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AN ILLUSTRATED CATALOGUE OF MACROSCOPIC SUBFOSSILS FROM LATE-PLEISTOCENE AND HOLOCENE WETLAND DEPOSITS IN NORTHERN INDIANA

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ABSTRACT. Subfossils from 16 holocene wetlands in northern Indiana were described and illustrated. A summary of the relative abundance, stratigraphic occurrence, chronology, and frequency of each taxon was presented. Approximately 57 taxa representing algae, vascular plants, mollusks, insects, and vertebrates were recorded in the survey. The subfossils range in age from recent (within 50 years before present) to 15,910 ± 90 years before present.

Recognizing the great value of peatlands and other wetland deposits as natural museums, Potzger (1936) remarked,

> In more recent times the Pleistocene not only left a trail of tell-tale relic colonies of northern plants here in Indiana, but also made its contributions to the fossil records by depositions in bogs and slowly-forming topographic features, where life records are neatly stored away as in a vast archive, preserving the story of the day when they were living forms, and linking the past to the present, partially interpreting for us the plant and animal world of today.

These subfossil remains, preserved in the wetland deposits of the region, include both microfossils, such as pollen and diatoms, and macroscopic remains, including leaves, seeds, fish scales, turtle shells, and a variety of other remains.

Although the fossil pollen from Indiana's Holocene peat deposits has received much attention, especially in the first half of the 20th century [see Swinehart (1997) for review], relatively few studies have focused on the macroscopic subfossils of Indiana's wetland deposits. Most studies on macroscopic subfossils have centered on individual sites (Potzger 1936; Friesner & Potzger 1946; Whitehead et al. 1982; Jackson et al. 1986; Swinehart & Starks 1994; Swinehart 1995a, b), and many of these were associated with the remains of ice-age megafauna. More recently, Swinehart & Parker (2000) conducted a comprehensive study of the subfossil biota of the peatlands of northern Indiana. Additionally, the Indiana State Museum has recently placed a higher priority on detailed studies of macroscopic plant subfossils associated with ice-age mammal remains (Swinehart 1996; Swinehart & Richards 2001), whereas previously these were often neglected (Richards et al. 1987; Hunt & Richards 1992).

With increased attention being devoted to macroscopic subfossils for palaeoenvironmental reconstructions, there is a need to develop resources that facilitate identification of subfossils and a need to record the stratigraphic occurrence and frequency of individual species in a given region. Determining the identity of subfossil biota is complicated by the fact that most remains are only fragments or reproductive propagules of organisms. Because most dichotomous keys and field guides focus on the descriptions of entire organisms, few resources exist that allow identification of depauperate subfossil fragments representing a variety of taxonomic phyla.

This paper summarizes the subfossil assemblages of 16 wetlands studied by the author during the past ten years. The objectives are to describe and illustrate subfossils recovered from northern Indiana wetlands and summarize their relative abundance, stratigraphic occurrence, chronology, and frequency.

METHODS

Subfossils are here defined as (1) remains of once living organisms that are composed, at least in part, of their original organic con-

Table 1.—List of sites in Indiana where macroscopic subfossils were surveyed.

Site name	Acronym	Location	County
Aker Mastodont Locality	AML	T33N, R1E, Sec. 3	Marshall
Binkley Fen	BIN	T38N, R13E, Sec. 31	Steuben
Blueberry Bog	BLB	T38N, R7E, Sec. 24	Elkhart
Bristol Fen	BRF	T38N, R6E, Sec. 26	Elkhart
Burket Bog	BUR	T32N, R5E, Sec. 20	Kosciusko
Celery Bog	CEL	T23N, R5W, Sec. 12	Tippecanoe
Dutch Street Bog	DSB	T35N, R10E, Sec. 11	Noble
Kiser Lake Fen	KLF	T33N, R7E, Sec. 13	Kosciusko
Little Arethusa Bog	LAB	T31N, R7E, Sec. 7	Kosciusko
Little Chapman Bog	LCB	T33N, R6E, Sec. 35	Kosciusko
Ropchan Memorial Bog	RMB	T38N, R12E, Sec. 22 & 23	Steuben
Shafer Mastodont Locality	SML	T23N, R6W, Sec. 7	Warren
Svoboda Fen	SVF	T35N, R11E, Sec. 8	Noble
Tamarack Bog	TAM	T35N, R9E, Sec. 7	Noble
Wilkinson Giant Beaver Locality	WBL	T31N, R8E, Sec. 14	Whitley
Yost Bog	YB	T38N, R8E, Sec. 32	Lagrange

stituents, or (2) inorganic material of biotic origin that has not yet been lithofied (i.e., mollusc shells, *Chara* tests). With the exception of *Potamogeton* achenes which were determined using the manuscript by Jessen (1955), subfossil seeds and achenes were identified using the text by Montgomery (1977). Mosses were identified with the assistance of Crum & Anderson (1981) and Janssens (1983); molluscs with the assistance of Harmen & Berg (1971). *Sphagnum* remains were not identified to species. Questionable subfossil material that seemed referable to a known taxon is preceded by the Latin abbreviation "cf." (*conferre*). Representative subfossils from each wetland were placed in vials with a 60% solution of ethanol. Voucher specimens were placed in the private museum of the author at Hillsdale College and are available for examination. Specimens were hand drawn from actual subfossil material by the author with the aid of dissecting scope and ruler.

Developmental stages of the peatlands were based on assemblages of subfossils that denoted seral stage and/or structural characteristics of the respective ecosystems and were determined by visual inspection of subfossil diagrams (see Swinehart & Parker 2000; Swinehart & Richards 2001).

A list of the sites and their general locations is presented in Table 1. Several sediment collection methods were used among the 16 sites. The general stratigraphy of each site is summarized in Fig. 1.

Ice-age mammal localities.—(Aker, Shafer, and Wilkinson deposits). A sump was excavated near the fossil mammal bones to drain water from the bone bed. Once the standing water was drained, disturbed muck was carefully removed from the site by hand, placed into buckets, and washed through a 1.2 mm mesh screen to recover possible bone fragments and other subfossils. The site was then divided into 2 m^2 units. Sediment from each unit was removed at 10 cm intervals from the top of the bone-bed to the bottom of the wetland deposit. This bulk material was washed through 1.2 mm mesh screens for recovery of macroscopic subfossils and small bones. In addition to bulk samples, smaller sediment samples were taken for the identification and quantification of smaller subfossils. A 50 cm^3 plastic container was pushed into the vertical profile of sediment adjacent to the bone bed at 10 cm intervals, beginning at the wetland surface and extending to the glacial drift at the bottom of the deposit.

Subfossils taken from screened bulk material were identified and counted. Additionally, the smaller (50 cm^3) sediment samples were carefully rinsed through a 0.2 mm mesh screen. The recovered subfossils were then identified and counted.

