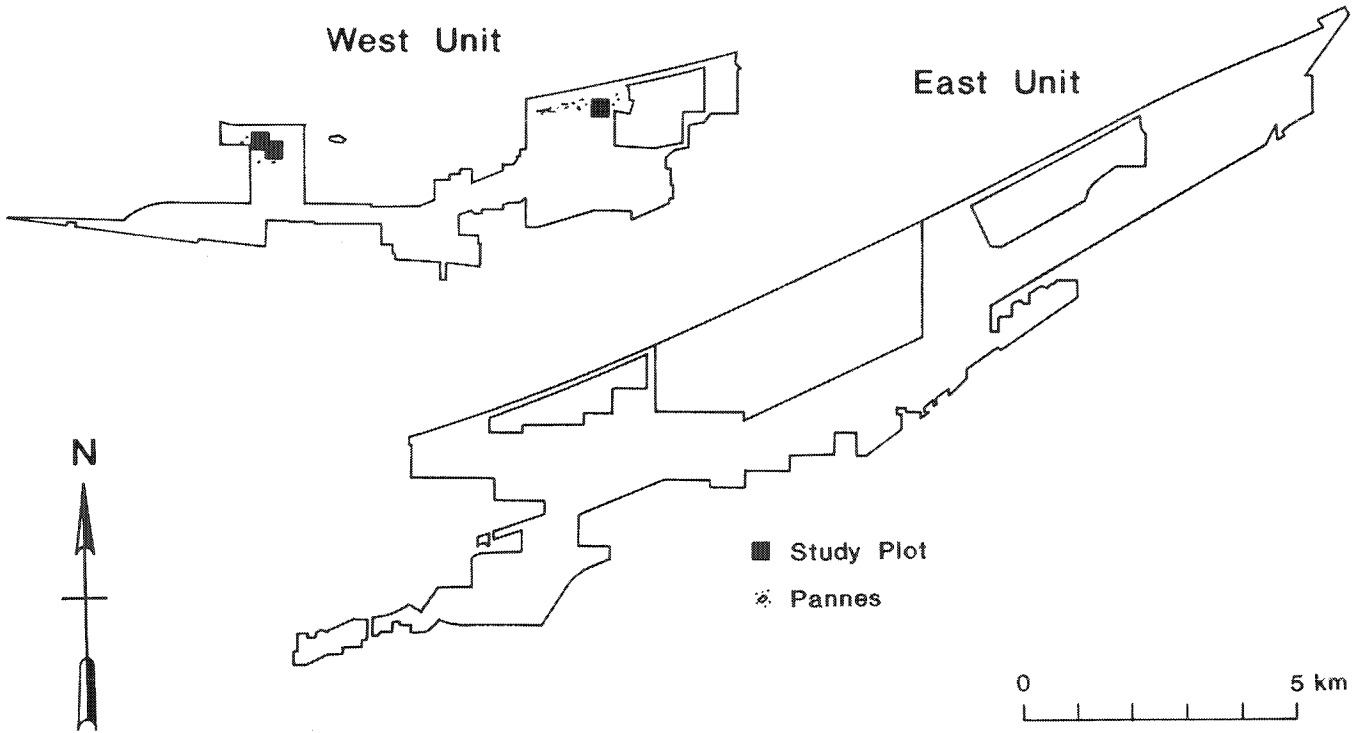

Fig. 41. Distribution of three plots in pannes, Indiana Dunes National Lakeshore.

Fig. 42. An aquatic area at Miller Woods.

canopy and a buttonbush shrub layer. The herbaceous layer had clumps of royal fern. One trapped in summer was an ecotone between a black oak savanna and a pond with a dense herb layer of blue joint grass and sedges. Another trapped in summer was the edge of a shallow pond densely populated with grasses and rushes.

White-tailed deer and white-footed mice each were present in three of the four plots, whereas common raccoons and fox squirrels were present in two. Other species taken or sign observed in this habitat were the northern short-tailed shrew, the common muskrat, and the red fox.

Developed Areas

Developed land at the Dunes National Lakeshore includes agricultural areas (3.6% of the area), pine plantations, razed residential areas (4.7%), park facilities (0.4%), rights-of-way (area assessment not currently available), and excavated areas (0.1%). Data were collected from all of these except park facilities.

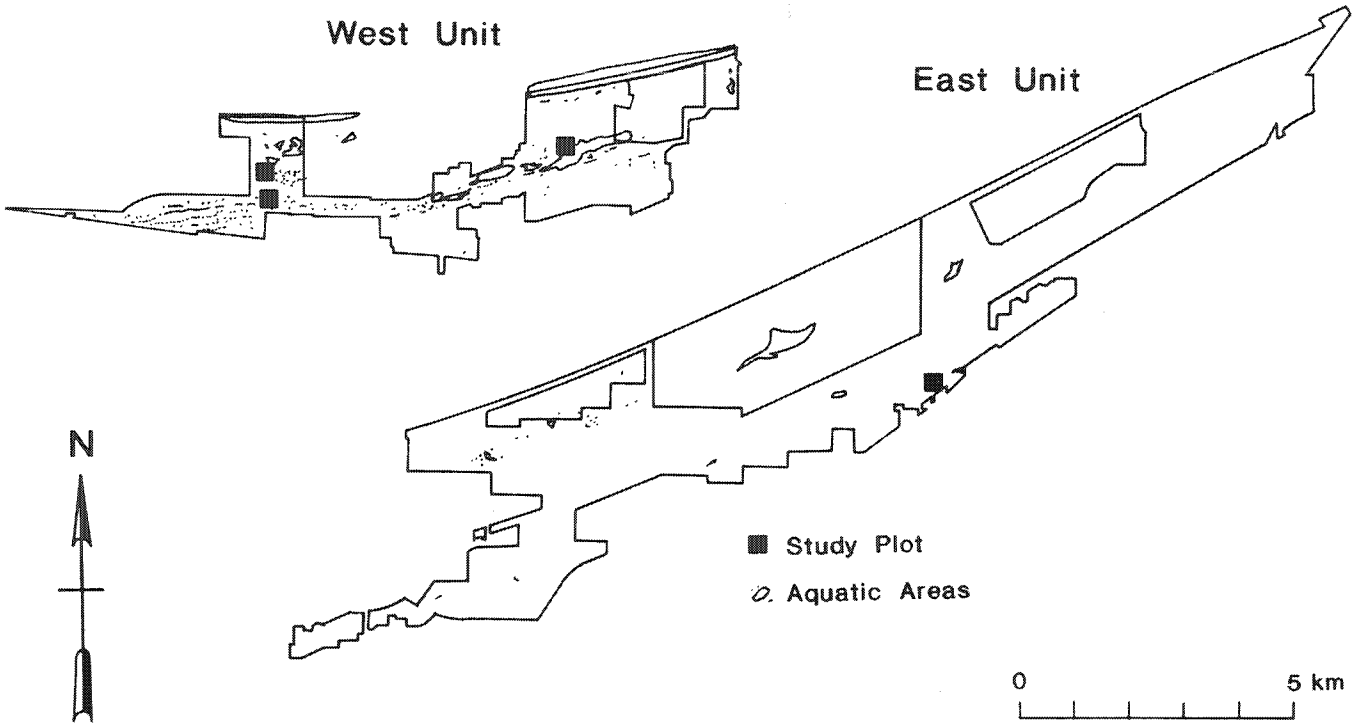

Fig. 43. Distribution of four plots in aquatic areas, Indiana Dunes National Lakeshore.

Agricultural Field; Old Field

Many of the agricultural areas are actually now old fields rather than cultivated areas per se (Fig. 44). Nine plots were studied in agricultural land, of which the vegetation was assessed in eight (Fig. 45). One summer plot was a recently harvested alfalfa field. The rest had somewhat different origins (abandoned croplands, pasture, mowed area), but all are presently early seral old fields. The canopy was totally absent in all; scattered shrubs were present in six. Shrubs consisted of blackberry, poison ivy, wild rose, shoots of maple and ash, and a variety of other species. The herbaceous layer consisted of a great variety of old field plant species: the dominants were the grasses—orchard grass (*Dactylus glomerata*), blue grass (*Poa* sp.), red top (*Agrostis* sp.), and fescue (*Festuca* sp.)—and the forbs—wild carrot (*Daucus carota*), asters, goldenrods, sedges, yarrow (*Achillea millefolium*), and evening primrose (*Oenothera biennis*).

In northern Indiana, the meadow vole is the most abundant species in the meadows, and 90 individuals of this species were in the nine plots we studied. Nine prairie voles were in four of the plots. Shrews are often common in wet meadows in northern Indiana, and 12 northern short-tailed shrews were taken in four plots. Only three masked shrews were taken. No meadow jumping mice were taken.

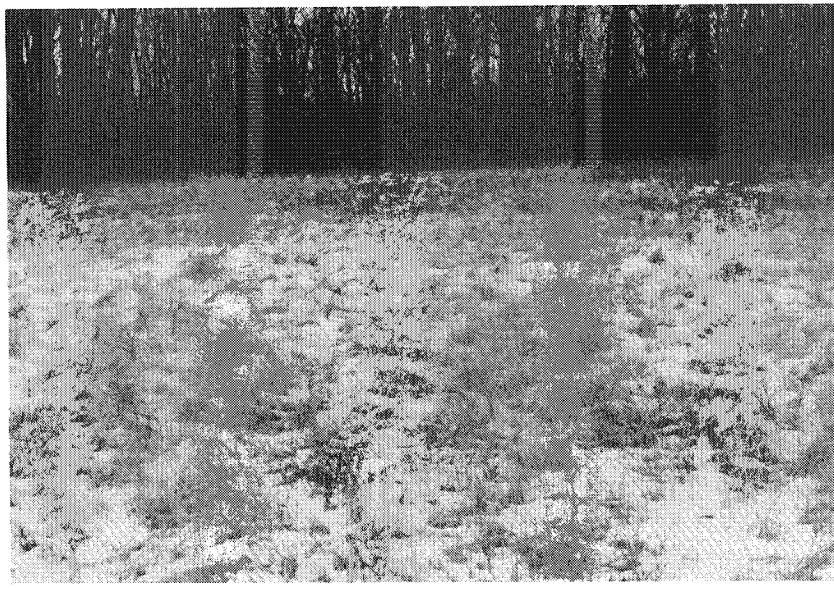

Fig. 44. An agricultural area near Lakeshore Headquarters.

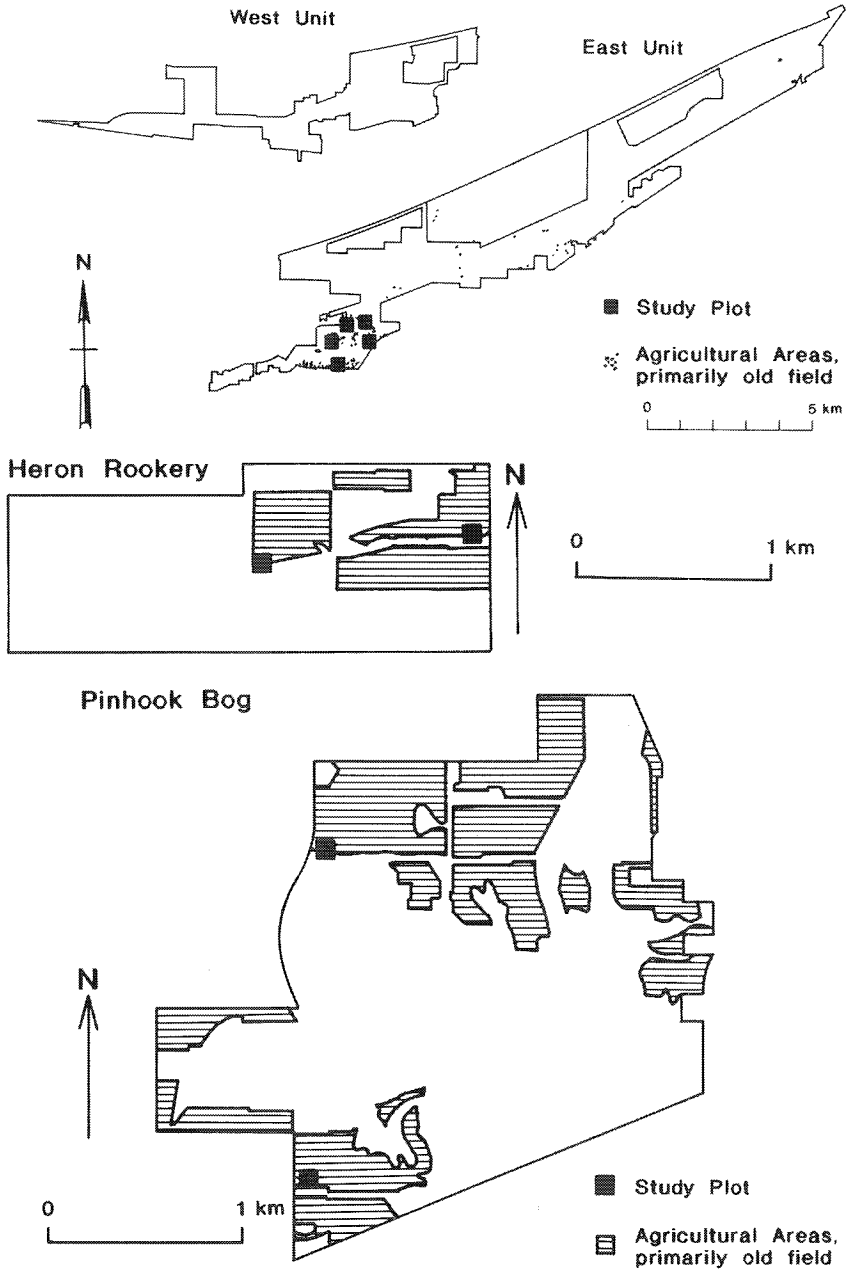

Fig. 45. Distribution of nine plots in agricultural areas, primarily old field, Indiana Dunes National Lakeshore.

Fourteen species of mammals were recorded from this habitat. These included, besides the species indicated above, four white-footed mice, three raccoons, two woodchucks, two Virginia opossums, two long-tailed weasels, one eastern cottontail, and one striped skunk in traps; and eastern chipmunk, eastern fox squirrel, meadow vole, and white-tailed deer for which sign or animals were observed in plots.

Pine Plantations

Three plots were in pine plantations (Figs. 46 and 47). The pines involved were Virginia pine in one plot and red pine and white pine in the other two. The shrub and herb layers were sparse in all plots, generally providing poor cover. A mixture of shrub species was present, but some of the major ones were blackberry, witch hazel (*Hamamelis virginiana*), juniper, Virginia creeper (*Parthenocissus quinque-*

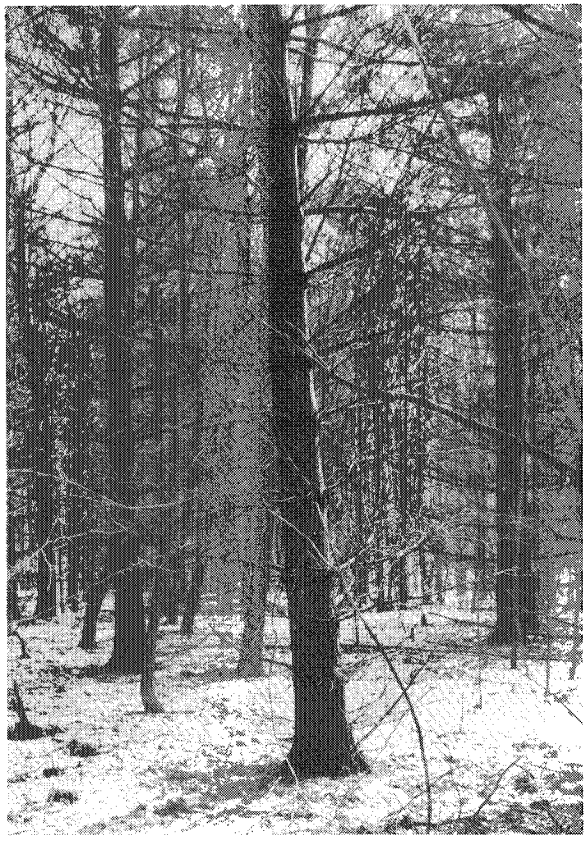

Fig. 46. Pine plantation near Lakeshore Headquarters.

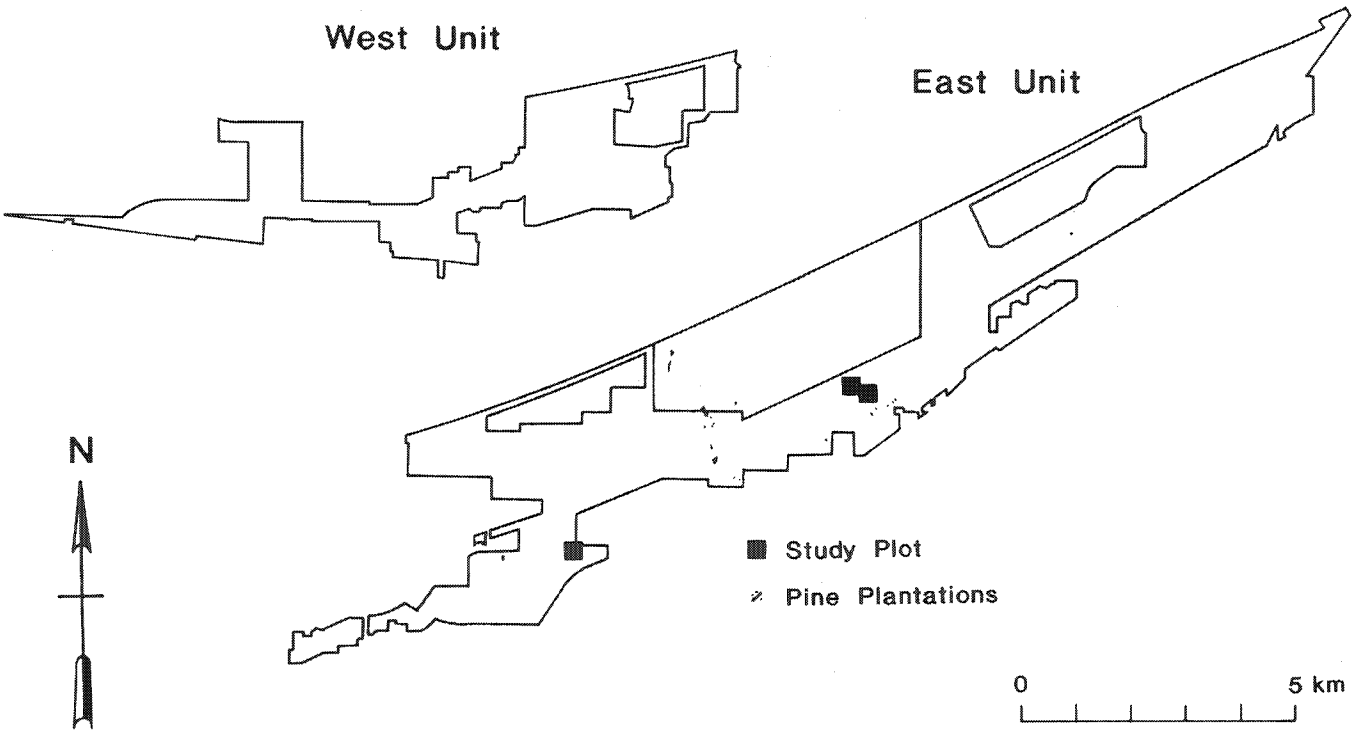

Fig. 47. Distribution of three plots in pine plantations, Indiana Dunes National Lakeshore.

folia), and shoots of wild black cherry, oak, sassafras, and ash. Some of the herbaceous plants present were little bluestem grass, panic grass, sheep sorrel (*Rumex acetosello*), and bracken fern.