Celery Bog.—An Osterburg hydraulic piston corer mounted on an all-terrain vehicle was used to collect a 10 m deep core with a diameter of 10 cm. The core extended from the surface of the wetland to glacial till at the bottom. Sections of the core, collected in 3 meter-long metal sleeves, were brought to the laboratory for analysis. The metal sleeves containing the cores were hand-sawed into 10 cm sections. The sediment from each 10 cm section was examined for identifiable subfossil remains.

A standard 20 ml volume was taken from each interval and gently rinsed through a 0.4 mm mesh sieve. The material remaining in the sieve was placed in a petri dish and examined under a dissecting microscope for identification and quantification of macroscopic subfossils.

Bristol Fen & Tamarack Bog.—Sediments in Bristol Fen were collected manually with a post-hole excavator at 15 cm intervals. Blocks of peat from each depth interval were rinsed with water on a 1 mm mesh screen. Rinsed material was sorted by hand. Sediments from Tamarack Bog were recovered using a 2.5 cm diameter Hillar corer. Sediments from 20–25 cm intervals were rinsed, and subfossils were identified with the aid of a dissecting microscope. Subfossils from Bristol Fen and Tamarack Bog were not counted.

Remaining sites.—Each site was systematically probed using metal rods. Coring was conducted at the deepest probe location in each peatland. A modified Hiller corer with a chamber diameter of 5 cm was used to collect sediments. Cores were sectioned into 25 cm lengths and placed into plastic bags. A standard 20 cm^3 volume was taken from each interval and gently rinsed through a 0.4 mm mesh sieve. The material remaining in the sieve was placed in a petri dish and examined under a dissecting microscope for identification and quantification of macroscopic subfossils. The remaining sediment from each sampling interval was also rinsed through a 0.4 mm mesh sieve. The material was then placed into a white enamel pan and examined for large, infrequent subfossils such as bones, large seeds and leaves that might not have been represented in the 20 cm^3 subsamples.

Radiocarbon dating.—Selection of material at different depths for radiocarbon (^{14}C) dating was based on the developmental stages represented in subfossil diagrams (see Swinehart & Parker 2000; Swinehart & Richards 2001). Whenever possible, aquatic and wetland bryophytes were excluded from the radiocarbon samples to reduce the potential for carbon loading. The samples were treated using the Acid-Base-Acid method and were analyzed by accelerator mass spectrometry at the Purdue University Rare Isotope Measurement (PRIME) Laboratory. All results are reported in years before present (ybp) and have been corrected to Delta ^{13}C of −25PDB.

Although radiocarbon dates are not available for all depths in each peatland, most major stratigraphic units have been dated (Fig. 1). Because of the cumulatively large number of radiocarbon dates and because the dates generally occur at the strata where major changes in biota occurred, it was possible in most cases to get a general idea of the earliest dated records for each taxon among the sites in northern Indiana. For species that are currently extant in Indiana, only the oldest radiocarbon date was reported for the respective taxa. For species that are currently extinct in Indiana, both the oldest and youngest available radiocarbon dates are reported.

RESULTS

Approximately 57 taxa were represented in the survey of macroscopic subfossils from the 16 Indiana wetlands (Table 2, Figs. 2–101). The subfossils range in age from recent (within 50 ybp) to 15,910 ± 90 ybp. The following is a list and description of each taxon including a summary of the current habitat, typical condition of the subfossils, and the stratigraphic occurrence of each taxon.

Kingdom Plantae
Division Thallophyta
Class Chlorophyceae
Order Charales
Family Characeae

Chara sp.: (Figs. 2, 3). *Habitat:* Springs, ponds, and lakes with highly alkaline waters, commonly forming dense mats on sandy or marly bottoms; in open areas and protected bays, often in association with water lilies. Although most common in shallow water, plants may be found at depths of several meters. *Description:* Subfossil oogonia (Fig. 2) are usually slightly less than 0.5 mm; oval; dark brown to black in color, generally opaque when entire; raised spiraling ridges separated by concave hollows; spirals unravel in a ribbon-like fashion when struc-

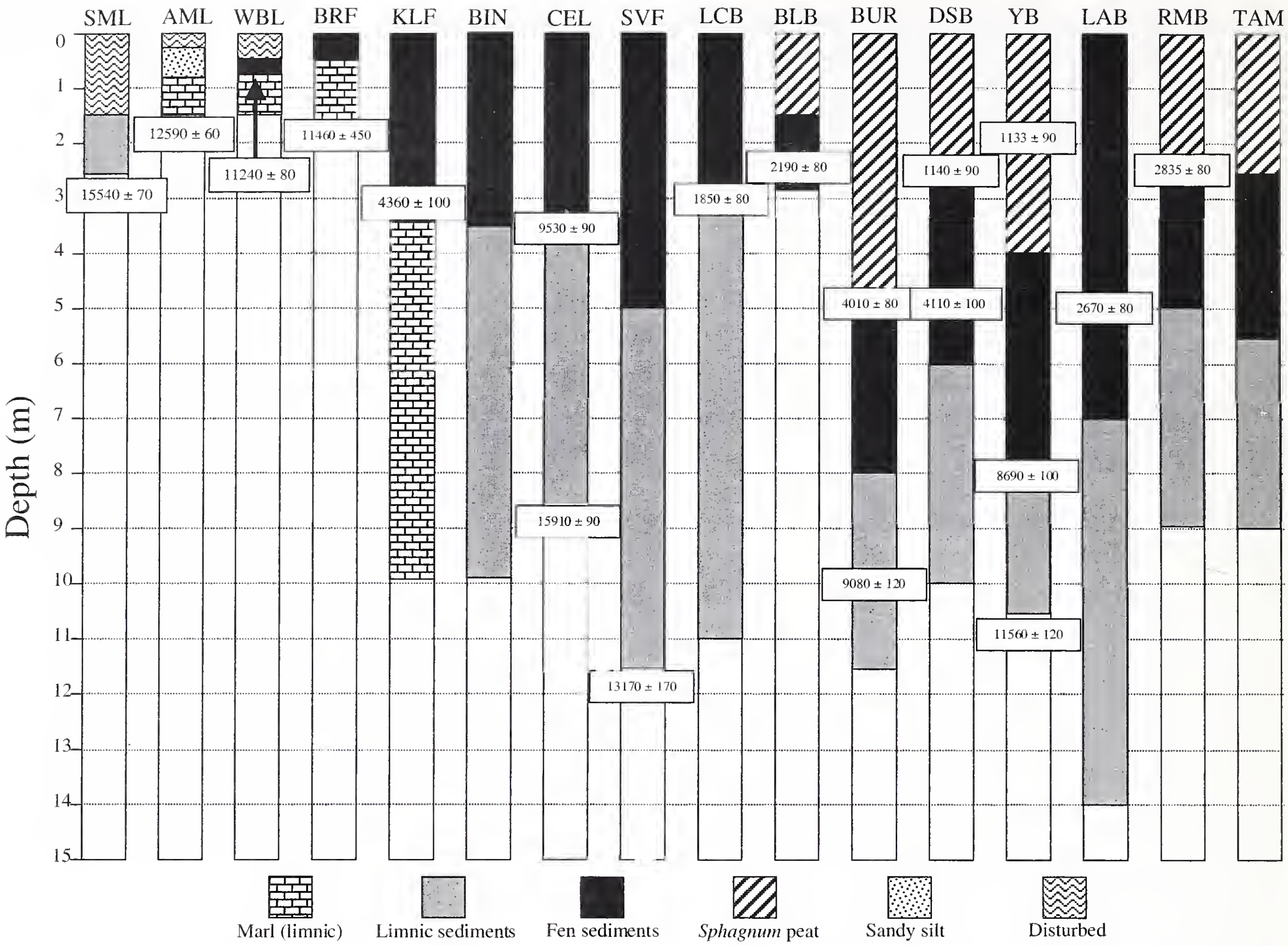


Figure 1.—General stratigraphy and associated radiocarbon dates for the 16 wetlands surveyed for macroscopic subfossils. SML = Shafer Mastodont Locality; AML = Aker Mastodont Locality; WBL = Wilkinson Giant Beaver Locality; BRF = Bristol Fen; KLF = Kiser Lake Fen; BIN = Binkley Fen; CEL = Celery Bog; SVF = Svoboda Fen; LCB = Little Chapman Bog; BLB = Blueberry Bog; BUR = Burket Bog; DSB = Dutch Street Bog; YB = Yost Bog; LAB = Little Arethusa Bog; RMB = Ropchan Memorial Bog; TAM = Tamarack Bog.

ture is damaged. Subfossil thalli (Fig. 3) are small fragments usually less than 4 mm in length; gray; lime-covered; cylindrical and sulcate; cell walls often visible at breakage points or where lime has been scraped away. *Stratigraphy:* Thalli comprised a large percentage of the marl in Kiser Lake Fen, Kosciusko County, Indiana, and were found throughout the marl stratum; vegetative thalli never found in organic sediments. Oogonia frequent in the early limnic sediments of some peatland basins, usually absent in the marsh, fen, and bog strata. *Chronology:* The oldest dated record is 12,590 ± 60 ybp (Aker Mastodont Locality). *Frequency:* 38%. *Abundance:* Frequent where found, although many of the marls lack identifiable remains of thalli.

Division Bryophyta
Subdivision Musci
Class Sphagnopsida
Order Sphagnales
Family Sphagnaceae

Sphagnum spp.: (Figs. 4–6). *Habitat:* Peatlands; in carpets or lawns and occasionally developing hummock/hollow complexes in acid conditions, restricted to isolated hummocks in more neutral to alkaline environments. *Description:* Leaf thalli (Fig. 4) light brown; composed of large, rhomboidal, hyaline cells bordered by narrow, linear cells (chlorophyllose when living); hyaline cells usually bearing large spherical or elliptical pores (Fig. 5). Occasionally, leaf thalli found attached to stem thalli (Fig. 6), but only in the uppermost, more recent sediments. *Stratigraphy:* Generally restricted to the upper 2–3 m of sediment. *Chronology:* The oldest dated record is < 9530 ± 90 ybp (Celery Bog). *Frequency:* 56%. *Abundance:* Extremely frequent where found, often comprising more than 90% of the peat.

Class Bryopsida
Order Bryales
Family Meesiaceae

Meesia triquetra: (Figs. 7–9). *Habitat:* In wet, highly alkaline, often marly areas; open fens or forested peatlands, mostly in boreal climates. No extant populations have been reported from Indiana. *Description:* Subfossils found as well-preserved fragments (Fig. 7) up to 40 mm in length; stems often radiculose; radicles dark reddish-brown in color; leaves (Fig. 8) golden to dark brown in color, keeled above shoulder, distinctly serrulate at margins (Fig. 9) from shoulders to the acute apex, cells rhomboidal to rectangular; costa pronounced, extending into the acumen. *Stratigraphy:* Found at the interface between fen peat and *Sphagnum* bog peat, always associated with *Calliergon trifarium* but in lesser quantity. *Chronology:* The youngest dated record is 59 ± 80 ybp (Little Arethusa Bog), and the oldest dated record is 4110 ± 100 ybp (Dutch Street Bog). *Frequency:* 31%. *Abundance:* Frequent where found; occurs as discrete strands.

Order Hypnobryales
Family Thuidiaceae

Thuidium delicatulum: (Figs. 10–12). *Habitat:* Moist soil and humus, most commonly on rotting logs in swamps or wet woodlands. *Description:* Fragments (Fig. 10) small, twice pinnate, dark brown in color, well preserved; primary branch leaves (Fig. 11) more or less ovate, with an acute apex (Fig. 12); costa pronounced, extending to the lower acumen, margins papillose-serrulate. *Stratigraphy:* Two fragments from basal sediments of Little Arethusa Bog. *Frequency:* 6%. *Abundance:* Extremely rare.

Family Amblystegiaceae

Campylium stellatum: (Figs. 13–15). *Habitat:* In open, wet areas of highly alkaline marshes and fens (Crum & Anderson 1981). Also found in swamps and on wet banks (Welch 1957). *Description:* Small fragments (Fig. 13) mostly less than 20 mm in length, light brown in color; leaves (Fig. 14) broad at base, narrowing to a slender, acute apex, entire, arising from stem at an acute angle, then spreading away from stem near shoulder; costa present, forked, one extension being longer than the other, often extending to midleaf; alar cells (Fig. 15) conspicuous, concentrated at leaf margin and not extending to costa. *Stratigraphy:* In sapric or hemic peat of Binkley Fen, also in silt at Wilkinson Giant Beaver Locality. *Chronology:* The oldest dated record is greater than 11,990 ± 90 ybp (Wilkinson Giant Beaver Locality). *Frequency:* 13%. *Abundance:* Rare where found, occurs as single strands.

Drepanocladus aduncus: (Figs. 16–19). *Habitat:* Wet calcareous areas including swamps marshes, sloughs, lakeshores, and sluggish streams. Most common in fens and mineral-rich lagg waters of bogs, often emergent and sometimes submergent. *Description:* Well preserved fragments (Fig. 16) up to 100 mm in length, light brown to reddish-brown in color; leaves (Fig. 17) entire, ovate-lanceolate, narrowing to a slender, channeled acumen, falcate, occasionally but not always secund, sometimes spreading in a form similar to *Amblystegium riparium*; costa pronounced, extending above midleaf; upper median cells of leaf (Fig. 18) rhomboidal-linear; alar cells (Fig. 19) somewhat conspicuous, extending from leaf margin to within three rows of cells from the costa, sometimes difficult to observe, often retained on stem when leaf is torn away. Although not characteristic of the species, the walls of the alar cells on many of the specimens are dark yellow-brown in color. *Stratigraphy:* Beginning at the upper reaches of limnic sediment and eventually forming peat, often replaced by *Calliergon trifarium* and *Meesia triquetra* before *Sphagnum* peat dominates within the top 2–3 m of the profile. *Chronology:* The oldest dated record is 13,170 ± 170 ybp (Svoboda Fen). *Frequency:* 81%. *Abundance:* Extremely abundant where found, often forming pure strata of entangled strands.