The white-footed mouse was the most abundant species, although the 10 individuals were all taken in one of the three plots. Six species of mammals were recorded in this habitat. Included from trapping were one northern short-tailed shrew and one common raccoon. Sign was seen of eastern mole, eastern cottontail, and white-tailed deer.

Razed Residential

The lakeshore has several areas where homes have been or are being removed. The areas are reverting to natural habitat (Fig. 48). Eleven plots were included in this habitat (Fig. 49); plant data were gathered for 6. All six had a sparse canopy, most including eastern cottonwood, but maple, elm, ash, and others were present in some plots. The shrub layer was thin but consisted of eastern cottonwood, ash, and willow seedlings, wild and multiflora rose (*Rosa multiflora*), Japanese honeysuckle, blackberry, grape, and red osier dogwood. The herb layer formed fair to excellent cover and was primarily of grasses (*Poa*, *Panicum*, *Festuca*), goldenrods, and asters.

Fig. 48. One of several razed residential areas near Lakeshore Headquarters.

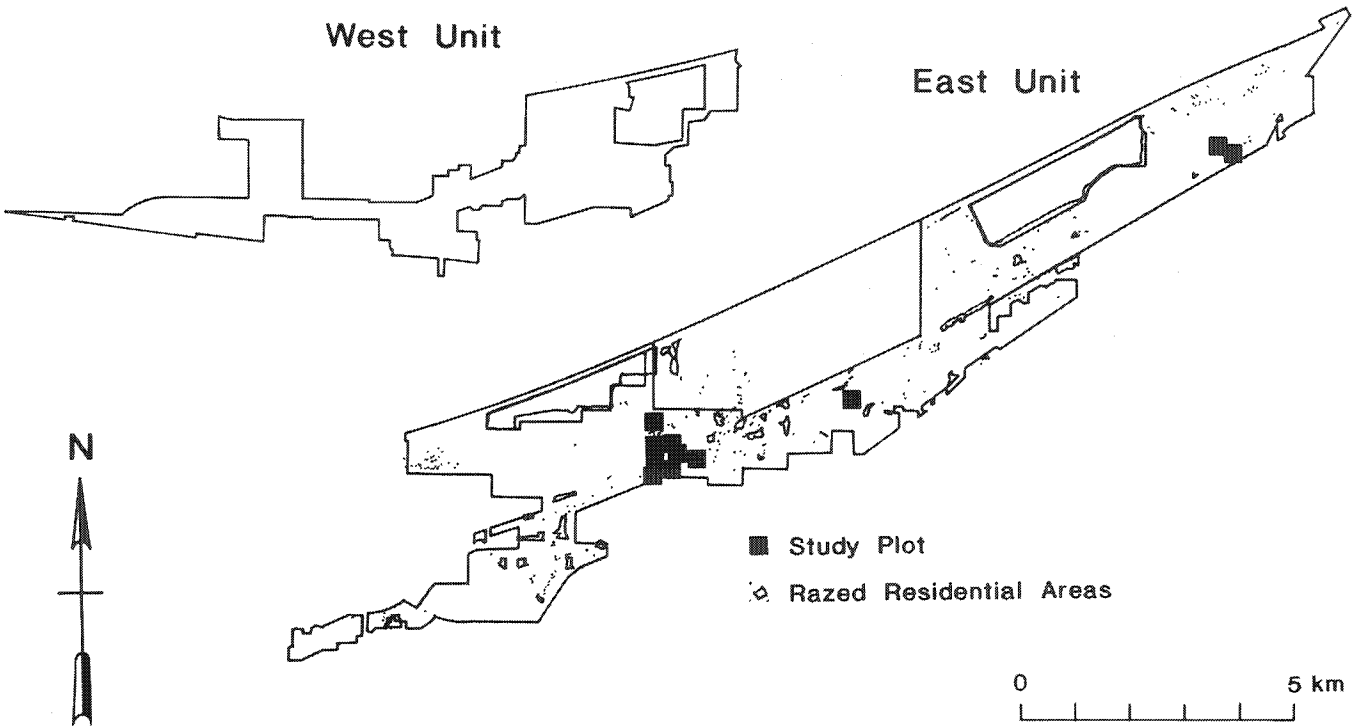

Fig. 49. Distribution of 11 plots in razed residential areas, Indiana Dunes National Lakeshore.

This habitat was transitional with no well developed mammal community. Nine species were recorded in this habitat. The white-footed mouse was the most common mammal present. It occurred in six of the plots, but only 18 individuals were taken (1.6 per plot). The raccoon, another common and wide-ranging mammal, was the only other species taken in more than one plot or in which more than one individual was taken. The others were northern short-tailed shrew, eastern mole, woodchuck, eastern fox squirrel, striped skunk, and white-tailed deer.

Rights-of-way

Six plots were studied in rights-of-way along roads, railroads, or bike trails (Figs. 50 and 51). One plot was disturbed wet woodland with a quaking aspen canopy and blackberry as the dominant plant in the shrub layer. Blue joint grass

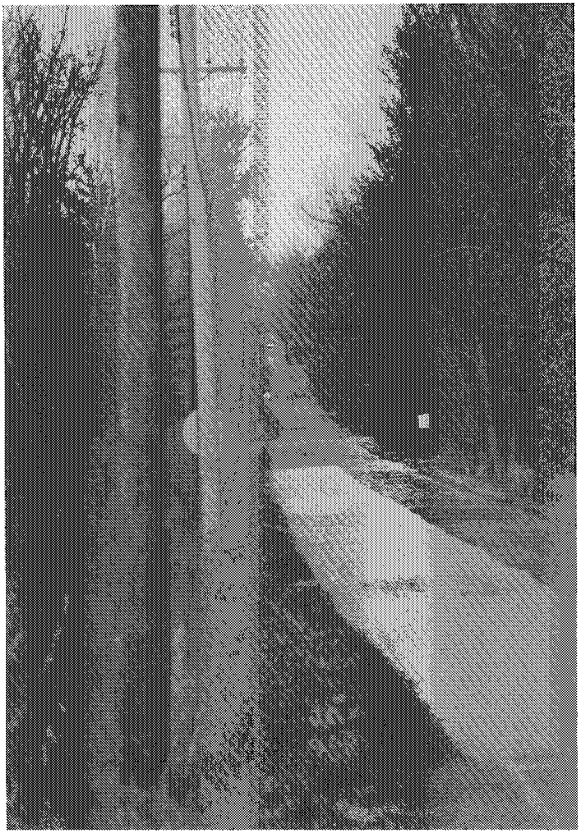

Fig. 50. Right-of-way, Waverly Road near State Route 12.

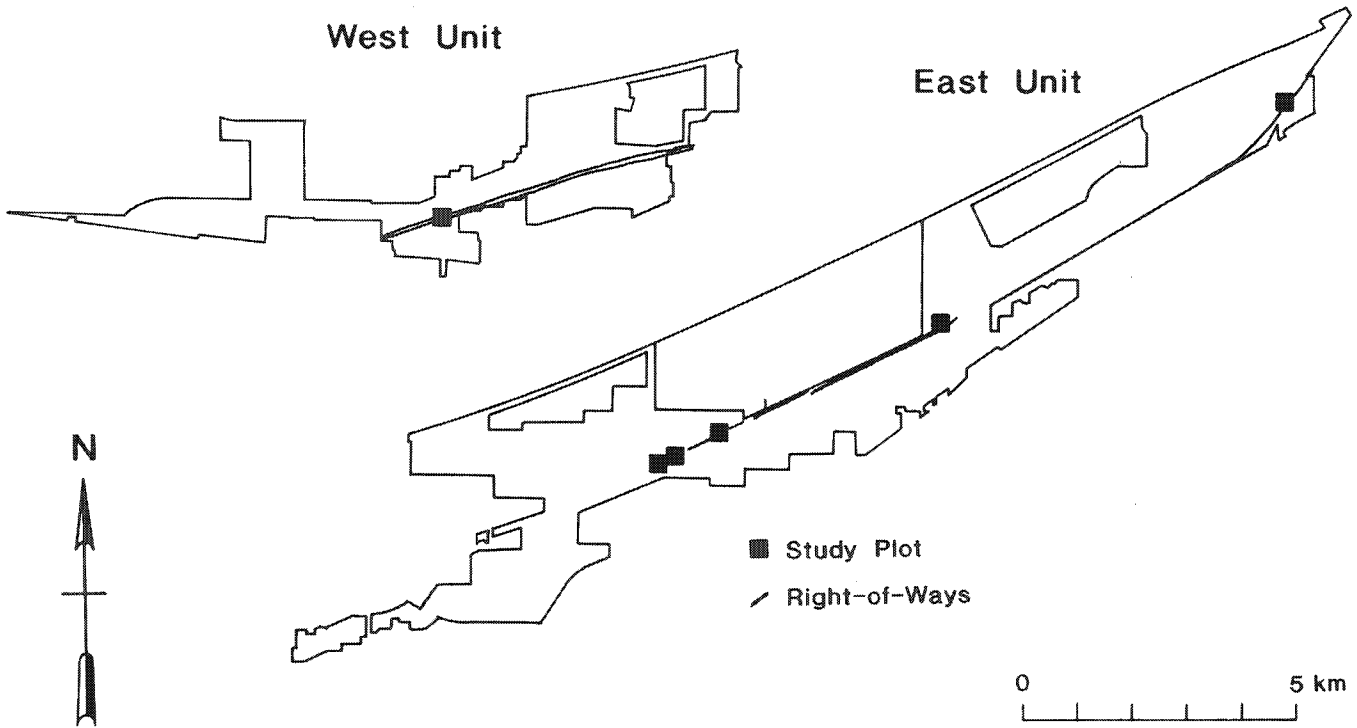

Fig. 51. Distribution of six plots in rights-of-way, Indiana Dunes National Lakeshore.

and touch-me-not (*Impatiens*) were the dominant herbaceous plants. The canopy layer was absent in the remainder of the plots. The shrub layer in the remainder ranged from sparse to thick but was rather sparse in most. Blackberries were one of the dominants in most, but rose, grapes, Japanese honeysuckle, *Spiraea*, and shining sumac (*Rhus copallina*) were other dominants in some of the plots. The herbaceous cover was fair to good in the two winter plots, good or excellent in the rest. Many different herbaceous plants were present, but some of the major dominant species were blue joint grass, other grasses, and rushes (*Juncus*). Several other plants (*Melilotus, Saponaria, Solidago, Clematis*, marsh shield fern [*Dryopteris thelypterus*], *Carex, Typha)* occurred as dominants in at least one plot each.

The mammals recorded in the most plots in this habitat were the eastern cottontail and the white-tailed deer. Both were found in four plots. The woodchuck and the prairie deer mouse were each found in two plots, and the latter species was taken in the greatest number (25). They were taken in winter from two plots—the plots with the least amount of ground cover, which is typical for this species. All other species—eastern mole, white-footed mouse, eastern fox squirrel, prairie vole, meadow vole, and meadow jumping mouse— were present in only one plot.

Excavated Areas

Excavated areas were where open sand existed because of human activities (Fig. 52). There were three plots in this habitat (Fig. 53). One had been on the site of a former fly ash seepage area, and another was on the site of an acid spill from a steel company. All plots lacked canopy; two had poor ground cover with scattered grasses, including little bluestem grass, sand reed, and nodding wild rye (*Elymus canadensis*). The third plot had cover of Joe-pye weed (*Eupatorium serotinum*), bulrush (*Scirpus cyperinus*), and spikerush (*Eleocharis* sp).

Only two mammals—a meadow vole and a common raccoon—were trapped in plots in this habitat; thus, as would be expected, it was not a good habitat for mammals. Even though not a good habitat for mammals, many mammals do pass through these areas. Signs were found of six additional species: Virginia opossum, eastern mole, woodchuck, prairie deer mouse, red fox, and white-tailed deer.

Mammals

Thirty-seven species of mammals are or recently were present at the Indiana Dunes National Lakeshore (Table 3; those marked with an x). These include the Virginia opossum, three species of shrews, the eastern mole, four species of bats, the eastern cottontail, seven species of squirrels, the American beaver, nine species of mice and rats, nine species of carnivores, and the white-tailed deer. Five additional species—star-nosed mole, northern myotis, Indiana myotis, hoary bat, and southern bog lemming—probably

occur there but have not been documented (Table 3). The number of species present at the lakeshore is 42 when the probable species are included. We think six additional species—pygmy shrew (*Sorex hoyi*), eastern pipistrelle (*Pipistrellus subflavus*), evening bat, Franklin's ground squirrel, western harvest mouse (*Reithrodontomys megalotis*), and bobcat (Table 3, marked as unlikely)—are not likely to be present.

Marsupials

Marsupials are characterized by a specialized pouch in the female, although not all species have pouches. Young marsupials are born in an immature condition, then climb into the pouch where they grasp a nipple and remain for a long developmental period. Marsupials are best known from Australia, though some species occur in South America. The Virginia opossum is the only species present in the United States.

Opossums

Virginia opossum. The Virginia opossum was listed as uncommon at the lakeshore by Krekeler (1981). However, Ecological Services of Texas Instruments, Inc., personnel recorded tracks or other sign in all six of the terrestrial

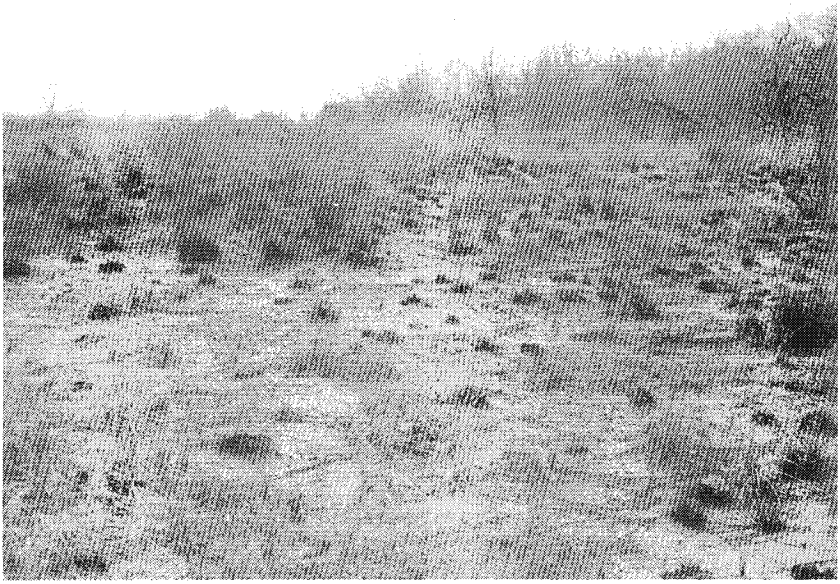

Fig. 52. Excavated area near Ogden Dunes.

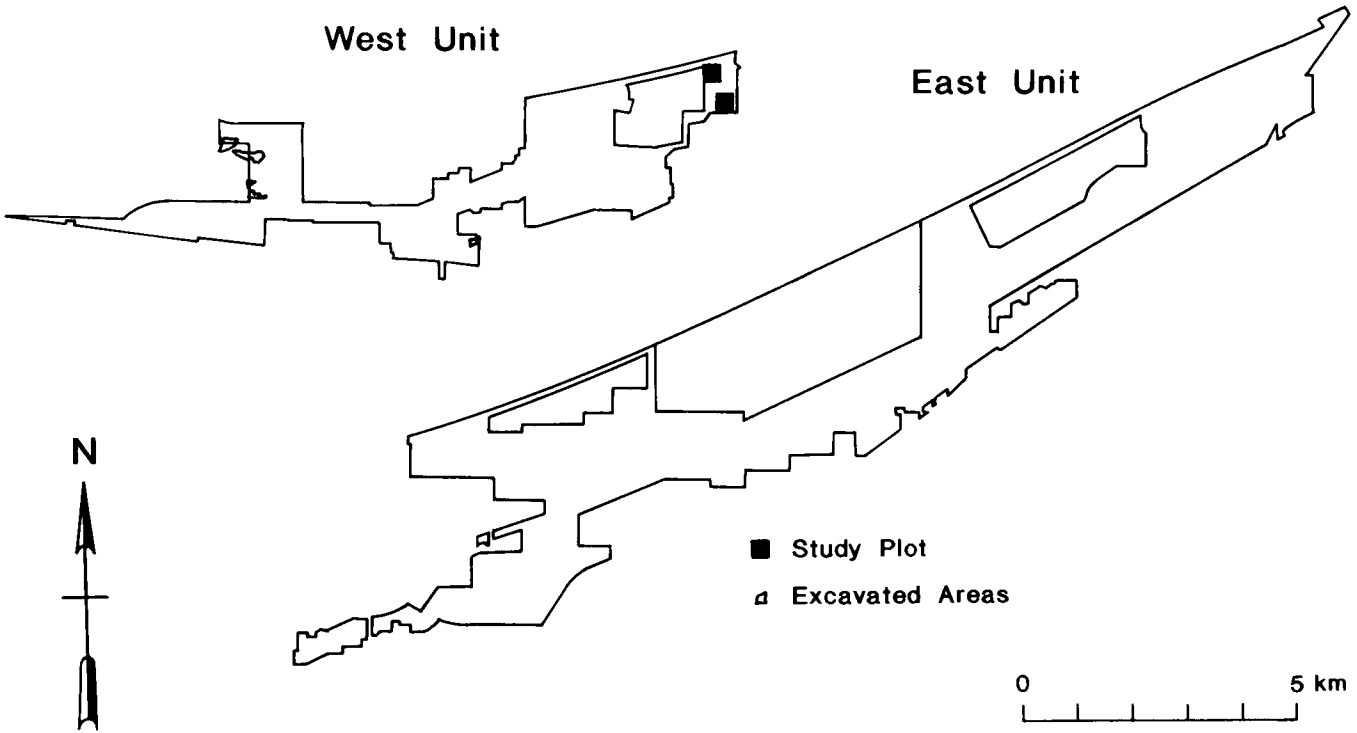

Fig. 53. Distribution of two of three plots in excavated areas, Indiana Dunes National Lakeshore.