Scorpidium scorpioides: (Figs. 20–22). *Habitat:* Open fens, often submergent or emergent (Crum & Anderson 1981). *Description:* Small fragments (Fig. 20) mostly less than 10 mm in length, light brown in color, more or less prostrate; leaves (Fig. 21) oblong-ovate, somewhat imbricate; costa lacking; cells at insertion enlarged; alar cells (Fig.

Table 2.—The occurrence of subfossil taxa in 16 wetlands in northern Indiana. The wetlands types are: (1) marsh, (2) marl fen, (3) fen, (4) tall-shrub bog, (5) leatherleaf bog, and (6) forested peatland. The sites surveyed (names abbreviated below) are: Shafer Mastodont Locality, Aker Mastodont Locality, Wilkinson Giant Beaver Locality, Bristol Fen, Kiser Lake Fen, Binkley Fen, Celery Bog, Svoboda Fen, Little Chapman Bog, Blueberry Bog, Burket Bog, Dutch Street Bog, Yost Bog, Little Arethusa Bog, Ropchan Memorial Bog, and Tamarack Bog.

	Wetland type																%
Species	SML (1)	AML (2)	WBL (2)	BRF (2)	KLF (2)	BIN (3)	CEL (3)	SVF (3)	LCB (4)	BLB (4)	BUR (5)	DSB (5)	YB (5)	LAB (6)	RMB (6)	TAM (6)	Fre-quency
Algae																	
Chara sp.		X			X	X	X						X		X		38
Bryophytes																	
Sphagnum spp.							X		X	X	X	X	X	X	X	X	56
Meesia triquetra									X			X		X	X	X	31
Thuidium delicatulum														X			6
Campylium stellatum			X			X											13
Drepanocladus aduncus	X	X		X	X	X	X	X	X	X	X	X	X	X			81
Scorpidium scorpioides								X									6
Calliergon stramineum						X		X	X						X		25
Calliergon trifarium									X	X	X	X		X	X	X	44
Polytrichum strictum													X				6
Conifers																	
Picea glauca	X	X	X	X													25
Picea mariana		X		X													19
Picea sp.	X									X							13
Larix laricina	X	X	X			X	X			X				X	X	X	56
Abies balsamea			X				X			X							19
Angiosperms																	
Potamogeton spp.	X	X	X	X		X	X			X	X	X	X	X		X	75
Najas flexilis	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	94
Eleocharis sp.		X					X						X				19
Scirpus subterminalis													X				6
Scirpus acutus-type		X	X		X	X	X		X	X	X	X	X	X	X	X	81
Carex cf. *pseudocyperus*										X							6
Carex spp.		X	X		X		X		X		X				X	X	50
Dulichium arundinaceum									X		X		X				13
Fuirena pumila													X				6

Table 2.—Continued.

Species	Wetland type																% Fre-
	SML (1)	AML (2)	WBL (2)	BRF (2)	KLF (2)	BIN (3)	CEL (3)	SVF (3)	LCB (4)	BLB (4)	BUR (5)	DSB (5)	YB (5)	LAB (6)	RMB (6)	TAM (6)	quen-cy
Ceratophyllum demersum	X				X		X	X	X		X	X		X			50
Nuphar advena			X	X				X	X		X	X		X	X		50
Nymphaea odorata			X						X	X	X		X				31
Brasenia schreberi			X			X	X		X	X	X	X	X	X			56
Sarracenia purpurea												X					6
Impatiens capensis								X									6
Myriophyllum exalbescens	X																6
Andromeda glaucophylla											X		X	X	X	X	31
Chamaedaphne calyculata											X	X	X				19
Vaccinium macrocarpon						X			X		X	X		X	X	X	44
Menyanthes trifoliata									X		X	X	X		X		31
Bidens sp.									X								6
Molluscs																	
Physa sayii			X		X												13
Lymnaea humilis		X	X	X	X												25
Lymnaea haldemani			X	X													13
Helisoma anceps			X	X	X												19
Helisoma campanulata			X	X	X												19
Gyraulus parvus		X	X	X	X				X								31
Pleurocera acuta					X												6
Amnicola limosa			X	X	X												19
Amnicola lustrica		X	X	X	X												25
Valvata tricarinata		X	X	X	X												25
Valvata sincera			X	X	X		X										25
Gastrocopta sp.					X												6
Retinella sp.					X												6
Helicodiscus parallelus			X														6
cf. *Elliptio dilatata*			X														6
Sphaerium sp.			X	X													13
Pisidium sp.		X	X	X	X								X	X			38

Table 2.—Continued.

Species	Wetland type																% Fre-quency
	SML (1)	AML (2)	WBL (2)	BRF (2)	KLF (2)	BIN (3)	CEL (3)	SVF (3)	LCB (4)	BLB (4)	BUR (5)	DSB (5)	YB (5)	LAB (6)	RMB (6)	TAM (6)	
Insects																	
Coleoptera					X	X	X		X	X	X		X	X	X	X	63
cf. *Micrasema* sp.								X									6
Fishes																	
Percidae									X								6
Centrarchidae					X				X					X			19
Reptiles																	
Sternotherus odoratus									X								6

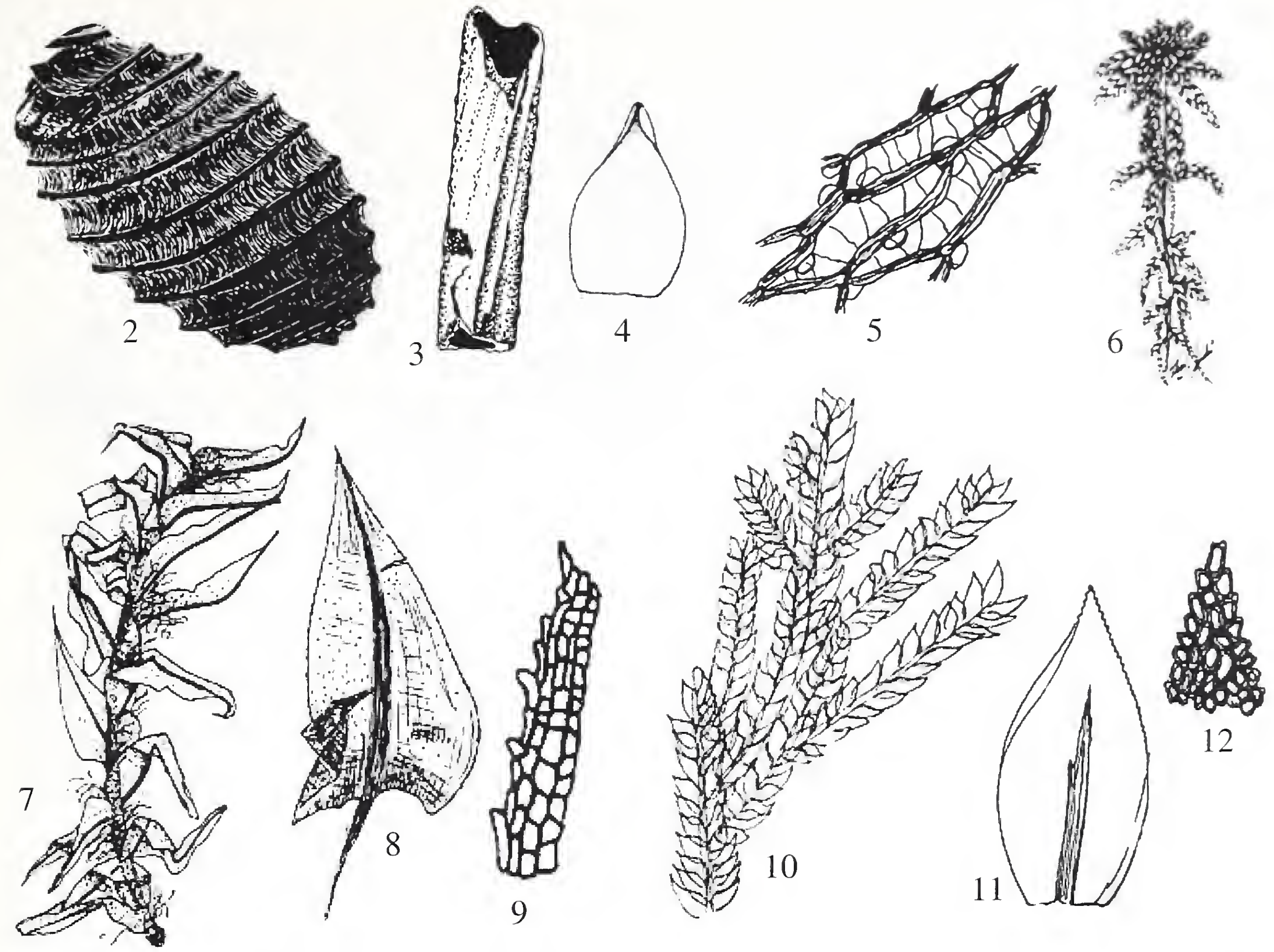
22) somewhat inconspicuous. *Stratigraphy:* Deep in the hemic peat of Svoboda Fen. *Chronology:* The oldest record is 13,170 ± 170 ybp (Svoboda Fen). *Frequency:* 6%. *Abundance:* Extremeley rare.

Calliergon stramineum: (Figs. 23–25). *Habitat:* Open, rich fens and sedge meadows, laggs (Crum & Anderson 1981). Extant populations have not been reported from Indiana. *Description:* Small shreaded fragments (Fig. 23) less than 10 mm in length, reddish-brown; leaves (Fig. 24) oblong, entire, imbricate, decurrent, more or less spreading; costa pronounced, extending to the apex; walls of cells at leaf base thickened; alar cells (Fig. 25) conspicuous, concentrated at the leaf margin and not extending to the costa. *Stratigraphy:* In hemic peat (fen stratum) between limnic sediments and *Sphagnum* peat. *Chronology:* The most recent dated record is 2835 ± 80 ybp (Ropchan Memorial Bog), and the oldest record is greater than 3680 ± 80 ybp (Little Chapman Bog). *Frequency:* 25%. *Abundance:* Rare where found; occurs as single small fragments.

Calliergon trifarium: (Figs. 26–29): *Habitat:* Highly alkaline, wet-fen habitats, often found as strands among other mosses and sedges (Crum & Anderson 1981). Extant populations have not been reported from Indiana. *Description:* Well preserved fragments (Fig. 26) up to 30 mm in length, terete, light brown in color; leaves (Fig. 27) elliptic to oblong, entire, imbricate, crowded and apressed at base of stem, somewhat loose spreading near tips (Fig. 28); costa present, about two-thirds the length of the leaf; alar cells (Fig. 29) enlarged, extending from leaf margin to costa. *Stratigraphy:* Found at the interface between fen peat (dominated by *Drepanocladus aduncus*) and *Sphagnum* peat. Almost always associated with *Meesia triquetra*. *Chronology:* The most recent dated record is 45 ± 80 ybp (Little Chapman Bog), and the oldest dated record is 4010 ± 80 ybp (Burket Bog). *Frequency:* 44%. *Abundance:* Extremely frequent where found, often comprising a large portion of the total volume of peat.

Family Polytrichaceae

Polytrichum strictum: (Figs. 30, 31). *Habitat:* On the dry tops of *Sphagnum* hummocks in bogs. *Description:* Well preserved fragments (Fig. 30) up to 40 mm in length, auburn