Table 3. Mammals present or possibly present at Indiana Dunes National Lakeshore.

Mammal	Presence
Marsupials (Didelphimorphia)	
Opossums (Didelphidae)	
Virginia opossum (*Didelphis virginiana*)	x[a]
Shrews and moles (Insectivora)	
Shrews (Soricidae)	
Masked shrew (*Sorex cinereus*)	x
Pygmy shrew (*Sorex hoyi*)	unlikely
Northern short-tailed shrew (*Blarina brevicauda*)	x
Least shrew (*Cryptotis parva*)	x
Moles (Talpidae)	
Eastern mole (*Scalopus aquaticus*)	x
Star-nosed mole (*Condylura cristata*)	likely
Bats (Chiroptera)	
Vespertilionid bats (Vespertilionidae)	
Little brown myotis (*Myotis lucifugus*)	x
Northern myotis (*Myotis septentrionalis*)	x?
Indiana myotis (*Myotis sodalis*)	likely
Eastern red bat (*Lasiurus borealis*)	x
Hoary bat (*Lasiurus cinereus*)	x?
Silver-haired bat (*Lasionycteris noctivagans*)	x
Eastern pipistrelle (*Pipistrellus subflavus*)	unlikely
Big brown bat (*Eptesicus fuscus*)	x
Evening bat (*Nycticeius humeralis*)	unlikely
Rabbits, hares, and pikas (Lagomorpha)	
Rabbits and hares (Leporidae)	
Eastern cottontail (*Sylvilagus floridanus*)	x
Rodents (Rodentia)	
Squirrels (Sciuridae)	
Eastern chipmunk (*Tamias striatus*)	x
Woodchuck (*Marmota monax*)	x
Franklin's ground squirrel (*Spermophilus franklinii*)	unlikely
Thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*)	x
Eastern gray squirrel (*Sciurus carolinensis*)	x
Eastern fox squirrel (*Sciurus niger*)	x
Red squirrel (*Tamiasciurus hudsonicus*)	x
Southern flying squirrel (*Glaucomys volans*)	x
Beavers (Castoridae)	
Beaver (*Castor canadensis*)	x
Mice, voles, and rats (Muridae)	
Native mice and rats (Sigmodontinae)	

Table 3. *Continued.*

Mammal	Presence
Western harvest mouse (*Reithrodontomys megalotis*)	unlikely
White-footed mouse (*Peromyscus leucopus*)	x
Prairie deer mouse (*Peromyscus maniculatus bairdii*)	x
Old World mice and rats (Murinae)	
Norway rat (*Rattus norvegicus*)	x
House mouse (*Mus musculus*)	x
Arvicoline rodents (Arvicolinae)	
Prairie vole (*Microtus ochrogaster*)	x
Meadow vole (*Microtus pennsylvanicus*)	x
Woodland vole (*Microtus pinetorum*)	x
Common muskrat (*Ondata zibethicus*)	x
Southern bog lemming (*Synaptomys cooperi*)	x?
Jumping mice (Zapodidae)	
Meadow jumping mouse (*Zapus hudsonius*)	x
Carnivores (Carnivora)	
Canids (Canidae)	
Coyote (*Canis latrans*)	x
Red fox (*Vulpes vulpes*)	x
Common gray fox (*Urocyon cinereoargenteus*)	x
Raccoons and allies (Procyonidae)	
Common raccoon (*Procyon lotor*)	x
Weasels, skunks, etc. (Mustelidae)	
Long-tailed weasel (*Mustela frenata*)	x
Least weasel (*Mustela nivalis*)	x
Mink (*Mustela vison*)	x
American badger (*Taxidea taxus*)	x
Striped skunk (*Mephitis mephitis*)	x
Cats (Felidae)	
Feral cat (*Felis catus*)	x
Bobcat (*Lynx rufus*)	unlikely
Deer (Artiodactyla)	
Deer (Cervidae)	
White-tailed deer (*Odocoileus virginianus*)	x

[a]X indicates mammal definitely recorded.

habitats they sampled—young foredunes, stable foredunes, black oak forest, black oak–swamp forest, Cowles Bog, and red maple swamp forest.

The Virginia opossum was common in the lakeshore area. It was in 10 of the 24 habitats used for sampling, and 93 were recorded dead on roads in 1984–87 (Table 4). Virginia opossums feed heavily on animals killed on the

road, which is why so many are killed on our highways. The Virginia opossum will eat anything remotely edible—insects, fruits, earthworms, dead fish, and garbage.

Table 4. Presence of the Virginia opossum (*Didelphis virginiana*) at Indiana Dunes National Lakeshore.

Habitat[a]	Plots with animals		Number of animals	
	Number	Percent	Total	Average/plot
Animals in traps				
Terrestrial shrubland				
Lowland (9)	1	11.1	2	0.22
Savanna				
Coniferous (4)	1	25.0	1	0.25
Upland forest				
Mixed deciduous (13)	2	15.3	2	0.05
Lowland forest				
Ephemeral (9)	4	4.4	4	0.44
Perennial (18)	1	5.6	1	0.06
Wetlands				
Pannes (3)	1	33.3	1	0.33
Developed				
Agricultural (9)	1	11.1	2	0.22
Animal or sign observed				
Barren ground				
Sand (5)	3	60.0		
Savanna				
Coniferous (4)	1	25.0		
Upland forest				
Coniferous (4)	1	25.0		
Lowland forest				
Ephemeral (9)	1	11.1		
Developed				
Excavation (3)	13	3.0		
Observed killed on road				
1984	51			
1985	27			
1986	11			
1987	4			
Total	93			

[a]Numbers in parentheses indicate number of plots.

Shrews and Moles

The Order Insectivora includes shrews and moles. Six species of shrews and two species of moles might be expected to be at the lakeshore.

The northern short-tailed and masked shrews are common at the lakeshore, and one specimen of the least shrew has been taken. The pygmy shrew could be present, but much effort has not provided documentation.

The eastern mole is common in many of the drier habitats at the lakeshore, and one star-nosed mole, a muck land inhabitant, was taken at Trail Creek Fen at the south edge of Michigan City. This is less than 3.2 km east of the lakeshore boundary. We suspect that this species will be found at the lakeshore.

Shrews

Masked shrew. The masked shrew is common in several habitats at the lakeshore, especially in wet areas. Mumford and Whitaker (1982), using snap traps in October 1974, found masked shrews in the following habitats east of the Bailly generating station:

1. Foredunes of marram grass. One masked shrew among 12 small mammals taken.
2. Narrow area at front of first line of older dunes. One of 13 small mammals taken.
3. Low black oak woods. One of four small mammals taken.

Mumford and Whitaker (1982) used sunken cans and snap traps from 21 September to 11 October 1978 to sample fauna at habitats in the Cowles Bog area and at Pinhook Bog. Results were as follows:

1. Red maple–yellow birch swamp near Cowles Bog. Two lines of traps including 2,312 trap nights yielded 33 masked shrews among 45 mammals taken, or 73% of the catch.
2. Cowles Bog. Sensitive fern, willow, and cattails were dominant plants. Masked shrews comprised 32 of 40 mammals taken, or 80% of the catch.
3. Pinhook Bog. *Vaccinium*, *Spiraea*, and *Sphagnum* were the dominant plants. The cover was fair. Forty-seven of the 71 animals taken were masked shrews, constituting 66% of the total catch.

At Trail Creek Fen, at the south edge of Michigan City, 12 of 22 (54.5%) of the mammals taken were masked shrews. This area is just to the east of the lakeshore. Krekeler (1981) listed the masked shrew as uncommon at the

lakeshore. It was recorded only at Cowles Bog during the Texas Instruments study.

We took only 35 masked shrews during the present study. This included individuals from eight of the habitats (Table 5), although they were most abundant in wet prairie (1.83/100 trap nights) and marsh (1.17/100 trap nights).

The masked shrew lives in areas where the soil remains moist, thus it often lives in dense vegetation or in mossy areas. This shrew feeds most heavily on insect larvae, slugs and snails, small spiders, and small insects.

We do not know why the catch of masked shrews was so low. A possible reason was the extreme drought that occurred in the first year of this study. More work with pitfalls is needed at the lakeshore.

Pygmy shrew. The pygmy shrew could be in the Indiana Dunes National Lakeshore area. Long considered rare throughout its range, pitfall trapping has

Table 5. Presence of the masked shrew (*Sorex cinereus*) at Indiana Dunes National Lakeshore.

	Plots with animals		Number of animals	
Habitat[a]	Number	Percent	Total	Average/plot
Animals in traps				
Barren ground				
Blowouts (5)	1	20.0	1	0.20
Prairie				
Wet (6)	3	50.0	11	1.83
Terrestrial shrubland				
Upland (4)	1	25.0	1	0.25
Savanna				
Oak (15)	2	13.3	3	0.20
Lowland forest				
Ephemeral (9)	1	1.1	1	0.11
Perennial (18)	1	5.6	1	0.06
Wetlands				
Marsh (12)	6	50.0	14	1.17
Developed areas				
Agricultural (9)	3	33.3	3	0.33
Earlier trapping (1978)	**Total**	**T/100 tn[b]**		
Bailly generating station	3	—		
Pinhook Bog	47	1.11		
Cowles Bog	32	8.00		

[a]Numbers in parentheses indicate number of plots.
[b]Total per 100 trap nights.

shown the pygmy shrew to be more abundant than previously thought. Two subspecies, *Sorex hoyi hoyi* in the north and *S. h. winnemana* in the south, exist in the eastern United States. The pygmy shrew is one of the smallest mammals in the world, and the southern subspecies in south-central Indiana is the smallest of the pygmy shrews, averaging only 2.0 g (Caldwell et al. 1981; Cudmore and Whitaker 1984). The northern subspecies could occur at the lakeshore because many northern relict species are in this area.

A pygmy shrew was taken in southeastern Wisconsin less than 120 km from the lakeshore. Also, one was taken in midwinter in a garage at Palatine, northwest of Chicago in Cook County, Illinois, about 80 km from the lakeshore. The pygmy shrew is not present, however, in the southern portion of the southern peninsula of Michigan (Baker 1983). We took none in our earlier extensive trapping at Bailly, at Cowles Bog, or at Pinhook Bog. We believe that pygmy shrews are rare if they are present at all at the lakeshore. To avoid missing one, however, the unicuspid teeth of all *Sorex* from the lakeshore should be carefully examined. The masked shrew has four large and one small unicuspids, all easily visible from the side. The pygmy shrew has the third and fifth extremely reduced, thus only three unicuspids are readily visible from the side.

Northern short-tailed shrew. The northern short-tailed shrew is one of the most common mammals at the lakeshore. Mumford and Whitaker (1982) took two individuals during their Bailly trapping efforts in 1974, two in the red maple–yellow birch swamp along Cowles Bog, five in Cowles Bog, and nine in Pinhook Bog in 1978. Krekeler (1981) listed it as common in the grasslands (including foredunes), marsh borders, woods, and thickets.

Texas Instruments personnel took 4 in the foredunes, 6 in black oak forest, 11 in black oak–swamp forest, 5 in the red maple swamp forest, and 56 in the transmission corridor, which actually includes several habitats.

During the present study, northern short-tailed shrews were taken in 17 of the 24 habitats studied (Table 6). They were most abundant in upland terrestrial shrubland, wet prairie, old field, ephemeral lowland forest, and mixed deciduous savanna.

The northern short-tailed shrew is often active on the surface but is primarily a burrower. It makes extensive, 2.5-cm-wide burrows just beneath the surface. This shrew feeds primarily on earthworms, insect larvae, snails, and centipedes. It is unique among mammals in having poison produced by its salivary glands. It can store food alive by biting and paralyzing it, thus preventing spoilage. Dorsoventrally flattened burrows or pierced snail shells around logs indicate the presence of this species.

Least shrew. The least shrew is a small brownish shrew with a short tail. It is smaller than the northern short-tailed shrew and has only four unicuspids rather than five; the fourth is hidden behind the third. The animal is small (63–88 mm

Table 6. Presence of the short-tailed shrew (*Blarina brevicauda*) at Indiana Dunes National Lakeshore.

Habitat[a]	Plots with animals		Number of animals	
	Number	Percent	Total	Average/plot
Animals in traps				
Prairie				
Dry (11)	2	18.2	3	0.27
Wet (6)	3	50.0	8	1.33
Terrestrial shrubland				
Lowland (9)	1	11.1	5	0.55
Upland (4)	1	25.0	9	2.25
Savanna				
Mixed deciduous (3)	1	33.3	4	1.00
Upland forest				
Oak (9)	4	50.0	5	0.63
Mixed deciduous (13)	3	23.1	6	0.46
Lowland forest				
Ephemeral (9)	4	4.4	12	1.33
Perennial (18)	2	11.1	6	0.33
Wetlands				
Marsh (12)	3	25.0	3	0.25
Aquatic shrublands (5)	2	40.0	3	0.60
Bogs (4)	1	25.0	3	0.75
Pannes (3)	1	33.3	1	0.33
Aquatic (4)	1	25.0	1	0.25
Developed				
Agricultural (9)	4	44.4	12	1.33
Pine plantations (3)	1	33.3	1	0.33
Razed residential (11)	1	9.1	1	0.09
Earlier trapping (1978)	**Total**	**T/100 tn[b]**		
Pinhook Bog	8	0.18		
Cowles Bog	5	1.25		
Swamp (northern edge, Cowles Bog)	2	0.09		

[a]Numbers in parentheses indicate number of plots.
[b]Total per 100 trap nights.

present throughout Indiana, but not many are recorded for the northern part of the state.

We did not take any least shrews during our studies, nor were any taken by Lyon (1923). Lyon listed it among mammals that probably occur or have lately occurred in the dune region of Porter County.

Lyon, however, did take a least shrew from subdunal woods on 31 October 1924. The specimen was deposited in the U.S. National Museum (240630). It seems that this specimen was from Tremont, as Sanborn (1925) reported that Lyon took one there in fall 1924. Sanborn (1925) reported least shrews from northern Porter County.

Moles

Eastern mole. This species is common at Indiana Dunes National Lakeshore and throughout Indiana, and Krekeler (1981) listed it as common throughout the lakeshore. Texas Instruments personnel recorded it from seven of their eight habitat categories (all but pond). The eastern mole is a dry-soils species, thus its burrows can be distinguished easily from those of the star-nosed mole, a muck land inhabitant. The chief foods of eastern moles are earthworms, various beetle larvae, and ants.

We found sign of the eastern mole in 10 of the 24 habitats examined (Table 7). Moles occurred in the greatest percentages of plots in pine plantations, oak savanna, excavated sand, and mixed deciduous forest.

Table 7. Presence of the eastern mole (*Scalopus aquaticus*) at Indiana Dunes National Lakeshore.

Habitat[a]	Plots with animals	
	Number	Percent
Prairie		
Wet (6)	1	16.7
Terrestrial shrubland		
Lowland (9)	1	11.1
Savanna		
Oak (15)	5	33.3
Upland forest		
Oak (9)	1	12.5
Mixed deciduous (13)	3	23.1
Lowland forest		
Ephemeral (9)	1	1.1
Perennial (18)	2	11.1
Developed		
Pine plantations (3)	2	66.7
Razed residential (11)	1	9.1
Rights-of-way (6)	1	16.7
Excavated sand (3)	1	33.3

Star-nosed mole. This is a species of muck land habitat; its burrows are usually evident when present. The star-nosed mole is present only in the northeastern portion of the state, and its range has apparently retracted in this century. It has never been taken at the lakeshore. On 28 October 1982, however, Whitaker trapped one at Trail Creek Fen at the southern edge of Michigan City just east of the lakeshore. We expect it to occur at the lakeshore.

Muck land habitats apparently suitable for star-nose moles were at Cowles Bog in hydromesophytic forest and along the Little Calumet River floodplain near Goodfellow. Burrows were present in mucky areas at both of these sites and further investigation is needed to ascertain whether the star-nosed mole is present.

Bats

Twelve species of bats are found in Indiana, all in the family Vespertilionidae. All are nocturnal, have well developed echolocation, and feed exclusively on flying insects.

Little information is available on bats of the Indiana Dunes National Lakeshore. Lyon (1923) had a record of the red bat. He stated that bats are frequently seen on summer evenings and probably represent the majority of the species of bats of the state. Krekeler (1981) listed eight of the nine bats of northeastern Indiana as mammals known to occur or possibly to occur in the lakeshore area (he omitted the eastern pipistrelle). The little brown myotis was recorded during the Texas Instruments study, but this record needs verification. Whitaker collected an eastern red bat at the lakeshore in 1963, Mumford and Whitaker (1982) recorded the silver-haired bat there, and we have records of eastern red bats, silver-haired, and big brown bats there during the current study. R. E. Mumford shot an evening bat 3.2 km northwest of Porter (Porter County) on 5 August 1958. This was in the present lakeshore. This species, however, has decreased in Indiana in recent years, and we doubt that it is still present in northwestern Indiana. For that matter, the single record could have been a stray. Thus there are definite records at the lakeshore for only three of the species—the big brown bat, the silver-haired bat, and the red bat—and an unverified record for the little brown myotis. The northern myotis and the hoary bat are undoubtedly present also. Three other species possibly occurring at the lakeshore are the Indiana myotis, the eastern pipistrelle, and the evening bat. It seems likely that the Indiana myotis is present, but the latter two species are less likely. The nine species are further discussed below.

Little Brown Myotis

Neither Lyon (1946) nor Mumford and Whitaker (1982) recorded the little brown myotis from Lake, Porter, or LaPorte counties. The only specific record of this species at the lakeshore is that of Texas Instruments personnel (1975–80). We tentatively consider it as a resident of the lakeshore but need to verify that by seeing additional specimens. The little brown myotis migrates to the karst regions of southern Indiana where it hibernates in large groups in caves. We have often seen small bats that we think are this species or perhaps the northern myotis flying about over openings in the Indiana Dunes State Park and elsewhere at the lakeshore. Major foods of this species are small moths, leafhoppers, beetles, and flies. The little brown myotis lives in large colonies in buildings, whereas the northern myotis lives in small colonies under the bark of trees.

Northern Myotis

This species has often been referred to as Keen's bat (*Myotis keenii septentrionalis).* Eastern and western United States populations, however, are currently recognized as separate species. No records of this species exist for any of the lakeshore counties (Mumford and Whitaker 1982), but we are confident that further work will show this species to be present at the lakeshore. Kurta (1982) stated that it is relatively uncommon in southern Michigan, and Long (1974) reported it as less common than the little brown myotis in the Lake Michigan drainage. This species forms small summer colonies under the bark of trees or sometimes in buildings, then migrates to caves and mines where it hibernates individually rather than in groups.

Indiana Myotis

The Indiana myotis is listed as a federally endangered species. No records exist for the northwestern 15 or so counties of the state (Mumford and Whitaker 1982), but Kurta (1982, 1993) located maternity trees in southern Michigan. We suspect it to be present at the lakeshore. It forms small summer colonies under the bark of dead trees, often along watercourses, and in winter it congregates in huge numbers in a very few caves. Major hibernacula are in southern Indiana. The species has been declining in recent years.

Eastern Red Bat

Lyon (1923) observed a female eastern red bat roosting in blackberry bushes in the lakeshore region. Whitaker shot a female eastern red bat at daybreak on 26 August 1963 as it was flying over the beach in what is now the lakeshore. This is likely one of the most common bats at the lakeshore and elsewhere in Indiana. It is solitary and hangs in trees during the daytime. The eastern red bat feeds most heavily on beetles, moths, and leaf- and froghoppers.

Our study recorded a young female collected in July 1987 by lakeshore personnel at the West Beach bathhouse. One was observed flying at the Indiana Dunes State Park on 27 August 1988. Two individuals were netted (one male, one female) over Dunes Creek, Indiana Dunes State Park, on 23 September 1988.

Hoary Bat

Like the eastern red bat, this is a solitary migrant that roosts in trees. It is the largest and one of the most colorful bats of Indiana. The hoary bat is present throughout the state but is not particularly common in any one place. It has been reported from Lake County by Hahn (1907). We are confident that this species is present at the lakeshore and produces young there.

Silver-haired Bat

Hahn (1909) reported that this species was present in Michigan City, LaPorte County. Mumford and Whitaker (1982) reported additional specimens taken from both Lake and LaPorte counties, including three individuals taken at the state park (a female 24 September 1928 by W. A. Weber and two individuals taken 3 May 1936 by J. Schmidt). During the present study, one individual was netted on an abandoned road on 9 September 1988, 0.8 km north and just east of the visitor's center.

The silver-haired bat is migratory. It spends the summer and has its young north of Indiana then migrates southward. A few individuals hibernate in caves or mines in southern Indiana, but most winter in states to the south. This species is fairly common in Indiana during migration from about 18 April to 28 May and from about 29 August to 6 November (Mumford and Whitaker 1982), when it should be relatively common at the lakeshore. Not enough information is available to indicate major foods of this bat.

Eastern Pipistrelle

This species is at the northern edge of its range in Indiana and is found primarily in the southern part of the state (Mumford and Whitaker 1982). The northern edge of its range correlates well with the southern edge of the Wisconsinan glaciation (Brack and Mumford 1984), although there are a few records from northern Indiana and southern Michigan (Kurta 1982). We do not expect this species, if present, to be common at the lakeshore.

Big Brown Bat

We conducted a search on 14 July 1987 for bats that might be present in abandoned buildings on lakeshore property. Unfortunately, most buildings are razed as soon as possible after acquisition. We did, however, examine 12 buildings. Some showed evidence of limited bat use, probably by solitary individuals as night roosts or by males as day roosts. One big brown bat was found in the Coronado Lodge, a large house on the north side of

State Route 12 just west of Mineral Springs Road. Also, big brown bats roost behind the barn doors at Chellberg Farm. The bats were observed there in 1987, 1988, and 1989 but seemed to be postmaternity congregations. In each of the years, they were present late in the season but not during June and July. One hundred thirteen bats were seen to emerge from behind this door on 27 August 1988.

Several summer colonies of big brown bats should exist in buildings or possibly in hollow trees at the lakeshore. The only definite maternity colony we found there was in a well-kept brick house 0.3 km east of 33E on U.S. Highway 20. The house, built in 1863, provides a dwelling for a colony of about 100 individuals. The north edge of the backyard of the house adjoins lakeshore property.

Other maternity colonies of big brown bats in the general vicinity and whose occupants could use the lakeshore as a feeding ground (big brown bats may easily forage up to 3.2 km from their summer roosts) are the following:

1. Lutheran Church at the south end of Mineral Springs Road (just north of Interstate 94 (I-94). About 20 bats in the colony. This colony is less than 1.6 km from lakeshore property.
2. Barn at Portage Park, southwest of I-94 and State Route 249. The colony consisted of about 80 bats on 9 September 1988. This colony is within 3.2 km of the lakeshore.
3. A colony is at the Hopkins residence, another old but well preserved two-story brick house (north on State Route 49 from State Route 6, first road to the right, then north on 250E, 0.8 km to house on the west). On 16 May, 43 bats emerged from the soffit of this house. Bats from this colony probably do not feed at the lakeshore because the house is about 6.4 km from there.

This is the only species likely to winter (hibernate) at the lakeshore. Most big brown bats leave the summer colony and seek a tiny crack or some unused attic, but a few may use the maternity colony area if it is suitable for winter use (Whitaker and Gummer 1992). Usually only one or very few bats are in any one building in winter, and the bats are solitary or nearly so within buildings (sometimes one finds a cluster of up to six or so, but seldom more).

This species is active from about 15 March, when maternity colonies begin to form, through about 15 November, when maternity colonies have disappeared. Females of this species have two young per year in eastern populations. Big brown bats feed most heavily on hard-bodied insects such as beetles, true bugs (particularly stinkbugs), and ants. The diet includes only about 5% moths, in contrast to several other species. Cucumber beetles are garden pests and are among the most important foods of this species. The

larva of the cucumber beetle, the corn rootworm, is a major agricultural pest. Much of the food of the big brown bat is of insect pest species.

Evening Bat

The evening bat is one of our lesser known bats. It is on the Indiana Department of Natural Resources endangered species list. The only colony of evening bats presently known in Indiana is in a church in Clay County. There is a record of this species from the lakeshore area (Mumford and Whitaker 1982), and there are three such records from Michigan. The lakeshore individual was shot by R. E. Mumford on 5 August 1958. This species has decreased greatly in recent years, and we doubt if it is currently present at the lakeshore. It is a southern species, and these records could indicate wanderers rather than a colony living at the lakeshore. The most northern previously existing colonies known from Indiana were in White, Cass, and Carroll counties.

We are aware of one additional colony of bats of undetermined identity. It is in the attic of a house owned by Mrs. Barc, east of the Porter–LaPorte county line on the north side of 425E. No bats were present during two separate visits.

Obviously, we have far too little information on bats of the Indiana Dunes National Lakeshore. Efforts should continue to locate colonies or otherwise to collect information on bats there. Posters have been used and could be used again to request information. Also, we should continue to alert lakeshore personnel and visitors to refer reports of bats (other than simply bats seen flying) to an animal ecologist at the lakeshore or to the naturalist at Indiana Dunes State Park.

Rabbits and Hares

The eastern cottontail was the only species of lagomorph (Family Leporidae) present at the lakeshore.

Eastern Cottontail

Lyon (1923) stated that eastern cottontails were fairly common in the region and that he had observed them in most habitats except the foredunes. Krekeler (1981) listed the eastern cottontail as common and observed it in habitats with dense ground cover, including foredunes, grasslands, thickets, small woodlots, and suburbs. Texas Instruments personnel found eastern cottontails (48) in the following eight habitats: transmission corridor (a variety of habitats; 24), black oak–swamp forest (9), young foredune and red maple swamp forest (4 each), stable foredune (2), black oak forest (2), pond (2), and Cowles Bog (1).

We found the eastern cottontail to be common during our study. Seven individuals were captured in live traps, and sign or sightings were recorded in plots in 13 of the habitats (Table 8). Fecal pellets and, in winter, tracks are commonly seen throughout the lakeshore. Sixty-five individuals were recorded

Table 8. Presence of the eastern cottontail (*Sylvilagus floridanus*) at Indiana Dunes National Lakeshore.

Habitat[a]	Plots with animals		Number of animals	
	Number	Percent	Total	Average/plot
Animals in traps				
Prairie				
Dry (11)	3	27.2	3	0.27
Upland forest				
Coniferous (4)	1	25.0	1	0.25
Lowland forest				
Ephemeral (9)	1	1.1	1	0.11
Wetlands				
Bog (4)	1	25.0	1	25.00
Developed areas				
Agricultural (9)	1	11.1	1	0.11
Animal or sign observed				
Prairie				
Dry (11)	2	18.2		
Terrestrial shrubland				
Lowland (9)	3	33.3		
Upland (4)	1	25.0		
Savanna				
Oak (15)	2	13.3		
Coniferous (4)	1	25.0		
Lowland forest				
Ephemeral (9)	1	1.1		
Perennial (18)	1	5.6		
Wetlands				
Marsh (12)	1	8.3		
Aquatic shrubland (5)	1	20.0		
Swamp (4)	1	25.0		
Developed areas				
Agricultural areas (9)	2	22.2		
Pine plantations (3)	2	66.7		
Rights-of-way (6)	3	50.0		
Observed killed on road				
1984	30			
1985	20			
1986	11			
1987	4			

[a]Numbers in parentheses indicate number of plots.

as killed on the road, and many more were seen during our travels between study areas.

Rodents

The rodents constitute the largest group of mammals at the lakeshore, both in terms of number of species and number of individuals. Seven species in the squirrel family, the American beaver, two sigmodontodine (previously cricetine) mice (two species of *Peromyscus*), at least four and probably five species of arvicoline (previously microtine) rodents (the common muskrat, three voles, and probably the bog lemming), two murines (Norway rat and house mouse), and the meadow jumping mouse (Zapodidae) bring the probable total of rodent species for the area to 18. Two of these are probably the most abundant mammals at the lakeshore—the white-footed mouse in the wooded and brushy areas and the meadow vole in the moist grassy areas. In dry grassy areas, the prairie deer mouse and the prairie vole are probably the most abundant species.

Squirrels

Seven species of squirrels are present at the lakeshore, although we should continue to watch for Franklin's ground squirrel, a species listed as threatened in Indiana. Squirrels are some of the most conspicuous species present—in great part because most are diurnal. The largest member of the squirrel family is the woodchuck. Much in evidence at the lakeshore are the eastern chipmunk, the eastern fox squirrel, and the red squirrel. Besides being diurnal, these three are both common and noisy. The eastern gray squirrel is uncommon, but is obvious where present; it is outnumbered by the eastern fox squirrel in most areas. The southern flying squirrel may often be common, but is seldom observed because it is nocturnal. The thirteen-lined ground squirrel has a spotty distribution but is found at several lakeshore localities.

Eastern chipmunk. The eastern chipmunk is common in many of the wooded habitats of the lakeshore, although Lyon (1923:218–219) stated that "chipmunks do not appear to be very common in the dunes. I have only one record of them in my notes but feel certain I have seen more than one. None were trapped though suitable traps baited with apples were set in what appeared to be good chipmunk habitat." Krekeler (1981) listed it as abundant in open woods, thickets, and suburbs. Texas Instruments personnel recorded captures of chipmunks in black oak–swamp forest (120 captures), black oak forest (18), stable foredunes (13), and red maple swamp forest (13).

The eastern chipmunk is active from about March to November but hibernates during winter. Unlike most other hibernators, it does not store extensive fat. Rather, it stores food and wakens periodically to eat. It is most active near dusk and dawn but may be out at anytime during daylight hours.

During our studies, 24 individuals were taken during routine trapping in 9 of the habitats, and sign or sight observations were made in 11 plots in 7 of the habitats. Seventeen were seen dead on the road (Table 9), and numerous individuals were

Table 9. Presence of the eastern chipmunk (*Tamias striatus*) at Indiana Dunes National Lakeshore.

	Plots with animals		Number of animals	
Habitat[a]	Number	Percent	Total	Average/plot
Animals in traps				
Savanna				
Oak (15)	1	6.7	2	0.13
Upland forest				
Oak (9)	1	12.5	1	0.12
Coniferous (4)	1	25.0	2	0.50
Mixed deciduous (13)	2	15.3	5	0.38
Lowland forest				
Ephemeral (9)	2	2.2	4	0.44
Perennial (18)	4	22.2	5	0.28
Wetlands				
Marsh (12)	1	8.3	3	0.25
Bog (4)	1	25.0	1	0.25
Developed				
Razed residential (11)	1	9.1	1	0.09
Animal or sign observed				
Terrestrial shrubland				
Upland (4)	1	25.0		
Savanna				
Oak (15)	2	13.3		
Upland forest				
Oak (9)	2	25.0		
Lowland forest				
Ephemeral (9)	1	1.1		
Perennial (18)	3	16.7		
Wetlands				
Marsh (12)	1	8.3		
Developed				
Agricultural (9)	1	11.1		
Observed killed on road				
1984	10			
1985	6			
1986	0			
1987	1			

[a]Numbers in parentheses indicate number of plots.

seen during our travels around the lakeshore property. The highest average numbers per plot were taken in upland coniferous forest and in ephemeral lowland forest. The major foods of this species are nuts and other larger seeds, but berries, invertebrates, and small vertebrates are also commonly eaten.

Woodchuck. Lyon (1923) stated that woodchucks were common in all wooded portions of the dunes as indicated by numerous burrows. He observed them up to 4 October. Krekeler (1981) listed the woodchuck as abundant in woods, farms, thickets, and railroad embankments. Texas Instruments personnel indicated they had seen nine individuals from black oak–swamp forest, Cowles Bog, pond, red maple swamp forest, and black oak forest.

We found this species to be relatively common. We took it in traps in 7 plots in 6 habitats; burrows or individuals were seen in 11 plots in 7 of the habitats; 61 were seen dead on the road; and a number of other individuals were seen while traveling between areas during our studies (Table 10). The woodchuck is active from late February and early March through early October and hibernates the rest of the year. Food of woodchucks is green plant material.

Franklin's ground squirrel. Neither Lyon (1923), Krekeler (1981), nor Texas Instruments personnel reported Franklin's ground squirrels from the lakeshore. Three Franklin's ground squirrels were taken, however, from Miller in Lake County, Indiana, in 1947 by Alex Bognar. The specimens are in the Field Museum of Natural History (73872, 73873, and 73874). We assume these were from Miller Station, which is only about 0.8 km south of present lakeshore property at Miller Woods. Two sets of 10 live traps were used to assess the area along the railroad at Miller Station for Franklin's ground squirrels in 1986–87 by Scott Johnson and other Indiana Department of Natural Resources personnel. This was close to the site where Bognar collected this species. No Franklin's ground squirrels were seen or taken there or elsewhere near lakeshore property during studies of the distribution of this species by the Indiana Department of Natural Resources personnel.

We have no evidence that this species currently exists at the lakeshore. We should, however, continue to watch for it, especially in view of continued habitat improvement and restoration efforts.

Thirteen-lined ground squirrel. Lyon (1923:218) found this species "not uncommon along the Chicago, Lake Shore [*sic*] and South Bend Railway just south of the dunes," and reported one "just north of Oak Hill Station and a few feet above the subdunal swamp." Krekeler (1981) listed it as common at the lakeshore and indicated its habitat as pastures, road borders, dunes, and weedy or cultivated fields. Texas Instruments personnel reported three individuals, two from the Cowles Bog area and one from the transmission corridor.

During the present study, a thirteen-lined ground squirrel was killed on Wagner Road just north of State Route 20; and two additional individuals were recorded as killed on a road just south of State Route 20 but off the

Table 10. Presence of the woodchuck (*Marmota monax*) at Indiana Dunes National Lakeshore.

Habitat[a]	Plots with animals		Number of animals	
	Number	Percent	Total	Average/plot
Animals in traps				
Terrestrial shrubland				
Lowland (9)	1	11.1	1	0.11
Upland forest				
Mixed deciduous (13)	1	7.7	1	0.08
Lowland forest				
Ephemeral (9)	1	1.1	1	0.11
Perennial (18)	1	5.6	1	0.06
Wetlands				
Marsh (12)	1	8.3	1	0.08
Developed				
Agricultural (9)	2	22.2	2	0.22
Animal or sign observed				
Prairie				
Wet (6)	1	16.7		
Terrestrial shrubland				
Lowland (9)	3	33.3		
Lowland forest				
Perennial (18)	1	5.6		
Developed				
Agricultural (9)	2	22.1		
Razed residential (11)	1	9.1		
Rights-of-way (6)	2	33.3		
Excavated sand (3)	1	33.3		
Observed killed on road				
1984	20			
1985	25			
1986	10			
1987	6			

[a]Numbers in parentheses indicate number of plots.

lakeshore property. We captured 15 individuals in traps in nine plots in four habitats (Table 11). Ten of the 15 animals taken were at West Beach. The three dry prairie plots were on the foredunes at West Beach. Two terrestrial shrubland plots were at an old sand mine near the Inland Marsh parking lot and two were at the Harbor Belt. Three thirteen-lined ground squirrels were taken in oak savanna, three were taken in coniferous savanna at West Beach,

Table 11. Presence of the thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*) at Indiana Dunes National Lakeshore.

Habitat[a]	Plots with animals		Number of animals	
	Number	Percent	Total	Average/plot
Animals in traps				
Prairie				
Dry (11)	3	27.2	4	0.36
Terrestrial shrubland				
Lowland (9)	3	33.3	4	0.44
Savanna				
Oak (15)	1	6.7	3	0.20
Coniferous (4)	2	50.0	4	1.00
Animal or sign observed				
Terrestrial shrubland				
Lowland (9)	1	11.1		
Observed killed on road				
1987	1			

[a]Numbers in parentheses indicate number of plots.

and one was taken in coniferous savanna at Miller Woods. Tracks and burrows were seen at one additional plot in terrestrial shrubland.

The thirteen-lined ground squirrel is not common at the lakeshore. It is, however, a species of dry open sandy soils, and this is where most individuals were found during our study. This squirrel is active from March or April through late October and hibernates the rest of the year. Main foods are various seeds, caterpillars and other insect larvae, and adult insects.

Eastern gray squirrel. Lyon (1923) did not report this species from the lakeshore area, but Krekeler (1981) indicated it as common in woods and suburbs. Texas Instruments personnel reported 1 from black oak forest, 16 from black oak swamp forest, and 6 from red maple swamp forest.

The eastern gray squirrel is not common at the lakeshore but is present. We took two individuals in one upland oak forest plot, observed them in another, and also observed them in one oak savanna plot (Table 12).

Fourteen individuals killed on the road are reported here, although it is not certain that all those from 1984 and 1985 were eastern gray squirrels. Definite individuals killed on the road were seen in upland forest near Chellberg Farm, on Stagecoach Road west of U.S. Highway 12, on U.S. Highway 12 east of State Route 49, on U.S. Highway 12 east of Beverly Drive, and on Beverly Drive near U.S. Highway 12.

Table 12. Presence of the eastern gray squirrel (*Sciurus carolinensis*) at Indiana Dunes National Lakeshore.

Habitat[a]	Plots with animals		Number of animals	
	Number	Percent	Total	Average/plot
Animals in traps				
Upland forest				
Oak (9)	1	12.5	2	0.25
Animal or sign observed				
Savanna				
Oak (15)	1	6.7		
Upland forest				
Oak (9)	1	12.5		
Observed killed on road				
1984	8			
1985	2			
1986	4			
1987	0			

[a]Numbers in parentheses indicate number of plots.