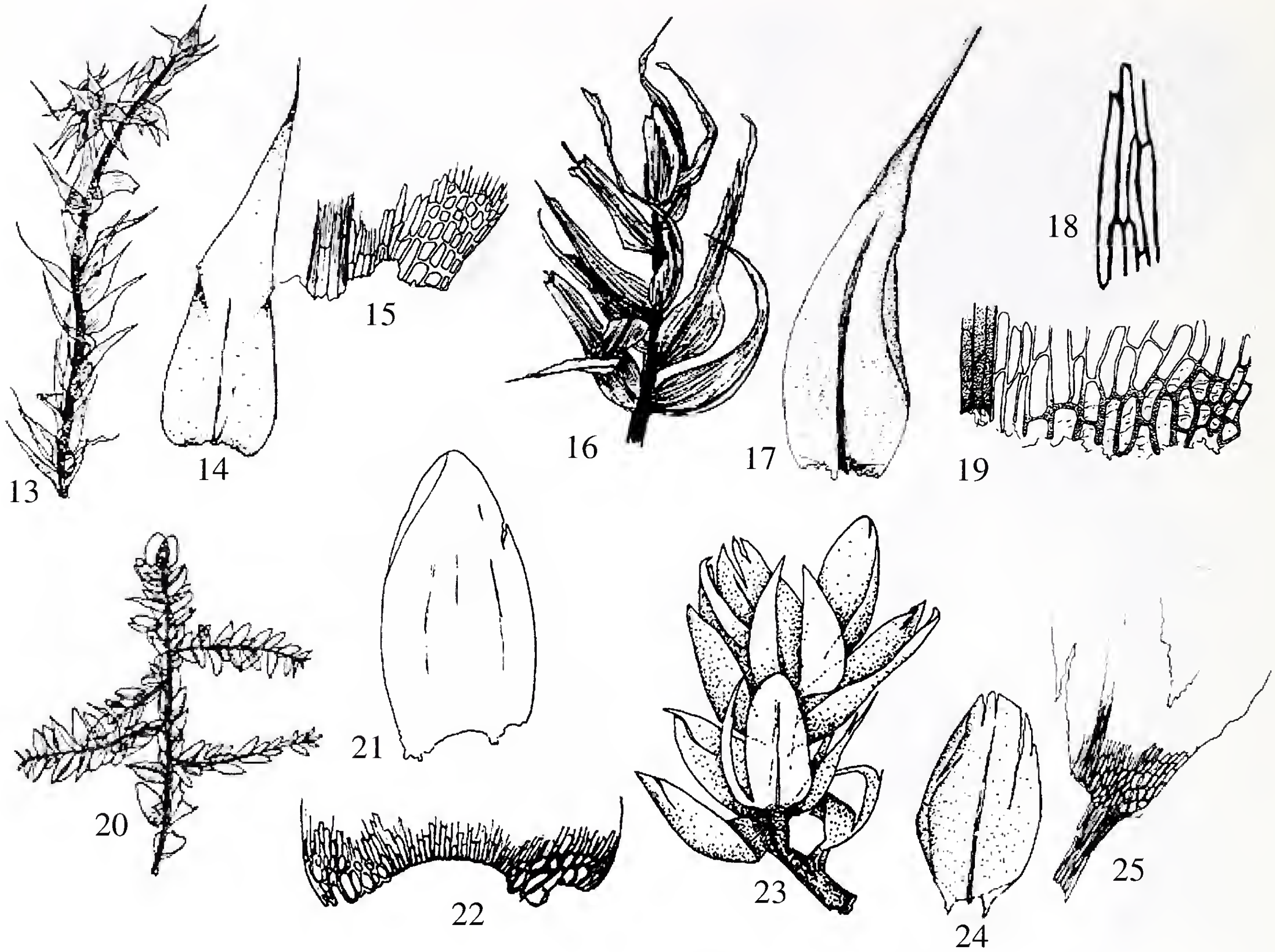
Figures 2–12.—2. *Chara* sp. oogonium (0.4 mm); 3. *Chara* sp. calcified stem-thallus (4 mm); 4. *Sphagnum* sp. branch leaf (2 mm); 5. *Sphagnum* sp. branch leaf cells; 6. *Sphagnum* sp. stem fragment with branches and leaves (9 cm); 7. *Meesia triquetra* stem fragment with leaves and radicles (20 mm); 8. *M. triquetra* leaf (3.5 mm); 9. Margin of leaf of *M. triquetra* showing serration; 10. *Thuidium delicatulum* fragment (4 mm); 11. *T. delicatulum* leaf (0.5 mm); 12. Apex of leaf of *T. delicatulum.*

in color; leaves (Fig. 31) straight and erect, base broad, becoming lanceolate and in-folded above shoulders, ending in a toothed awn, cells at shoulder laterally elongate and cramped; costa pronounced, excurrent, bearing lamellae. *Stratigraphy:* In upper layers of *Sphagnum* peat stratum in Yost Bog, Lagrange County, Indiana. *Frequency:* 6%. *Abundance:* Frequent in Yost Bog as individual strands in *Sphagnum* peat.

Division Spermatophyta
Subdivision Gymnospermae
Order Coniferales
Family Pinaceae

Picea glauca: (Figs. 32, 34). *Habitat:* Well-drained coniferous swamps, lakeshores and stream borders, mixed forests (Voss 1972), and occasionally in peatlands; mostly in boreal climates. Extinct in Indiana. *Description:* Cones (Fig. 32) well preserved, elongate 30–50 mm in diameter; seeds intact within axles of scales; leaves (Fig. 34) fragmented, poorly preserved, mostly apices, thick, four-angled in cross-section, not distinguished from *P. mariana*. *Stratigraphy:* In deeper sediments of silt and especially marl deposits. *Chronology:* The most recent dated record is 11,240 ± 80 ybp (Wilkinson Giant Beaver Locality), and the oldest dated record is 15,540 ± 70 ybp (Shafer Mastodont Locality). A piece of spruce wood dating 15,910 ± 90 ybp from the basal sediments of Celery Bog is probably *Picea glauca*, but the specific species cannot be determined definitively. *Frequency:* 25%. *Abundance:* Cones and leaves infrequent where found.

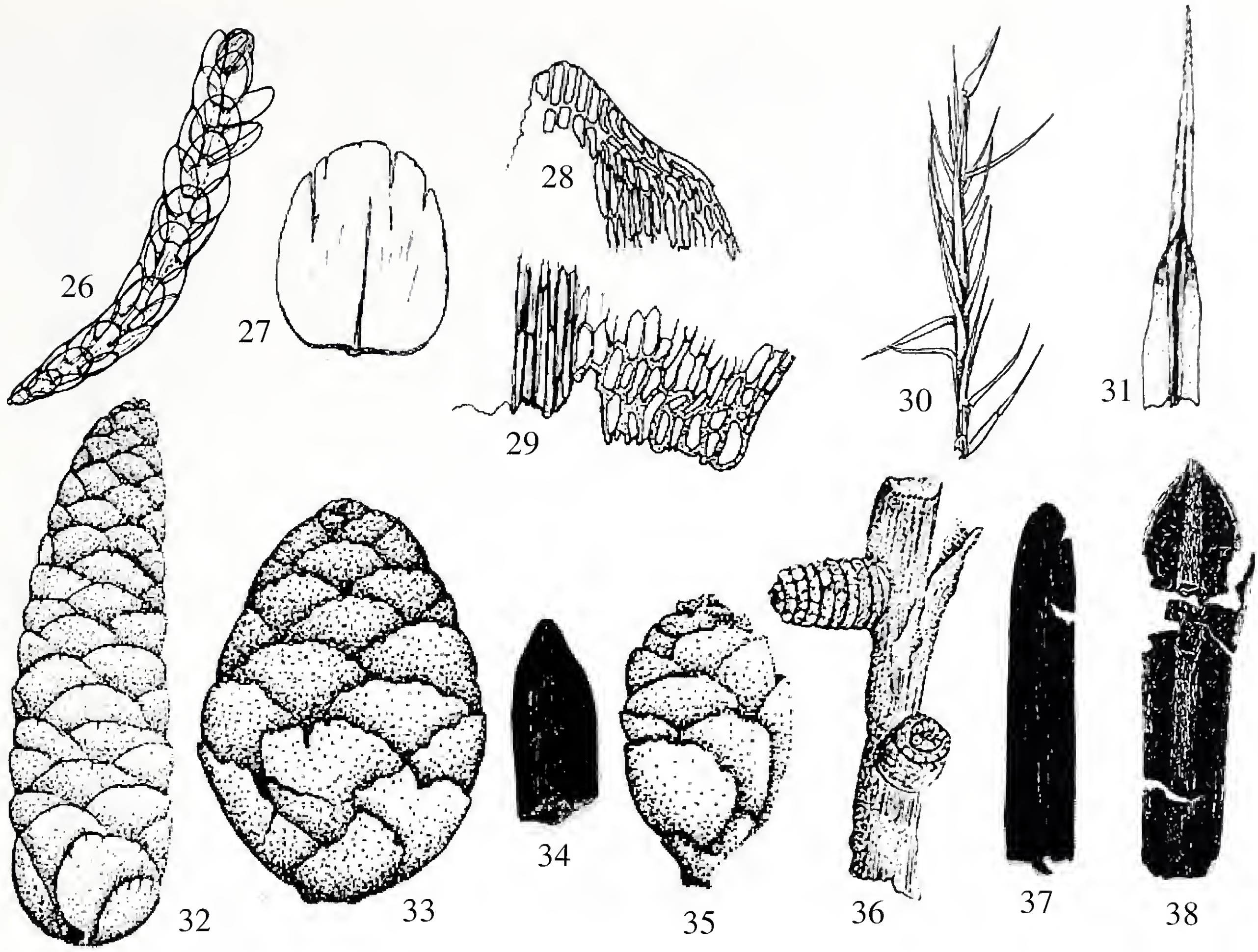
Picea mariana: (Figs. 33, 34). *Habitat:* In wet, often nutrient-poor areas such as swamps, low lakeshores, and bogs. In the southern portions of its range, it is restricted entirely to bogs. Extinct in Indiana. *Descrip-*