Eastern gray squirrels were seen in black oak forest at Miller Woods, and one was observed in black oak forest at Dune Acres. Both eastern gray and eastern fox squirrels occur at Miller Woods.

This species is active all year. It feeds on many plant foods, especially nuts, acorns, berries, seeds, and buds. Gray squirrels store acorns, hickory nuts, and other such foods in the ground for winter use.

Eastern fox squirrel. Lyon (1923) frequently saw this species in the wooded portions of the lakeshore, and Krekeler (1981) reported it as common in open woods, thickets, and on farms. Texas Instruments personnel reported 9 individuals in black oak forest, 53 in black oak swamp forest, 1 in Cowles Bog, and 5 in red maple swamp forest.

This species is common throughout the Indiana Dunes National Lakeshore. Only four were actually trapped (Table 13), but individuals were seen or sign recorded in 20 plots in 8 different habitats. Also, 119 records were made of individuals killed on the roads, and numerous live individuals were seen during our travels about the area.

This species is active all year and, like the eastern gray squirrel, feeds on a variety of foods. It spends much time in the fall burying hickory nuts and acorns. The question often arises as to how the squirrel relocates stored nuts. Large numbers of nuts are buried and the squirrel probably finds them by olfaction and

by looking in places they might logically have stored them. On one occasion Whitaker watched an eastern fox squirrel at the lakeshore cutting hickory nuts. Whitaker was standing on a soft sand trail; the squirrel was cutting the nuts perhaps 40 m from the trail and over hard ground. The squirrel would cut several nuts, then come down the tree and over to the trail where it would find and bury several nuts. Then it went back to the original tree and cut more nuts. It repeated this process

Table 13. Presence of the eastern fox squirrel (*Sciurus niger*) at Indiana Dunes National Lakeshore.

	Plots with animals		Number of animals	
Habitat[a]	Number	Percent	Total	Average/plot
Animals in traps				
Savanna				
Oak (15)	1	6.7	1	0.07
Lowland forest				
Perennial (18)	1	5.6	1	0.06
Wetlands				
Swamp (4)	1	25.0	1	0.25
Developed areas				
Razed residential (11)	1	9.1	1	0.09
Animal or sign observed				
Terrestrial shrubland				
Upland (4)	1	25.0		
Savanna				
Oak (15)	5	33.3		
Upland forest				
Oak (9)	2	25.0		
Mixed deciduous (13)	3	23.1		
Lowland forest				
Perennial (18)	5	27.8		
Wetland				
Aquatic (4)	2	50.0		
Developed areas				
Agricultural (9)	1	11.1		
Rights-of-way (6)	1	16.7		
Observed killed on road				
1984	79			
1985	27			
1986	9			
1987	4			

[a]Numbers in parentheses indicate number of plots.

three or four times, cutting nuts in the woods, and then searching out and burying different nuts on the soft trail.

Maple seeds and the flowers and young fruits of tulip trees are often eaten when ripening. The squirrels cut and drop these items just like they do with nuts later in the year.

Red squirrel. Lyon reported the red squirrel to be fairly common in the wooded portions of the lakeshore. Krekeler (1981) reported it as common in woods, on farms, and in suburbs. Texas Instruments personnel reported 7 individuals from black oak forest, 46 from black oak swamp forest, 1 from Cowles Bog, and 8 from red maple swamp forest.

Although not many were trapped or actually observed on the plots, we found red squirrels to be common in the wooded portions of the lakeshore, especially in jack pines on the dunes and in other conifer and mixed forests (Table 14). Seven were taken in one of four plots in coniferous forest. Sign or squirrels were observed

Table 14. Presence of the red squirrel (*Tamiasciurus hudsonicus*) at Indiana Dunes National Lakeshore.

	Plots with animals		Number of animals	
Habitat[a]	Number	Percent	Total	Average/plot
Animals in traps				
Terrestrial shrubland				
Lowland (9)	1	11.1	1	0.11
Upland forest				
Coniferous forest (4)	1	25.0	7	1.75
Mixed deciduous (13)	1	7.7	1	0.08
Lowland forest				
Ephemeral (9)	1	1.1	2	0.22
Animal or sign observed				
Terrestrial shrubland				
Lowland (9)	1	11.1		
Upland forest				
Coniferous forest (4)	1	25.0		
Lowland forest				
Perennial (9)	3	16.7		
Observed killed on road				
1984	7			
1985	7			
1986	2			
1987	0			

[a]Numbers in parentheses indicate number of plots.

in five plots, including three of nine perennial lowland forest plots. Sixteen individuals killed on the road were seen, and a number of other individuals were observed during our travels around the lakeshore.

The red squirrel is active throughout the year. It will eat a small amount of insect material but mainly feeds on a variety of nuts and seeds, storing great quantities in the ground. Pine cones are gathered and often placed in large stores called middens.

Southern flying squirrel. Lyon (1923) did not see southern flying squirrels but listed them as almost certain to be present at the lakeshore. Krekeler (1981) indicated they are common in woods and suburbs. Texas Instruments personnel collected three from black oak–swamp forest.

Only two southern flying squirrels were taken during our studies; one in black oak forest and one in black oak savanna (Table 15). Scrubby black oak is a good habitat for southern flying squirrels because old woodpecker holes and other openings that are present provide nest holes or refuges. Southern flying squirrels are undoubtedly much more common than our data would indicate. They are reported to occur in the lakeshore maintenance buildings at Furnessville, although we have no specific details. Southern flying squirrels feed heavily on nuts and seeds but eat much insect material or even bird eggs or young.

American Beavers

Beavers had nearly disappeared from Indiana by about 1840 (Lyon 1936), although there were scattered and questionable later records. American beavers were reintroduced from Wisconsin and Michigan into Jasper–Pulaski and Kankakee fish and wildlife areas in 1935. Later introductions and transplantations were made into other areas. Brooks (1955) knew of 326 colonies in 43 counties. The majority were in northwestern Indiana including Lake, Porter, and LaPorte counties.

Table 15. Presence of the southern flying squirrel (*Glaucomys volans*) at Indiana Dunes National Lakeshore.

Habitat[a]	Plots with animals		Number of animals	
	Number	Percent	Total	Average/plot
Animals in traps				
Savanna				
Oak (15)	1	6.7	1	0.70
Upland forest				
Oak (9)	1	12.5	1	0.12

[a]Numbers in parentheses indicate number of plots.

Lindsey et al. (1969:529) provided a photograph of a beaver lodge taken in 1968 "in the part of Cowles Bog east of the road into Dune Acres." Krekeler (1981) listed the American beaver as uncommon at the lakeshore, but he did say that it has caused some high water problems on the road leading into Dune Acres (at Cowles Bog). Texas Instruments personnel did not list it during their study.

A beaver colony was on the Salt Creek watershed, and beaver sign was seen on the lower portions of the Little Calumet River during our study. A colonyhad been on the Little Calumet north of Chesterton, but the beavers were trapped a few years ago. Kemil Beach lifeguards observed a beaver swimming east in Lake Michigan and, later in the day, park visitors reported an exhausted beaver on the beach near Derby Ditch. Tom Sobat reported fresh beaver cuttings along Derby Ditch on 17 October 1990.

Mice and Rats

Most mice and rats are currently placed in the family Muridae, with three subfamilies, the Sigmodontinae (previously the Cricetinae), the Arvicolinae (previously the Microtinae), and the Murinae. The Sigmodontinae includes the native mice and rats. Their molariform teeth do not grow throughout the life of the animal but mature and form roots. The cusps of the molariform teeth are in two rows. The western harvest mouse and two species of *Peromyscus* are the sigmodontine species considered here. The Arvicolinae includes the voles, the common muskrat, and the bog lemmings. These animals feed exclusively on green vegetation, an exceedingly harsh food that rapidly wears down the teeth. They have adapted to this diet by evolving teeth with a series of loops and triangles on a flat occlusal surface. The teeth continue to grow throughout the life of the animal as they are worn down. The Murinae includes the Old World mice and rats, *Mus* and *Rattus*. Like the sigmodontines, the murines have rooted teeth, but the cusps of the molariform teeth are in three longitudinal rows. The meadow jumping mouse is in a separate family, the Zapodidae.

Native Mice and Rats. The Sigmodontinae constitutes one of the largest groups of mammals in North America both in terms of numbers of species and of numbers of individuals. Only two species are present at the lakeshore, although one of them, the white-footed mouse, is the most abundant mammal there.

Western harvest mouse. The western harvest mouse was first taken in Indiana in 1969 at Willow Slough State Fish and Wildlife Area in Newton County (Whitaker and Sly 1970). It probably moved into Indiana at about that time from Illinois, and by 1975 it had extended its range to include at least seven counties of northwestern Indiana (Ford 1975). It was present in Newton and Jasper counties but had not crossed the Kankakee River to the north into Lake and Porter counties. Should the Kankakee River be crossed, harvest mice could presumably become part of the fauna of the lakeshore.

White-footed mouse. The white-footed mouse is the most abundant small mammal at the Indiana Dunes National Lakeshore. It is most abundant in wooded and shrubby habitats but encroaches on most other habitats as well. This species often enters buildings in wooded areas.

Lyon (1923) stated that it was the most common mammal at the lakeshore—found in every situation except the foredunes where it is replaced by the prairie deer mouse. Krekeler (1981) listed this species as abundant in foredunes, dry and wet woods, thickets, and marsh borders. The white-footed mouse (445 individuals) was taken in 22 of the 24 habitats and in 98 of the 168 (58.3%) plots trapped (Table 16). The only habitats from which it was not taken were barren grounds and excavated areas—both habitats lacked plant cover, an essential for this species. The white-footed mouse was taken at its greatest abundance in ephemeral lowland forest, oak upland forest, mixed deciduous savanna, mixed deciduous upland forest, coniferous savanna, and pine plantations.

Prairie deer mouse. The deer mouse occupies a variety of habitats from woods to dry open areas, but only the prairie deer mouse is present in Indiana. The prairie deer mouse lives in dry open areas—never in woods. Unlike all other species of small mammals of Indiana, it can live in areas with little or no herbaceous vegetation, such as recently plowed or harvested fields or in open sandy areas. It often shows an inverse relation to plant cover. The prairie deer mouse uses the soil as cover. Its tracks are often obvious in loose or damp sand on the dunes or in light snow in plowed fields where it has emerged from one burrow and entered another.

Hahn (1909) did not think this species was common in Indiana. He recorded it from only five counties. However, Evermann and Clark (1920) stated that it was abundant on the dunes along Lake Michigan.

Lyon (1923) recorded this species as being uncommon at the lakeshore. He took 11 individuals, 9 from foredunes among sand reeds and dwarf cherries (*Prunus pumila*) and 2 from an interdunal meadow. This species and the house mouse were the only species Lyon took in the foredunes. Traps set in sand reed on a blowout 46 m above the lake took only the white-footed mouse. Because Lyon found numerous footprints of this species in the loose sand on the dunes but took few specimens, he thought a few mice made many tracks. We think, however, that this species is much more common on the dunes than his traps indicated.

Krekeler (1981) recorded the prairie deer mouse as abundant in foredunes, grasslands, thickets, and old fields. Texas Instruments personnel did not record it during their study; rather, they recorded 66 white-footed mice from the young foredunes. We suspect that some prairie deer mice were included in that number.

We recorded prairie deer mice from 10 of the habitats, but this species was most common in dry prairie and on rights-of-way (Table 17). The prairie deer

Table 16. Presence of the white-footed mouse (*Peromyscus leucopus*) at Indiana Dunes National Lakeshore.

Habitat[a]	Plots with animals		Number of animals	
	Number	Percent	Total	Average/plot
Animals in traps				
Prairie				
Dry (11)	3	27.2	10	0.91
Wet (6)	3	50.0	9	1.50
Terrestrial shrubland				
Lowland (9)	4	66.7	6	0.67
Upland (4)	2	50.0	4	1.00
Savanna				
Oak (9)	10	66.7	18	1.20
Coniferous (4)	3	75.01	5	3.75
Mixed deciduous (3)	3	100.0	20	6.67
Upland forest				
Oak (9)	8	100.0	59	7.38
Coniferous (4)	4	100.0	16	4.00
Mixed deciduous (13)	12	92.38	1	6.23
Lowland				
Ephemeral (9)	7	7.8	70	7.78
Perennial (18)	13	72.25	3	2.94
Wetlands				
Marsh (12)	6	50.0	15	1.25
Aquatic shrubland (5)	2	40.0	4	0.80
Swamp (4)	1	25.0	8	2.00
Bog (4)	2	50.0	10	2.50
Pannes (3)	1	33.3	3	1.00
Aquatic (4)	3	75.0	10	2.50
Developed				
Agricultural (9)	2	22.2	4	0.44
Pine plantations (3)	1	33.3	10	3.33
Razed residential (11)	6	54.5	18	1.64
Rights-of-way (6)	1	16.7	2	0.33
Animal or sign observed				
Savanna				
Coniferous (4)	1	25.0		
Earlier trapping (1978)	**Total**	**T/100 tn[b]**		
Swamp (northern edge, Cowles Bog)	10	0.43		
Pinhook Bog	5	0.13		

[a]Numbers in parentheses indicate number of plots.
[b]Total per 100 trap nights.

Table 17. Presence of the prairie deer mouse (*Peromyscus maniculatus bairdii*) at Indiana Dunes National Lakeshore.

Habitat[a]	Plots with animals		Number of animals	
	Number	Percent	Total	Average/plot
Animals in traps				
Prairie				
Dry (11)	6	54.5	31	2.82
Wet (6)	2	33.3	4	0.67
Terrestrial shrubland				
Upland (4)	1	25.0	1	0.25
Savanna				
Oak (15)	3	20.0	3	1.20
Coniferous (4)	1	25.0	7	1.75
Mixed deciduous (3)	1	33.3	1	0.25
Wetlands				
Pannes (3)	1	33.3	3	1.00
Developed areas				
Rights-of-way (6)	2	33.3	25	4.17
Animal or sign observed				
Barren ground				
Disturbed (5)	3	60.0		
Developed areas				
Excavated sand (3)	1	33.3		

[a]Numbers in parentheses indicate number of plots.

mouse feeds primarily on the seeds of the various grasses where it lives and also heavily on cutworms and other caterpillars that live among the clumps of grass. Today, the prairie deer mouse is an important species of cultivated fields in Indiana. We recommend a concurrent study of the prairie deer mouse and the white-footed mouse in habitats as the vegetation varies from prairie to brush and woods to evaluate the original relationship of these two.

Introduced Mice and Rats. The introduced mice and rats were previously placed in their own family, the Muridae. This family has now been expanded, however, to include three subfamilies: the native Cricetinae and Microtinae as well as the Murinae. The species of Murinae have been introduced accidentally and are usually in habitats created or disturbed by humans, although sometimes they invade native habitats.

House mouse. This little mouse has been transported around the world by humans and has caused millions of dollars in damage through spoilage of food and other items. In Indiana, it is common in cultivated fields when adequate cover is

available; unlike the prairie deer mouse, it vacates immediately once the cover is removed. These two species are the primary small mammals of the Indiana corn and soybean fields, although the white-footed mouse is sometimes present.

The house mouse invades beaches, offshore islands, and estuarine areas. It sometimes builds rather large populations, especially if other species are not present.

Lyon (1923:218) stated, "In spite of the large number of weekend visitors to the dunes who leave much food scattered about, and the numerous cottages toward Waverly Beach, the house mouse does not appear to be common in the region." Lyon took only two individuals, both in the foredunes area. One was at Big Blowout, opposite Furnessville and more than 1.6 km from a permanent dwelling, and the other was about 274 m from a weekend cottage. Lyon further reported the mice of one cottage to be white-footed mice, but both it and the house mice can and do inhabit buildings of the area. Krekeler (1981) listed the house mouse as common around farms, suburbs, ditches, grain fields, and meadows. Five were taken from the young foredunes during the Texas Instruments studies.

None were taken in any of our plots in the 24 habitats during the present studies; our only records were sight records at residential areas and some from Chellberg Farm. Two individuals were taken among 70 mammals from snap traps at Pinhook Bog by Whitaker and Mumford in 1978.

The house mouse is not abundant at the lakeshore, although it would probably be more abundant if more of the land were cultivated. The scarcity of house mice is probably a reflection of the large amount of natural habitat at the lakeshore.

Norway rat. This is the common rat associated with garbage dumps, barns, grain storage units, and suburban warehouses. It is a major pest almost everywhere it occurs, ruining foods and other materials and carrying disease.

Lyon (1923) did not trap or see any Norway rats, but he did say that residents reported them to be in outbuildings of the store at Waverly Beach. Krekeler (1981) reported them as common around farms, suburbs, and ditches. None were reported during the Texas Instruments studies.

We found rat droppings in abandoned buildings at Tremont and along Waverly Road in July 1987. These buildings have since been destroyed. We assume rats to occur in some of the buildings at the lakeshore, but none were taken in our traps.

Microtine Rodents. This is the other major group of mice and rats of North America. Members of this group are herbivorous and have rootless or continuously growing teeth that aid in maintaining adequate dentition because the animals feed heavily on green vegetation with its very abrasive cellulose. All five species of microtines present in the state are probably present at the lakeshore, although the southern bog lemming has not been taken to date.

Prairie vole. Lyon (1923) took three adult and four young prairie voles: three in burrows in woods in traps set for woodland voles and the others in an interdunal meadow. Krekeler (1981) listed it as uncommon in relatively dry fields with cover of grasses or weeds. Texas Instruments personnel did not record it during their study.

We took 17 individuals in eight plots in five habitats (Table 18) during our study. It was most abundant in agricultural lands (i.e., old field). This species lives in much drier and more sparsely vegetated areas and is much less common at the lakeshore than the meadow vole. Like the meadow vole, it feeds entirely on green vegetation.

Meadow vole. The meadow vole is abundant, especially in northern Indiana. It is most often collected in moist meadows with abundant green vegetation, especially grasses. In drier, more sparse fields, it tends to be replaced by the prairie vole. Lyon (1923) took prairie voles and also woodland voles at the lakeshore but did not take meadow voles. We suspect he did not trap in proper habitat for this species. Krekeler (1981) listed the meadow vole as abundant in moist areas with dense grass or weedy cover, including foredunes, marshes, and shores of ponds and streams. Texas Instruments personnel listed it in their summary table but did not indicate that it was found in any particular habitat.

Meadow voles are abundant at the Indiana Dunes National Lakeshore: 171 were taken in 28 plots in 13 of the habitats (Table 19). Meadow voles were most abundant in agricultural areas (i.e., old field) and upland terres-

Table 18. Presence of the prairie vole (*Microtus ochrogaster*) at Indiana Dunes National Lakeshore.