Figures 13–25.—13. *Campylium stellatum* fragment (15 mm); 14. Leaf of *C. stellatum* (2.5 mm); 15. Alar cells of *C. stellatum*; 16. *Drepanocladus aduncus* fragment (10 mm); 17. Leaf of *D. aduncus* (3.5 mm); 18. Median leaf cells of *D. aduncus*; 19. Alar cells of *D. aduncus*; 20. *Scorpidium scorpioides* fragment (10 mm); 21. Leaf of *S. scorpioides* (2 mm); 22. Base of leaf of *S. scorpioides* showing alar cells; 23. *Calliergon stramineum* fragment (8 mm); 24. Leaf of *C. stramineum* (1.5 mm); 25. Portion of leaf base of *C. stramineum* showing alar cells.

tion: Cones (Fig. 33) well-preserved, ovate-obovate, 15–30 mm in length; seeds intact within axels of scales; leaves (Fig. 34) fragmented, poorly preserved, mostly apices, thick, four-angled in cross-section, not distinguished from *P. glauca*. *Stratigraphy:* In peaty marl. *Chronology:* The most recent dated record is 11,460 ± 450 ybp (Bristol Fen), and the oldest dated record is 15,590 ± 60 ybp (Aker Mastodont Locality). *Frequency:* 19%. *Abundance:* Cones and leaves infrequent where found.

Larix laricina: (Figs. 35–37). *Habitat:* Swamps, lakeshores and stream borders, fens, and bogs. Restricted to peatlands in the southern portions of its range. Pioneering opportunists, they prefer open areas where competition for light with other trees is minimal. *Description:* Cones (Fig. 35) poorly preserved, fragile, stalked; twigs (Fig. 36) bearing woody spurs with many annual whorls of leaf scars; spurs seem to be more decay resistant due to dense xylem; leaves (Fig. 37) well preserved at least in hemic and fibric peat, compressed, brown in color, blades translucent when viewed under lighted dissecting scope, gradually thinning from midrib to leaf margin. *Stratigraphy:* Most common in brown moss peats, less common in *Sphagnum*. Abundant *Larix* macrofossils were found only in peatlands that are currently dominated by tamarack (with the exception of the Aker, Wilkinson, and Shafer localities which have been anthropogenically altered), suggesting that tamarack bogs may have a unique developmental history and ecology. *Chronology:* The oldest dated record is 15,540 ± 70 ybp (Shafer Mastodont Locality). *Frequency:* 56%.



Figures 26–38.—26. *Calliergon trifarium* fragment (8 mm); 27. Leaf of *C. trifarium* (1.2 mm); 28. Apex of *C. trifarium* leaf; 29. Portion of leaf base of *C. trifarium* showing alar cells; 30. *Polytrichum strictum* fragment (21 mm); 31. Leaf of *P. strictum* (4 mm); 32. *Picea glauca* cone (44 mm); 33. *Picea mariana* cone (25 mm); 34. *Picea* sp. leaf fragment (1 mm); 35. *Larix laricina* cone (16 mm); 36. Twig of *L. laricina* (11 mm); 37. Leaf of *L. laricina* (4 mm); 38. *Abies balsamea* leaf (6 mm).

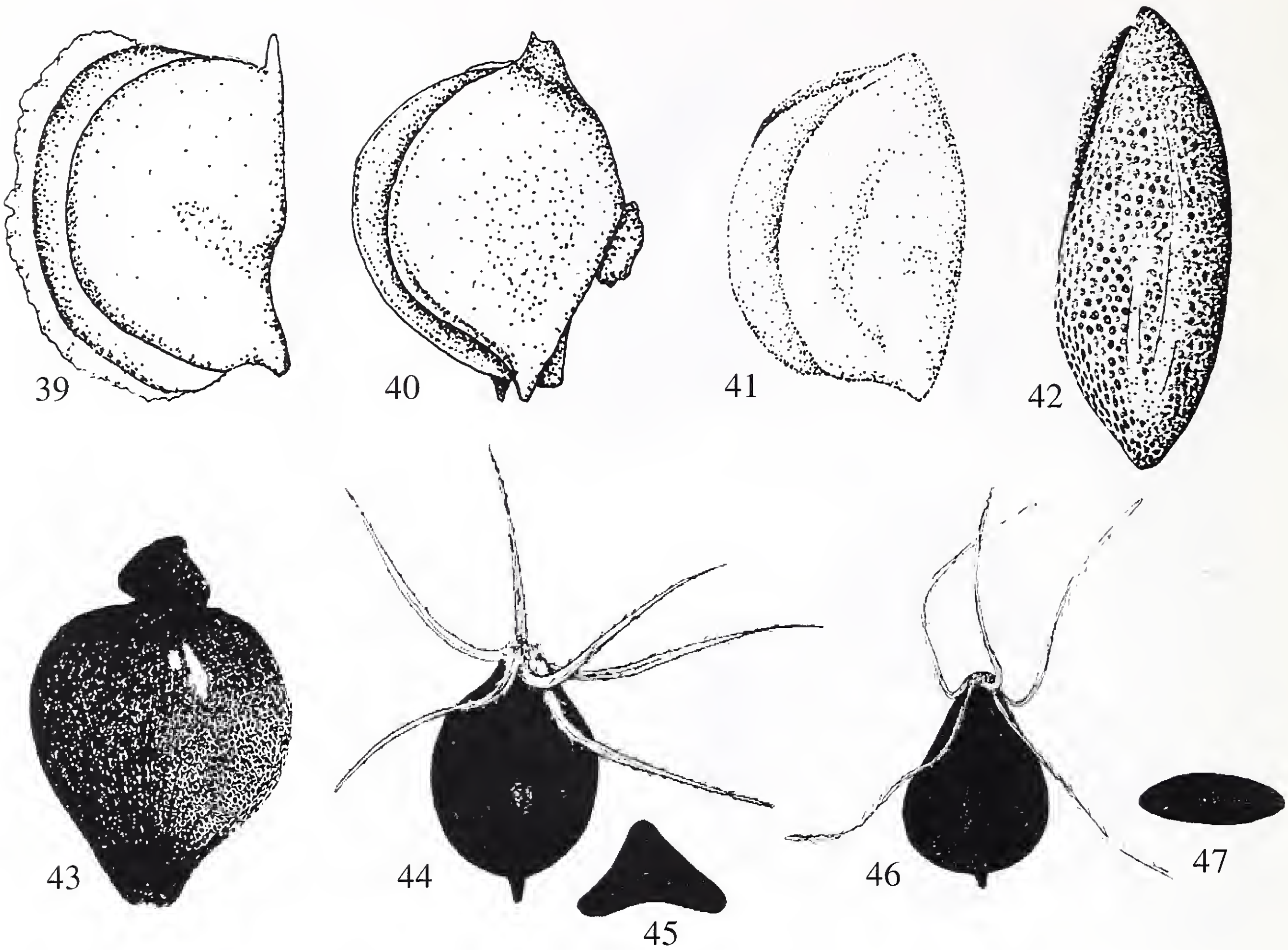
Abundance: Leaves frequent where found; cones and twigs rare; spurs were abundant in limnic sediments at the Shafer Mastodont locality, infrequent to rare at other localities.