	Plots with animals		Number of animals	
Habitat[a]	Number	Percent	Total	Average/plot
Animals in traps				
Prairie				
Dry (11)	1	9.1	5	0.45
Terrestrial shrubland				
Upland (4)	1	25.0	1	0.25
Wetlands				
Marsh (12)	1	8.3	1	0.08
Aquatic shrublands (5)	1	20.0	1	0.20
Developed				
Agricultural (9)	4	44.4	9	1.00

[a]Numbers in parentheses indicate number of plots.

Table 19. Presence of the meadow vole (*Microtus pennsylvanicus*) at Indiana Dunes National Lakeshore.

Habitat[a]	Plots with animals		Number of animals	
	Number	Percent	Total	Average/plot
Animals in traps				
Barren ground				
Sand (5)	1	20.0	3	0.60
Prairie				
Wet (6)	1	16.7	1	0.17
Terrestrial shrubland				
Lowland (9)	1	11.1	1	0.11
Upland (4)	2	50.0	34	8.50
Savanna				
Mixed deciduous (3)	1	33.3	1	0.25
Lowland forest				
Ephemeral (9)	1	11.1	1	0.11
Wetlands				
Marsh (12)	5	41.7	14	1.17
Aquatic shrublands (5)	2	40.0	3	0.60
Swamp (4)	2	50.0	8	2.00
Pannes (3)	2	66.7	13	4.33
Developed				
Agricultural (9)	8	88.8	90	10.00
Rights-of-way (6)	1	16.7	1	0.17
Excavated sand (3)	1	33.3	1	0.33
Animal or sign observed				
Terrestrial shrubland				
Lowland (9)	1	11.1		
Savanna				
Coniferous (4)	1	25.0		
Lowland forest				
Ephemeral (9)	1	11.1		
Perennial (18)	1	5.6		
Wetlands				
Marsh (12)	1	8.3		
Developed				
Agricultural (9)	1	11.1		
Rights-of-way (6)	1	16.7		
Earlier trapping (1978)	**Total**	**T/100 tn[b]**		
Pinhook Bog	3	0.07		
Cowles Bog	4	1.00		

[a]Numbers in parentheses indicate number of plots.
[b]Total per 100 trap nights.

trial shrubland. Thirty-four were taken in one plot in upland terrestrial shrubland. The cover here was heavy and included dogwood, poison ivy, roses, some small pines, many forbs, and few grasses. The soil was moist. This species is cyclic, forming population highs every 3–4 years. It feeds entirely on green plants.

Woodland vole. Lyon (1923) took two woodland voles: a male in damp sphagnum and cranberry along an interdunal pond and a female in a burrow on a wooded dune. Lyon found many subterranean burrows perhaps used by this species, but traps set in them took mostly white-footed and prairie deer mice and prairie voles. Krekeler (1981) listed the woodland vole as uncommon in woods, thickets, and grasslands; Texas Instruments personnel caught two individuals in black oak–swamp forest.

Woodland voles should be fairly common in subterranean burrows in woodlands of the lakeshore area, but none were taken in our study plots. In forested hills of south-central Indiana, we have taken numbers in pit traps set for shrews. We did take four woodland voles in pitfalls set especially for this species in black oak woods in September and October 1989 in Porter County, 0.3 km east of 300E on U.S. Highway 20 near Chesterton.

Common muskrat. Lyon (1923) stated that some muskrats are said to be trapped each winter from the Great Marsh and interdunal ponds. Krekeler (1981) listed the common muskrat as common in marshes, ponds, and streams of the dunes area. Texas Instruments personnel reported 4 from the black oak–swamp, 13 from Cowles Bog area, and 53 from a pond.

Only four common muskrats were taken in our standard plots (Table 20), but the muskrat is common at the lakeshore. We have observed several on the Little Calumet River (south of Bailly Homestead and west of Howe Road) and in the ditches along I-94. Youngsters trapped several in these ditches in fall 1987. In 1988, three muskrat houses were near the bridge on Long Lake at West Beach, and muskrats were seen in the big pond between Lake Street and Miller Woods. Many were killed by automobiles (Table 20).

Southern bog lemming. Lyon (1923) did not record this species from the lakeshore. Krekeler (1981) recorded it as uncommon in bogs and in areas with lush ground cover of grass, but we have no indication that he ever saw a specimen. Texas Instruments personnel did not capture any southern bog lemmings.

We believe this species to be present, but apparently no specimen is available from the Indiana Dunes National Lakeshore. It was not evident in our sampling, and we have not taken it in extra trapping. We did find bright green fecal pellets, probably from this species, at a razed residential site on Waverly Road on 28 February 1988. Meadow voles produce dull green or brownish fecal pellets.

Jumping Mice

Meadow jumping mouse. Lyon (1923) included the meadow jumping mouse as a species almost certain to be in the lakeshore region, but no specific evidence of its presence was available. Krekeler (1981) indicated it as uncommon in moist areas with dense cover of weeds and shrubs. Texas Instruments personnel reported 4 individuals from the young foredunes and 23 from the transmission corridor.

We took 15 during the present study in three habitats (Table 21), 13 in one plot in aquatic shrublands. Also, Mumford and Whitaker (1982) took one at Cowles Bog and five at Pinhook Bog in fall 1978 and one from a flat depression behind the foredunes east of the Bailly generating station in October 1974.

This species is one of relatively few small mammal hibernators. It hibernates from early October to late April. It feeds on a variety of insect materials, especially caterpillars early in spring, and also numerous forbs and grass seeds as they become available during summer and fall. The meadow jumping mouse also feeds heavily on small subterranean fungi, *Endogone*, and its relatives.

Carnivores

Other than the common raccoon, which is abundant and obvious, the carnivores are difficult to assess as inhabitants of the lakeshore. Being relatively

Table 20. Presence of the common muskrat (*Ondatra zibethicus*) at Indiana Dunes National Lakeshore.

	Plots with animals	
Habitat[a]	Number	Percent
Animal or sign observed		
Savanna		
Coniferous (4)	2	50.0
Wetlands		
Marsh (12)	1	8.3
Aquatic (12)	1	25.0
Observed killed on road		
1984	34	
1985	4	
1986	1	
1987	1	

[a]Numbers in parentheses indicate number of plots.

large, they are less abundant than small mammals. They are often thought of as problem animals to many members of the general public. Hunting of these animals for predator control over the years has sharpened their instincts, making them difficult to capture or to observe.

Dogs and Foxes

Three native members of the canid family are under consideration here—the red and common gray foxes and the coyote. Dogs, perhaps some of them feral, are present also, but they will not be considered further.

Coyote. The coyote has always maintained itself in Indiana, but in recent years it has increased in abundance. Apparently, it has never been abundant at the lakeshore. Krekeler (1981) reported it as rare. His report, however, is not backed by any specific record. Texas Instruments personnel did not record the coyote during their studies. It could have been there in the past, although Rand and Rand (1951) found no bones of this species during their work. No verified record of this species exists at the lakeshore.

A coyote was seen by Noel Pavlovic at Tolleston Dunes on 7 August 1990, and lakeshore rangers have seen them several times near the Heron Rookery starting in June and July 1990. Also, Dan Fagre saw one in a cornfield just south of the lakeshore in 1991. It is not yet clear whether coyotes are resident at the lakeshore, but if not, it seems only a matter of time until they are.

Red fox. Red and common gray foxes are often confused, primarily because the gray fox has some reddish coloration. The red fox is easily identified because it is all red above with a white tail tip.

Table 21. Presence of the meadow jumping mouse (*Zapus hudsonius*) at Indiana Dunes National Lakeshore.

	Plots with animals		Number of animals	
Habitat[a]	Number	Percent	Total	Average/plot
Animals in traps				
Prairie				
Wet (6)	1	16.7	1	0.17
Terrestrial shrubland				
Upland (4)	1	25.0	1	0.25
Wetlands				
Aquatic shrublands (5)	1	20.0	13	2.60
Earlier trapping (1978)	**Total**	**T/100 tn[b]**		
Pinhook Bog	5	0.13		
Cowles Bog	1	0.25		

[a]Numbers in parentheses indicate number of plots.
[b]Total per 100 trap nights.

Lyon (1923) stated that red foxes are not rare at the lakeshore, although they are not seen frequently. Some were apparently taken for their fur in the 1920's. Lyon's wife saw one individual, and Lyon saw tracks of a fox he assumed to be a red fox. Krekeler (1981) listed the red fox as common in old fields and thickets and around farms. Texas Instruments personnel recorded tracks of fox but did not specify which species. They recorded it in young foredunes, stable foredunes, black oak forest, black oak–swamp forest, Cowles Bog, and red maple swamp forest.

During the present study, tracks or scat of the red fox (identification based primarily on habitat) were seen on eight occasions in five habitats (Table 22). One was found dead along the roadside in 1984–85. Four were seen from a helicopter during the 1991 lakeshore survey for deer.

Common gray fox. The common gray fox is a resident of the deeper woods and should not be uncommon in the forests of the lakeshore. Lyon (1923), however, did

Table 22. Presence of the red and common gray foxes (*Vulpes vulpes* and *Urocyon cinereoargenteus*) at Indiana Dunes National Lakeshore.

	Plots with animals	
Habitat[a]	Number	Percent
RED FOX		
Animal or sign observed		
Prairie		
Dry (11)	2	18.2
Terrestrial shrubland		
Upland (4)	1	25.0
Savanna		
Oak (15)	2	13.3
Coniferous (4)	1	25.0
Wetlands		
Aquatic shrubland (4)	1	25.0
Developed		
Excavated sand (3)	1	33.3
Observed killed on road		
1984–85	1	
1986	0	
1987	0	
COMMON GRAY FOX		
Animal or sign observed		
Upland forest		
Oak (9)	1	12.5

[a]Numbers in parentheses indicate number of plots.

not mention it as being present, and Krekeler (1981) lists it as rare in thickets and woods. We suspect that some of the foxes recorded by Texas Instruments personnel on the basis of tracks in black oak forest, black oak–swamp forest, Cowles Bog, and red maple swamp forest might well have been gray foxes. We expect the gray fox to
be at least as common as the red fox in the lakeshore area because of the amount of forest present.

We have one definite record of the common gray fox during the present study. It was seen at Howes Prairie on 11 August 1987 (Table 22). More recently, Dan Fagre saw two in the area just east of Dune Acres.

Raccoon

The common raccoon is the only animal in its family at the Indiana Dunes National Lakeshore.

Common raccoon. The common raccoon is obvious at the lakeshore because it is abundant and often enters campgrounds and other places where people are likely to deposit garbage. Seemingly this was not always so, as Lyon (1923:213) said, "Residents state that a few 'coons' are taken each season for their fur. I have no personal knowledge of the animal and I have never been fortunate enough to find foot prints that might have been made by it." Krekeler (1981) lists it as common in woods near ponds and streams and on farms. Texas Instruments personnel listed tracks or one or two raccoons taken in all eight habitats they studied.

A number of common raccoons were collected from the lakeshore for parasite studies. Many of the raccoons harbored nematodes (*Baylisascaris procyonis*, *Arthrocephalus* sp., and *Capillaria* sp.), larvae of lungworms, and oocysts of two genera of coccidian Protozoa (*Eimeria* and *Isospora* sp.). During the present study, 55 raccoons were trapped in 38 plots in 18 habitats, sign was seen in more areas, and 167 individuals were recorded as killed on the road (Table 23).

Weasels

This family contains a diverse assemblage of species. Five are present at the Indiana Dunes National Lakeshore: two weasels, the mink, the badger, and the striped skunk.

Long-tailed weasel. This is a common weasel in Indiana and is found throughout the state. The animal is brown in summer and may turn white in winter, but the tip of the tail is always black.

Lyon (1923:213) states, "These animals are fairly common in the region although I have never seen any." He reported that in the dunes region and near Chesterton a trapper had taken about 200 individuals in the past 3 winters, but only two of them were in white pelage. Texas Instruments personnel did not

Table 23. Presence of the common raccoon (*Procyon lotor*) at Indiana Dunes National Lakeshore.

Habitat[a]	Plots with animals		Number of animals	
	Number	Percent	Total	Average/plot
Animals in traps				
Prairie				
Wet (6)	1	16.7	2	0.33
Terrestrial shrubland				
Lowland (9)	2	22.2	2	0.22
Upland (4)	1	25.0	2	0.50
Savanna				
Oak (15)	1	6.7	1	0.70
Mixed deciduous (3)	1	33.3	1	0.25
Upland forest				
Oak (9)	1	67.5	6	0.75
Coniferous (4)	1	25.0	2	0.50
Mixed deciduous (6)	6	46.1	9	0.69
Lowland forest				
Ephemeral (9)	5	55.6	6	0.67
Perennial (18)	4	22.2	7	0.39
Wetland				
Marsh (12)	3	25.0	5	0.42
Swamp (4)	2	50.0	2	0.50
Bog (4)	1	25.0	1	0.25
Aquatic (4)	1	25.0	1	0.25
Developed areas				
Agricultural (9)	3	33.3	3	0.33
Pine plantations (3)	1	33.3	1	0.33
Razed residential (11)	3	27.3	3	0.27
Excavated sand (3)	1	33.3	1	0.33
Animal or sign observed				
Barren ground				
Sand (5)	3	60.0		
Prairie				
Wet (6)	1	16.7		
Terrestrial shrubland				
Lowland (9)	2	22.2		
Savanna				
Coniferous (4)	1	25.0		
Upland forest				
Oak (9)	1	12.5		
Mixed deciduous (13)	1	7.7		
Lowland forest				
Perennial (18)	4	22.2		

Table 23. *Continued.*

Habitat[a]	Plots with animals		Number of animals	
	Number	Percent	Total	Average/plot
Wetland				
Marsh (12)	3	25.0		
Aquatic shrublands (5)	1	20.0		
Aquatic (4)	2	50.0		
Developed				
Razed residential (11)	1	9.1		
Excavated sand (3)	2	66.7		
Marsh (12)	3	25.0		
Observed killed on road				
1984	79			
1985	49			
1986	29			
1987	10			

[a]Numbers in parentheses indicate number of plots.

report this species. Krekeler (1981) listed the long-tailed weasel as uncommon in woods, near ponds and streams, and on farms.

During our studies, we took six long-tailed weasels in traps in three habitats. We observed tracks of four—one at Howe's Prairie and another in upland forest (Table 24). This species is probably relatively common but is seldom seen. It feeds primarily on small mammals.

Least weasel. The least weasel is a tiny prairie species with a 2.5-cm-long tail. Dice (1928) reported the first least weasel from Indiana. It was from Wells County and was killed by a dog as it ran from under a corn shock. Lyon (1936) reported this species only from Pulaski and Wells counties.

The least weasel has now been taken sparingly throughout the northern three quarters of Indiana, and there is one earlier record for Porter County (Mumford and Whitaker 1982). A specimen taken by A. L. Rand on 10 June 1950 is in the Field Museum of Natural History, Chicago (112538), but there is no specific locality.

The first individuals definitely from the lakeshore were collected during the Texas Instruments studies—one from the young foredunes and one from the black oak–swamp forest. The foredunes is suitable habitat because this species inhabits open fields and feeds heavily on meadow mice. The forest habitat is atypical. Krekeler (1981) reported the least weasel as uncommon in open and cultivated fields, presumably on the basis of the Texas Instruments

Table 24. Presence of the long-tailed weasel (*Mustela frenata*) at Indiana Dunes National Lakeshore.

Habitat[a]	Plots with animals		Number of animals	
	Number	Percent	Total	Average/plot
Animals in traps				
Lowland forest				
Ephemeral (9)	2	2.2	3	0.33
Wetlands				
Marsh (12)	1	8.3	1	0.08
Developed areas				
Agricultural (9)	1	11.1	2	0.22
Animal or sign observed				
Prairie				
Dry (11)	1	9.1		
Upland forest				
Oak (9)	1	12.5		
Observed killed on road				
1984–85	1			
1986	0			
1987	0			

[a]Numbers in parentheses indicate number of plots.

reports and consultation with R. E. Mumford. We did not take this species from plots during our studies, but one was killed by a car on 275E, just north of U.S. Highway 20 in October 1990.

Mink. The mink is weasel-like but is much larger than the long-tailed weasel. It has a bushy rather than a thin tail.

Lyon (1923) said that a number of minks are trapped each year in the lakeshore region. He collected a dead mink from the bottom of a dry interdunal pond. Texas Instruments personnel took two minks, both from Cowles Bog. Krekeler (1981) listed the mink as uncommon along the borders of ponds, streams, and marshes.

We saw a mink in a cattail marsh at Dune Acres on 9 January 1988. An adult and three young were seen by Rol Hesselbart along a marsh on Kemil Road in 1990.

American badger. Lyon (1923) listed the American badger as probably present or recently present in the lakeshore region. Texas Instruments personnel did not report it. Krekeler (1981) states that it may well be at the lakeshore. Brennan (1923) reported in detail a specimen from the Furnessville Blowout, which is now within the boundary of the state park (west end).

In fall 1986, a badger was found near a trash can in a parking lot at the lakeshore. Its claws had been removed, and we suspect that it had been transported there from some other locality.

An American badger was found dead on 7 September 1990 in Porter County on Highway 30 about 14.5 km west of Highway 49, 0.8 km west of 600W (center of section 23). This is about 14.5 km south of the present lakeshore boundary.

On two occasions we have recorded sign that may have been made by badger—tracks in black oak forest at Howe's Prairie on 11 August 1987 and excavations in dry prairie at the proposed campground on 14 July 1987. Larry Reed, Westchester Animal Clinic, reported treating a badger captured in the western part of the east unit during 1990.

Finally, on 9 April 1989, a badger was seen by Mark Harbin and Andrea Halcarz just west of the parking lot near the entrance to Dune Acres. It disappeared from view but apparently went down a large burrow at the base of a tree on a sandy bank.

Striped skunk. Lyon (1923) reported that the skunk was common in the area and that some were taken each year for fur. He was given the carcasses of two by a trapper who had taken seven by 30 November 1922. Texas Instruments personnel collected one striped skunk from stable foredunes and one from black oak forest and saw tracks in black oak–swamp forest and in red maple swamp forest. Krekeler (1981) listed it as uncommon in thickets, woods, and grasslands and stated that it forages along the beach of Lake Michigan.

Two striped skunks were taken in traps during our study, and one was observed (Table 25). None were recorded as killed on the road.

Table 25. Presence of the striped skunk (*Mephitis mephitis*) at the Indiana Dunes National Lakeshore.

	Plots with animals		Number of animals	
Habitat[a]	Number	Percent	Total	Average/plot
Animals in traps				
Developed				
Agricultural (9)	1	11.1	1	0.11
Razed residential (11)	1	9.1	1	0.09
Animal or sign observed				
Upland forest				
Oak (9)	1	12.5		

[a]Numbers in parentheses indicate number of plots.

Cats

The house cat and the bobcat need to be mentioned. The bobcat can be recognized by its very short or bobtail, in contrast to the long tail of the familiar house cat (although an occasional house cat has no tail and some breeds have bobtails).

House cat. We have had some indication that the house cat is or may become a problem animal at the lakeshore. Apparently, some were sighted at the Heron Rookery. The house cat is found around residences, but to date we have seen no sign that house cats are a problem or that feral populations of house cats occur at the lakeshore.

Bobcat. The bobcat is exceedingly rare and is listed as endangered in Indiana, although observations continue to be made. The latest confirmed records are from Monroe County (1970), Perry County (1975), Jefferson County (1982), Lawrence County (1982), Parke County (1987), Harrison County (1988; tracks at Department of Natural Resources scent station), Crawford County (1988), Warrick County (1990), DeKalb County (1993), and Steuben County (1993). In addition, numerous unconfirmed reports are made to the Indiana Department of Natural Resources, but many of these are probably erroneous. Unconfirmed reports include two each from LaPorte and Starke counties. It is unlikely, but the bobcat could still exist in wooded areas of the lakeshore.

Deer

White-tailed Deer

The white-tailed deer had been extirpated from the lakeshore region for many years at the time of Lyon's writing (Lyon 1923). Actually, the species was extirpated from the state by 1900 (Mumford and Whitaker 1982). Restocking of deer in Indiana began in 1934 when 35 deer were released in seven counties. In addition, a few deer may have entered Harrison County by crossing the Ohio River from Kentucky. By 1955, more than 400 deer had been introduced into 22 counties. Population estimates for the state were 900 in 1943, 1,200 in 1944, and more than 2,900 by 1946. The estimate was at 5,000 by 1951, and a deer hunting season was opened that year. By 1966, deer were probably present in all counties, and they are presently abundant throughout the state.

In 1975–80, Texas Instruments personnel observed deer or tracks in all eight habitats they studied: young foredunes (tracks), stable foredunes (1 deer observed), black oak forest (9), black oak–swamp forest (3), Cowles Bog (3), red maple swamp forest (4), pond (2; tracks), and transmission corridor (tracks). Krekeler (1981) stated that the species was common in woods, thickets, swamps, and farms.

The white-tailed deer is abundant at the Indiana Dunes National Lakeshore. During our study, we recorded deer by tracks, fecal pellets, or actual observation in 62 plots in 20 of the 24 habitats (Table 26). Fourteen deer were found dead on the highways of the lakeshore from 1984 to 1987 (Table 26).

Deer have been counted (aerial census) by lakeshore personnel in 1982, 1984, 1988, and 1989 (Fig. 54). The actual counts were 85, 29, 214, and 349 deer, respectively. Similar counts for 1991 and 1992 were 166 and 207. The actual populations, however, are higher than that. It is not known what proportion of the deer were observed, and only about 75% of the lakeshore was flown. These data are by section of the lakeshore in which the deer were seen, by grouping of the deer, and by habitat (Fig. 55).

Discussion

Geographic Distribution of the Mammals

Most of the species of mammals at the lakeshore live throughout the area within their respective habitats. Comments are in order concerning the few that do not.

Species Near the Limits of Their Range

The pygmy shrew, very rare if present, would be the northern subspecies and would be at the southern limit of its range. The southern subspecies, *Sorex hoyi winnemana*, lives in the unglaciated hill country of southern Indiana.

The star-nosed mole is presently limited to the northeast in Indiana. If it is present at the lakeshore, it would be at the western edge of its range in Indiana.

The Indiana myotis, eastern pipistrelle, and evening bat, if they are present, would be near the northern limits of their ranges. The silver-haired bat winters to the south and has its young to the north. It passes through the dunes in spring and fall on its annual migration.

The western harvest mouse would be a recent immigrant at the northeastern limits of its range. It could possibly manage to cross the Kankakee River and to establish populations in the dunes area.

Species With Limited Geographic Ranges Within the Lakeshore

The thirteen-lined ground squirrel seems limited to the western part of the lakeshore. Ten of the 15 individuals from plots were from West Beach, 2 were from the Inland Marsh area, 2 were from the Harbor Belt, and 1 was from inland woods. Three individuals killed on the road were recovered along Wagner Road.

The Franklin's ground squirrel was once present near Miller. We should continue to watch for this species in the western part of the lakeshore.

Table 26. Presence of the white-tailed deer (*Odocoileus virginianus*) at Indiana Dunes National Lakeshore.

Habitat[a]	Plots with animals	
	Number	Percent
Animals or sign observed		
Barren ground		
Sand (5)	2	40.0
Prairie		
Dry (11)	2	18.2
Wet (6)	1	16.7
Terrestrial shrubland		
Lowland (9)	3	33.3
Upland (4)	2	50.0
Savanna		
Oak (15)	7	46.7
Coniferous (4)	2	50.0
Upland forest		
Oak (9)	3	37.5
Coniferous (4)	3	75.0
Mixed deciduous (13)	3	23.1
Lowland forest		
Ephemeral (9)	4	44.4
Perennial (18)	11	61.1
Wetlands		
Marsh (12)	3	25.0
Aquatic shrublands (5)	1	20.0
Aquatic (4)	3	75.0
Developed		
Agricultural (9)	3	33.3
Pine plantation (3)	2	66.7
Razed residential (11)	1	9.1
Rights-of-way (6)	4	66.7
Excavated sand (3)	2	66.7
Observed killed on road		
1984	1	
1985	0	
1986	2	
1987	11	

[a]Numbers in parentheses indicate number of plots.

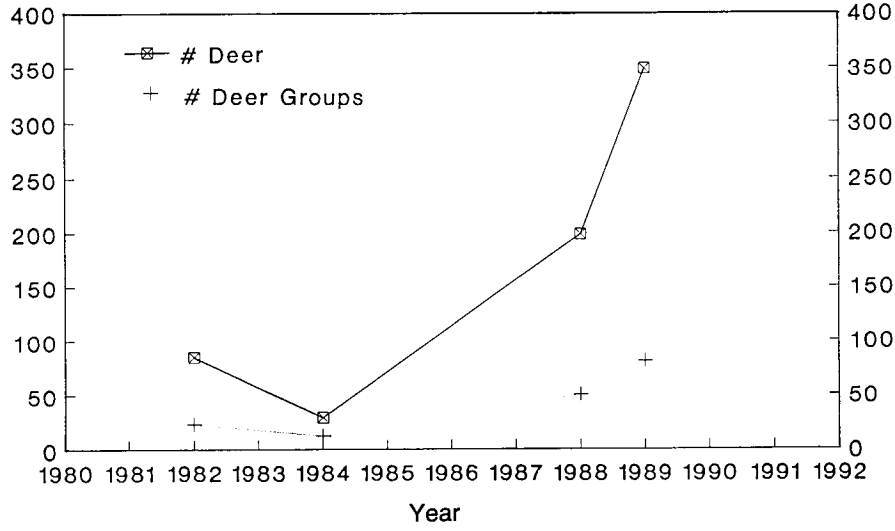

Fig. 54. Deer counted by aerial census at Indiana Dunes National Lakeshore.

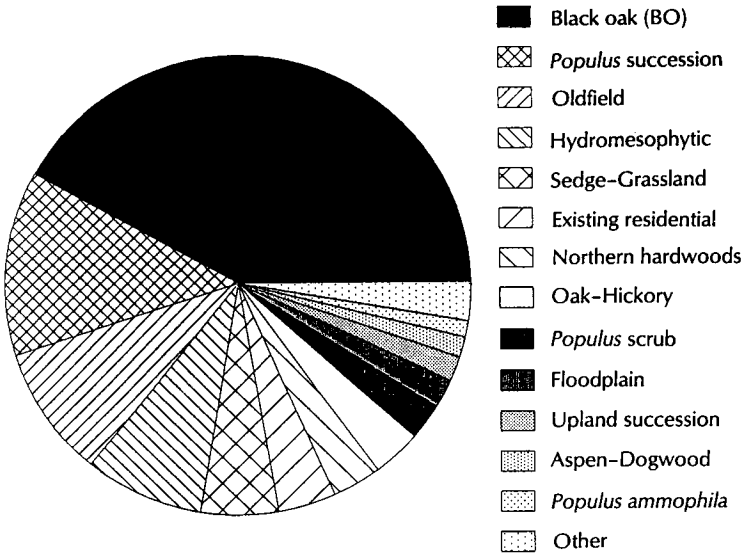

Fig. 55. Percentage of white-tailed deer in various habitats at Indiana Dunes National Lakeshore.

The eastern gray squirrel is not common at the lakeshore but has been seen throughout the area. It reaches its greatest abundance in Miller Woods.

Extirpated Mammals

A number of mammal species became extinct (throughout their range) or extirpated (eliminated from part of their range, but the species still survives elsewhere) in Indiana at the end of Pleistocene times. Many of these could have been present in the area that is presently the lakeshore. Pleistocene fossils recorded by Lyon (1936) for this area are of the elk, the white-tailed deer, the bison, the united-horn musk-ox (*Symbos cavifrons* Leidy), the Pleistocene horse (*Equus* sp.), the mastodon (*Mammut americanus* Kerr), and the mammoth (*Elephas columbi*).

Several species of mammals have been extirpated from Indiana within the past 150 years including the following species that could have occurred at the lakeshore. Dates are the approximate year of the last report from the lakeshore area if available (marked with an asterisk) or from Indiana (Lyon 1936; Mumford and Whitaker 1982).

Rodentia	
Porcupine (*Erethizon dorsatum*)	1918*
Carnivora	
Gray wolf (timber wolf; *Canis lupus*)	1908
Red wolf (*Canis rufus*)	1832
Black bear (*Ursus americanus*)	1850*
Fisher (*Martes pennanti*)	1855
River otter (*Lutra canadensis*)	1900*
Mountain lion (*Felis concolor*)	1830*
Lynx (*Lynx lynx*)	1880*
Bobcat (*Lynx rufus*)	1880*
Artiodactyla	
Elk (wapiti; *Cervus elephus*)	1830
Bison (*Bos bison*)	1731*

Franklin's ground squirrel and the bobcat, presently existing in Indiana, were at the lakeshore in recent times but seem to have been extirpated. The beaver and the white-tailed deer were extirpated from the lakeshore area but have been reintroduced. The badger decreased so greatly in Indiana that late records were listed for Lake, Porter, and LaPorte counties as 1927, 1927, and 1871, but this species has recently increased and is present at the lakeshore.

Threatened or Endangered Species

The only threatened or endangered species of mammal presently known to exist at the lakeshore is the badger. Other endangered or threatened species that could be present, but have not been documented, are the Indiana myotis (federal endangered list), the evening bat and the bobcat (state endangered list), and the Franklin's ground squirrel (state threatened list; Whitaker and Gammon 1988). The star-nosed mole is listed as a mammal of special concern in Indiana, which means it is being monitored.

Biological Succession of the Mammals

The Indiana Dunes National Lakeshore area is outstanding in its diversity and its ability to attract people for both recreational and educational purposes. The lakeshore shows that the public and the federal government can unite to set aside and to ecologically improve a major tract of land in the heart of some of the most populated and polluted land in the country. This is encouraging in this time of ecological crises, the biggest of which is our ever-expanding human population.

Biologically, the Indiana Dunes is best known for the pioneering studies of plant succession by Cowles (1899) and of animal succession by Shelford (1917). The mammals, however, have never been adequately studied there. One of our objectives was to obtain information on succession of mammals as it occurs at the lakeshore.

The area was divided into 24 habitats, which can be thought of as seral stages, although it is artificial to divide a continuum into stages. To be sure, one can tell grassland from shrubland from forest stages. It is not always easy, however, to determine into which category to place grassland that includes a few shrubs, shrubland with some trees, and so on.

Some of the successional sequences at the dunes are indicated in their simplest and most direct form (Fig. 56). This sequence often proceeds to completion or at least to late stages as indicated by the vast amount of forest currently present at the lakeshore (over 50% of the area, even with all of the human disturbance).

In drier situations today, the result is most often oak forest (beech–maple is presumably the ultimate climax at the lakeshore). Some small stands of beech–maple forest can be found, but this type of forest was farthest back from the lakefront and was almost entirely eliminated as the area was developed.

The normal sequence may be interrupted at any time by nature (blowouts) or by humans. The habitat then reverts to an earlier stage or to the beginning. These interruptions have occurred many times; thus, one finds

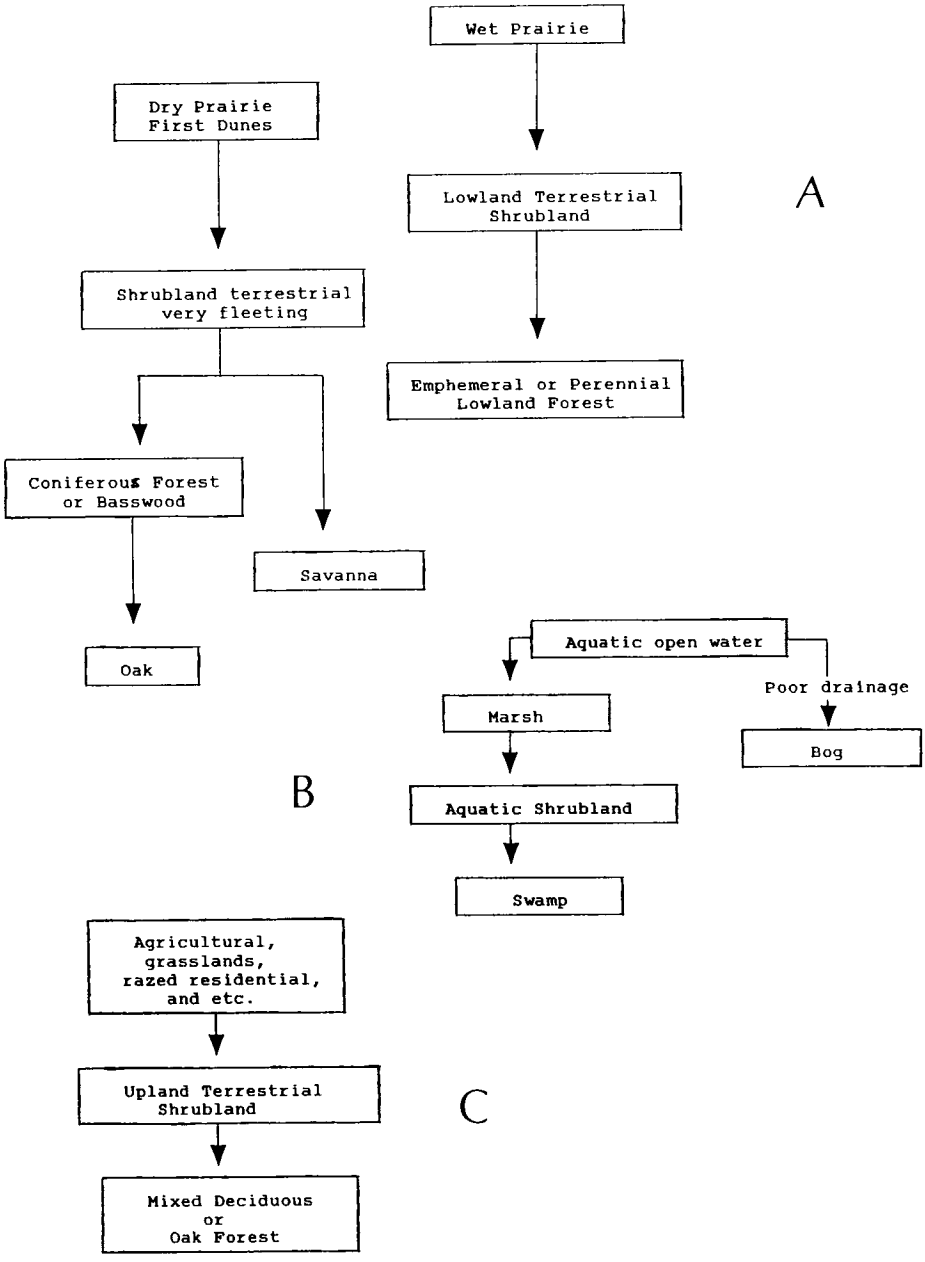

Fig. 56. Some routes of successional development at Indiana Dunes National Lakeshore: *A.* Succession from dry or wet prairie; *B.* Aquatic succession; *C.* Succession on disturbed areas. Interruption of the sequence at any point, primarily through blowouts or human activity, can revert an area to an earlier seral stage or to the beginning.

a mixture of habitats superimposed on the basic original pattern of marram grass and other grasses on the foredunes with small shrubby areas and forested dunes behind. One finds open sand and shrub stages (and also sometimes old buried forests) in active blowouts at various places in the oak forest.

When we think of awe-inspiring natural sights, we think of the Grand Canyon, Alaska, and other areas of breathtaking beauty. We have been in some of these places, but we also find it awe-inspiring to be at the top of a blowout overlooking the southern end of Lake Michigan at the Indiana Dunes National Lakeshore as a fall storm moves in. One can see, hear, and feel nature in action as the sand is picked up by the wind on the lake side, transported up the hill and over the top, and dropped to cover the mature oak forest on the far side of the dune. As the wind comes out of the gray billowy clouds from the north, one can visualize the movement inland of the entire dune. Ultimately the natural forces strip away the vegetation and confuse the normal pattern of black oaks on the dunes and red oaks in the interdunal depressions. One knows, however, that the process of succession will begin again in these areas denuded by the wind and wind-borne sand.

Move down the slope on this same windy fall day to the first line of dunes and it becomes clearer how the entire process of dune formation develops and succession begins. Sit and watch clumps of marram grass as the wind comes in and, broken by the grass, drops some of its sand on the back side of the clump. The old stems of this grass can serve as roots when they become buried. Knowing this, it is easy to understand how the dune will continue to grow upward and outward and how the process of dune formation has started.

Humans have also played a major role in bringing the dunes to where they now are. Many more lines of dunes were present 200 or more years ago, extending some 16–26 km from the lakeshore. Dune formation and succession was broken only by the natural processes such as the initiation of wandering dunes through exposure of sand by erosion or by the death of certain dune-holding species such as eastern cottonwood. The latter dunes were presumably of beach–maple climax forest unbroken by roads, railroads, factories, and smoke.

Then humans moved in. The back dunes were cleared and leveled. Railroads, roads, houses, and factories were built, and most of the land, including the series of dunes back from the lakefront, was cleared. Houses were built along the lakeshore, but fortunately much of the land between the foredunes and the cleared area was spared. Several other favorable things occurred. In 1925, the State of Indiana set aside a major portion of this area, including about 4.8 km of beach, as the Indiana Dunes State Park. Senator Paul Douglas and conservation minded citizens pressed for saving this unique area. The Indiana Dunes National Lakeshore was authorized by the U.S. Congress in 1966 and was formally established in 1972.

Since 1972, principal lakeshore management objectives have included acquiring as much land as possible to complete the master plan and to reverse the effects

of humans—to raze the human-made structures and to let nature take its course through the seral stages. Five of the habitats present, the developed areas, are a direct result of human activities and are not part of the natural processes. The developed habitats include agricultural lands, pine plantations, razed residential areas, rights-of-way, and excavated areas. Presumably, much of this nonnatural area will be developed as park facilities or will be allowed to progress through natural stages to climax. The agricultural lands and razed residential areas will probably revert through shrub stage to forest. The pine plantations are expected to revert to hardwood on death of the pines. The excavated areas will remain as grassland, shrubland, or forestland depending on the amount of moisture, nutrients, and soil pollutants present. The rights-of-way will continue to exist as long as the associated roads, railroads, and other related items are maintained.

The general elements of plant succession at the Indiana Dunes National Lakeshore have been outlined (Fig. 56). Plants are the producers in any ecosystem, and they also form the structural basis of the habitat. Animals are, therefore, dependent on plants both for energy and for habitat, and animal succession parallels or follows plant succession.

Mammalian succession at the lakeshore is represented by few species in contrast to the number of species of plants and insects. Mammals move about much more than smaller animal forms. The larger mammals such as the Virginia opossum, carnivores, rabbits, beaver, deer, and bats move between habitats almost at will when the habitats have been fragmented into small patches such as at the lakeshore. We will not consider these species further in relation to succession. We will consider the less mobile small mammals—the rodents and the insectivores—in a discussion of succession.

Factors such as soil moisture, fertility, and exposure can affect the progress of succession in different ways. We have outlined several of the possible sequences at the lakeshore (Fig. 56).

The first sequence of habitats is from dry prairie, which exists on the first line of dunes or in interrupted areas. The small mammals of the dry prairie, listed in order of decreasing abundance with total and mean (in parentheses) per plot, were

Prairie deer mouse	31	(2.82)
White-footed mouse	10	(0.91)
Prairie vole	5	(0.45)
Thirteen-lined ground squirrel	4	(0.36)
Northern short-tailed shrew	3	(0.27)

Three are prairie species: the prairie deer mouse, the prairie vole, and the ground squirrel. They can be considered as the characteristic small mammals of this habitat. The white-footed mouse is a woodland species, but it is the most common small mammal at the lakeshore and is catholic as to habitat. It often moves across

areas of poor habitat in getting to its more normal habitats, which is why it was common even in dry prairie. It was the most important mammal by presence or abundance in 16 of the 24 habitats.

Only three northern short-tailed shrews were found in dry prairie habitat; thus, they are not particularly important. They probably were taken in clumps of vegetation where the soil was more moist than was generally true in dry prairie.

Little upland terrestrial shrubland is present on the foredunes because the foredune prairie develops into oak forest. Usually only a narrow strip of such habitat is present, and time is insufficient for a major mammal assemblage to develop. No study plots were located in the upland terrestrial shrubland in our study. The best direct indication of the change in the mammal community from open dunes to woodland is probably data that J. O. Whitaker and R. E. Mumford collected 16–18 October 1974. They set four lines of traps on the foredunes just east of Bailly generating station. Each line contained 288 traps and was run for 2 nights (576 trap nights each).

The first trap line was on the front line of dunes in pure marram grass in full fruit. The cover value ranged from fair to good. Piles of marram grass heads and cuttings were common. Whitaker and Mumford took one masked shrew, one northern short-tailed shrew, eight white-footed mice, and two meadow voles in this line. There seemed to be too much vegetation for prairie deer mice but too little for either of the voles, although two meadow voles were taken. The meadow vole rather than the prairie vole was probably present because of the proximity to the wet depression (discussed in the next paragraph), where the meadow vole was the dominant small mammal.

The second trap line was in a depression behind the foredunes. The vegetation consisted of almost pure marram grass but with few fruits. Again, piles of marram grass heads and cuttings were present. Small mammals taken were 1 northern short-tailed shrew, 7 white-footed mice, 10 meadow voles, and 1 meadow jumping mouse. The cover was heavy (nearly 100% of the ground covered in most places), and it was wet, which can explain the dominance of the meadow voles.

The third trap line was at the terrestrial shrub interface between the open areas and the forest. A mixture of brushy species, forbs, and grasses was present. The cover was in the form of two clumps of grasses, and the rest of the area was open sand. The animals taken were one masked shrew, nine white-footed mice, and three meadow voles. All the animals, except for the one shrew, were in the clumps.

The last trap line was in the black oak forest, although it was on the first line of dunes and a number of shrubby species were still present. Cover was sparse. One masked shrew and three white-footed mice were taken there.

Small mammals are indicated below for each of the three types of upland forest at the lakeshore—coniferous forest, mixed forest, and oak forest. Coniferous forest develops only on the first lines of dunes, whereas mixed or oak forest develops either on the dunes proper or secondarily from either agricultural (old

field) or razed residential land through an upland shrub stage. The small mammals in the wooded habitats in order of decreasing abundance with total and mean (in parentheses) per plot were

	Coniferous	Mixed	Oak
White-footed mouse	16 (4.00)	81 (6.23)	59 (7.38)
Northern short-tailed shrew		6 (0.46)	5 (0.63)
Eastern chipmunk	2 (0.50)	5 (0.38)	1 (0.12)
Eastern fox squirrel		3 plots	1 plot
Eastern gray squirrel			1 (0.25)
Red squirrel		1 (0.08)	

Thus the community in the upland forest was characterized by the northern short-tailed shrew, four species of squirrels, and the white-footed mouse.

A second major upland successional route at the lakeshore starts with disturbed land, usually either abandoned agricultural land or razed residential areas. Most of this habitat is away from the lake, and the soil is of fertile loam rather than sand as is on the front dunes. The species present, with total and mean (in parentheses) per plot and in order of decreasing abundance, were

	Old field	Razed residential
Meadow vole	90 (10.00)	
White-footed mouse	4 (0.44)	18 (1.64)
Northern short-tailed shrew	12 (1.33)	1 (0.09)
Prairie vole	9 (1.00)	
Masked shrew	3 (0.22)	
Eastern chipmunk	1 plot	1 (0.09)
Eastern fox squirrel	1 plot	

The most abundant mammal in the old fields was the meadow vole followed by the northern short-tailed shrew and the prairie vole. In the razed residential areas, the white-footed mouse was the most abundant species. In this sequence, when the old agricultural land or razed residential areas were allowed to grow unmolested by humans, they went through upland terrestrial shrubland then into mixed or oak woods. The mammals of the two kinds of woods are listed above, whereas the most abundant small mammals in the terrestrial shrubland, with total and mean (in parentheses) per plot and listed in decreasing order of abundance, were

Meadow vole	34	(8.50)
Northern short-tailed shrew	9	(2.25)
White-footed mouse	4	(2.25)

The data from upland terrestrial shrubland paralleled the data from old fields and from the razed residential areas, with the meadow vole, the northern short-tailed shrew, and the white-footed mouse being the dominant species.

The next major step from upland shrubland is upland forest. Here the meadow vole dropped out, and the white-footed mouse was the dominant small mammal, along with the squirrels.

Another successional sequence begins with wet prairie and goes through wet shrubland to lowland forest, either ephemeral (with water less than half of the year) or perennial (with water more than half of the year). In wet prairie, the most abundant small mammals, with total and mean (in parentheses) per plot, were

Masked shrew	11	(1.83)
White-footed mouse	9	(1.50)
Northern short-tailed shrew	8	(1.33)
Prairie deer mouse	4	(0.67)
Meadow vole	1	(0.17)
Meadow jumping mouse	1	(0.17)

Of these species, all but the white-footed mouse and the prairie deer mouse were expected inhabitants. The white-footed mouse is nearly everywhere at the lakeshore, and the prairie deer mouse is a species of the dry rather than wet prairie. We suspect that the prairie deer mice were taken on dry sandy areas within the wet prairie. We were surprised to find that only one meadow vole was taken in the six wet prairie plots because the meadow vole is a major inhabitant of this habitat. On 27 and 28 April 1977, J. O. Whitaker and R. E. Mumford collected 54 mammals in the wet portion of Hoosier Prairie, of which 30 individuals were meadow voles. Other small mammals taken were 11 masked shrews, 8 white-footed mice, and 5 northern short-tailed shrews. We felt that this association was probably fairly representative of an early wet prairie community.

If the wet prairie proceeds into lowland terrestrial shrubland and then into ephemeral or perennial lowland forest, the following small mammals, with total and mean (in parentheses) per plot and listed in decreasing order of abundance, are present:

		Lowland forest	
	L. shrubland	Ephemeral	Perennial
White-footed mouse	6 (0.67)	70 (7.78)	53 (2.94)
Northern short-tailed shrew	5 (0.55)	1 (1.33)	6 (0.33)
Eastern chipmunk		4 (0.44)	5 (0.28)
Thirteen-lined ground squirrel	4 (0.44)		
Masked shrew		1 (0.11)	1 (0.06)

Red squirrel		2 (0.22)	
Meadow vole	1 (0.11)	1 (0.11)	
Eastern fox squirrel			1 (0.06)

Relatively few mammals were taken in lowland terrestrial shrubland, but the white-footed mouse was the most abundant species in all three of these habitats. It was followed by the northern short-tailed shrew in lowland shrubland and perennial lowland forest and by the eastern chipmunk in ephemeral lowland forest. The chipmunk was third in perennial lowland forest. The thirteen-lined ground squirrel was found in two plots and was second in abundance in lowland shrubland. This had to be by chance because this species would not normally be found in this habitat.

The last sequence that will be outlined is the aquatic sequence in which open water gives rise to marsh and in turn to aquatic shrublands and to swamp. Small mammals of these habitats (in decreasing order of abundance; mean per plot in parentheses) were

	Marsh	Shrubland	Swamp
White-footed mouse	15 (1.25)	4 (0.80)	8 (2.0)
Meadow vole	14 (1.17)	3 (0.60)	8 (2.0)
Masked shrew	14 (1.17)		
Meadow jumping mouse			13 (2.60)
Northern short-tailed shrew	3 (0.25)	3 (0.60)	
Eastern chipmunk	3 (0.25)		
Prairie vole	1 (0.08)	1 (0.20)	
Eastern fox squirrel			1 (0.25)

The data for this sequence did not provide clear results. The meadow vole and the masked shrew were common in marsh along with the white-footed mouse—not much different from expected. One might have expected, however, some meadow jumping mice here with that combination of species, especially because the meadow jumping mouse was the most abundantly taken small mammal in shrubland. However, the white-footed mouse and meadow vole were common also in both aquatic shrubland and in swamp. No successional trends seemed apparent here; one would expect the meadow vole to drop out as the woody vegetation moved in and crowded out the grassy plants. These habitats, however, were not pure. We suspect that the grassy habitat present in both shrubland and in swamp allowed meadow voles to thrive there. One would not expect the prairie vole to be present, but some of these plots had other than the intended habitat present (i.e., some patches were dry grassy areas that allowed this species to live).

Some of these sequences do not clearly demonstrate mammalian succession. This may be because of the few species of mammals involved and because of the

diversity of some of the plots that included (or were close to) features other than those of the intended habitat.

The changes that seem to indicate succession can best be summed in generalities. In the early seral stages, one of three mammalian species is likely to be dominant depending on the amount of ground cover and moisture. If plant cover is sparse and the ground is dry, the prairie deer mouse is likely to be the major (and only) species present (it is likely to be replaced by the white-footed mouse in wetter situations, if enough cover is present). In situations with adequate herbaceous ground cover, the meadow vole is likely to be present in moist or lush grassy cover and is the dominant small mammal in grassy fields. In rather dry situations with less lush ground cover, the prairie vole may be the major species. Also, the thirteen-lined ground squirrel is occasionally found in open areas. If no other species becomes dominant, the white-footed mouse is likely to dominate because it is so abundant throughout the lakeshore. Also, as woody vegetation invades the former open areas, the white-footed mouse soon becomes the dominant small mammal in all habitats, but it is joined by the various species of tree squirrels as the forest grows toward maturity.

Effects of Past Manipulations on the Mammals

Manipulation at the lakeshore has been extensive as this is one of the more developed areas of the world. Fortunately, citizens and government stepped in before all the natural areas had been destroyed, and development has now stopped for the area currently under lakeshore jurisdiction. The area is still used, but the general trend now is toward natural seral stages. Much of the area near the beach (i.e., many lines of dunes) was not developed with the exception that roads and houses and other structures were built. Nearly all of the structures are being razed (about 700 by the year 2010), and some of the roads are being restored to former habitats. Much of the farmland is now being allowed to return to its natural state and is presently in various seral stages: grassland, shrubland, or young forest. Railroads and roads traverse the area, and maintenance of rights-of-way has provided different habitats than would have been present had nature been allowed to take its original course.

The major effects of these changes on the mammals of the region are difficult to pinpoint. It is evident that many species have disappeared, although the reason may be not so much due to the above changes as it is to the proximity to so many people. Many of the larger mammals, especially, simply disappear as they become too closely associated with people and the animal's habitat subsequently becomes diminished and fragmented. These species were discussed earlier, but included are the porcupine, the gray and red wolves, the black bear, the fisher, the river otter, the mountain lion, the lynx (perhaps), the bobcat, the elk, and the bison.

The white-tailed deer and the beaver were also extirpated but have been reintroduced to the area. The deer has increased to the density where control measures may be needed. The beaver is present and should continue to increase with increased protection, habitat improvement, and decreased habitat fragmentation. As these trends continue, other species could be considered for reintroduction. Some of the better possibilities would seem to be the porcupine, the fisher, the river otter, the bobcat, and perhaps the elk.

Besides direct manipulation by humans, we wonder about the effects of minerals and chemicals presumably entering the soil from the many factories in the area. We suspect that small mammal diversity and numbers may be reduced at the lakeshore from this cause, but additional comparative data on similar habitats away from the lakeshore in areas lacking such concentrations are needed to determine this. The foredunes seem to be particularly impoverished, but we cannot be sure of the cause. In addition to general impoverishment, there seems to be much variation in communities along the front lines of dunes, both on the tops and in the interdunal valleys. Much of the impoverishment and mammal community variation seems dependent on moisture and, perhaps, soil structure: Is the soil of a nature that the animals can construct burrows? Much more work is needed on the front lines of dunes to better determine the extent of the mammal species there and to determine reasons for impoverishment and variation.

A species that often invades when humans manipulate the environment is the introduced house mouse. It is the most common small mammal of Vigo County, Indiana (Whitaker 1967), where it lives primarily in the cultivated fields. We have been surprised at its paucity here, given the extent of manipulation in the lakeshore area. We would have expected the house mouse to be common in the early seral stage fields that had been previously under cultivation and had good cover. The species is nomadic, moving to other fields with adequate cover when crops are harvested. Also, house mice often become established on dunes especially when other species are lacking but always in good cover. We were surprised not to find this species in some numbers in the heavy stands of marram grass when other species were lacking.

Even though the area has been heavily utilized, the great amount of habitat that has been structurally unaltered may be a reason for the lack of house mice, along with lack of continually cultivated fields. House mice are common in fields under cultivation when herbaceous cover is ample or in early seral stages after the fields have been allowed to remain fallow (i.e., in fields of foxtail [*Setaria*]). Another factor may be the extensive woodlands (which house mice shun) separating the marram grass dunes from other habitats. The house mouse has lived alongside humans and their pollutants for centuries, and the sand of the Indiana Dunes National Lakeshore seems similar to that of dunes elsewhere.

The presence of humans has disrupted or changed habitats, probably providing more habitat diversity (mainly more open areas) than previously existed. This diversity has probably affected some species in a positive way, particularly the meadow voles and perhaps the meadow jumping mouse. The rights-of-way provide habitat not originally existing and add to increased habitat diversity.

Consideration of Current and Anticipated Lakeshore Operations on the Mammals

Presumably, there will be increasingly greater visitation at the lakeshore. Given the size of the area and the land use objectives, however, it seems unlikely that increased visitation or current or anticipated lakeshore operations will greatly affect mammal populations, other than effects from allowing succession to take its course. The greatest effects will be in the early seral stage areas in the locations currently or recently listed as developed agricultural and residential areas. Species existing in open areas will ultimately be replaced by woodland species in much of this area. Areas excluded will be prairie or other areas that reach climax before attaining woodland status and areas artificially kept in early seral stage.

More land will be acquired and will add to habitat diversity. Additional trails will not greatly affect mammals other than allowing in more light, which will create heavier vegetation and greater habitat diversity.

An east–west corridor will be added and Highway 12 will be improved as a scenic corridor. These developments will probably create more early seral stage habitat along their rights-of-way when they pass through wooded areas.

Heavy air pollution presumably continues at the lakeshore. This is, of course, not part of any operation of the lakeshore but is a factor to be considered. Whether air pollution is affecting the mammals is not clear, and if it is, whether the effects will become greater or this condition will be ameliorated through continued emphasis on ecological considerations is not clear. Studies should be conducted on pollutants and effects of pollutants at the lakeshore to obtain baseline data.

Mammals Exposed to Heavy Recreational Use

We see little effect of recreational use on mammals presently at the lakeshore except that some species can become acclimated to humans in such a way that they become tame. This, of course, happens particularly around picnic areas, campgrounds, and other facilities where food is available. Species most affected are Virginia opossum, eastern chipmunk, eastern gray

squirrel, eastern fox squirrel, red squirrel, common raccoon, and striped skunk.

Acclimatization has the benefit of giving visitors the opportunity of seeing animals close at hand. This behavior, however, often induces people to feed or attempt to pet or handle wild animals—an act that occasionally leads to disaster.

A number of species of mammals have disappeared from the lakeshore area—mostly from human disturbance and habitat disruption rather than from recreational use. The lakeshore property is large and is once again becoming more natural and less fragmented. Also, access is becoming more limited, so we do not suspect anticipated recreational use to be a major detriment to populations of wild mammals.

Effects of Fragmentation of Habitat on the Mammals

Fragmentation is the breaking of habitats into smaller and more isolated areas. This process often poses a threat to natural populations because of less overall habitat—often to the point that many habitat patches may be too small to support the wildlife and also because dispersal becomes more difficult.

Fragmentation could be a problem for species that live in open areas where we now have old fields in previously cultivated or otherwise developed areas. Most of these areas are being allowed to revert to natural habitat. Presumably, there will be less open habitat as succession proceeds toward the climax communities that once existed. Species such as the meadow and prairie voles and the meadow jumping mouse will probably become less abundant as old field gives way to wooded habitats. These and other species of the open areas, however, should be able to hold their own on the natural wet and dry grasslands encompassed in the lakeshore area.

Although fragmentation is increasingly a problem in many areas as habitat disappears because of development, it seems not to be a major problem at the lakeshore. Restoration efforts are producing relatively large tracts of natural habitats. Care should be taken, however, to maintain a number of large grassland areas within the lakeshore area.

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