Abies balsamea: (Fig. 38). *Habitat:* Coniferous and mixed forests; occasionally in cedar swamps, fens, and bogs. *Description:* Leaves (Fig. 38) often well preserved, though seldom entire, dark brown, thick, opaque even when observed with a lighted dissecting scope, somewhat revolute near petiole, in-folded margins compress to a thickening along the majority of the blade, midrib raised on both sides. *Stratigraphy:* Lower strata; most common in marl. *Chronology:* The only dated record is 15,910 ybp (Celery Bog). *Frequency:* 19%. *Abundance:* Leaves frequent where found; cones have not yet been found and are likely very rare in lake and wetland deposits.

Subdivision Angiospermae
Class Monocotyledoneae
Order Najadales
Family Potamogetonaceae

Potamogeton praelongus: (Fig. 39). *Habitat:* Lakes, in water up to 7 m (Voss 1972), in clear waters, often associated with *Ceratophyllum demersum*, *Najas flexilis*, *Potamogeton amplifolius*, *P. gramineus*, *P. natans*, *P. pectinatus*, and *P. robbinsii* (Swink & Wilhelm 1994). *Description:* Opercle of achene keeled and winged, ventral margin wavy, beak ventral. *Stratigraphy:* In marl, Wilkinson Giant Beaver Locality, Whitley County. *Abundance:* Infrequent to frequent where found.

Potamogeton obtusifolius: (Fig. 40). *Habitat:* Lakes and ponds. *Description:* Achene (Fig. 40) bearing two projections at base, opercle more or less keeled, sides convex. *Stra-*



Figures 39–47.—39. *Potamogeton praelongus* achene (4 mm); 40. *Potamogeton obtusifolius* achene (2.5 mm); 41. *Potamogeton pusillus* achene (1.3 mm); 42. *Najas flexilis* achene (2.5 mm); 43. *Eleocharis* sp. achene (1.8 mm); 44. *Scirpus subterminalis* achene with bristles (3 mm); 45. *S. subterminalis* achene (c.s.); 46. *Scirpus* cf. *S. acutus* achene with bristles (2 mm); 47. *S. acutus* achene (c.s.).

tigraphy: In marl, Wilkinson Giant Beaver Locality, Whitley County. *Abundance:* Infrequent to frequent where found.

Potamogeton pusillus: (Fig. 41). *Habitat:* Lakes and ponds and occasionally quiet waters of streams, in shallow waters less than 2 m (Voss 1972), prefers calcareous waters, often associated with *Elodea canadensis*, *Myriophyllum exalbescens*, *Najas flexilis*, *Nuphar advena*, *Potamogeton natans*, *P. nodosus*, *P. pectinatus*, *P. zosteriformis*, and *Vallisneria americana* (Swink & Wilhelm 1994). *Description:* Small, well-preserved, relatively smooth achenes (Fig. 41), yellow-brown in color. *Stratigraphy:* Limnic sediments, including marl. *Chronology:* The oldest dated record is 15,540 ± 70 ybp (Shafer Mastodont Locality). *Abundance:* Infrequent to frequent where found.

Family Najadaceae

Najas flexilis: (Fig. 42). *Habitat:* Extremely common in lakes, ponds, marshes, sloughs, rivers and streams. Also found on soft bottoms of open waters in peatlands. Commonly associated with *Ceratophyllum demersum*, *Elodea canadensis*, *Lemna minor*, *Myriophyllum exalbescens*, *Potamogeton foliosus*, *P. natans*, *P. nodosus*, *P. pectinatus*, and *Vallisneria americana* (Swink & Wilhelm 1994). Fruits abundantly. *Description:* Achenes (Fig. 42) extremely well preserved, fusiform, glossy, mostly reddish in color but varying from gray to light brown or yellowish, surface slightly alveolate when viewed under magnification. *Stratigraphy:* Characteristic of limnic sediments, in silt, clay, gyttja, and marl. *Chronology:* The oldest dated record is 15,540 ± 70 ybp (Shafer Mastodont Locality). *Frequency:* 94%. *Abundance:* Extremely frequent, probably the most common and numerous macrofossil in aquatic sediments. Found in almost every deposit, including humified material. Present in similar abundance in recent lake sediments of Bear Lake, Noble County, Indiana, Spotted Turtle Pond, Elkhart County, Indiana, and other extant, eutrophic lakes and ponds.

Family Cyperaceae

Eleocharis sp.: (Fig. 43). *Habitat:* Lake and pond shores, stream borders, bogs and fens, marshes, swamps, and wet depressions. *Description:* Achenes (Fig. 43) small, less than 2 mm, black in color, glossy, somewhat alveolate. *Stratigraphy:* Hemic peat. *Chronology:* The oldest dated record is 12,070 ± 50 (Aker Mastodont Locality). *Frequency:* 19%. *Abundance:* Rare where found.

Scirpus subterminalis: (Figs. 44, 45). *Habitat:* In water to 1 m in lakes, ponds, peatland pools, and rivers; on sand, muck, marl, or peat (Voss 1972); usually calcareous habitats often with *Scirpus validus* (Swink & Wilhelm 1994). *Description:* Achenes (Fig. 44) well preserved, more or less elliptical in long section tapering abruptly to a sharp style, three-angled/triangular in cross section (Fig. 45), 6 bristles bearing antrorsed teeth. *Stratigraphy:* In hemic peat of Yost Bog. *Frequency:* 6%. *Abundance:* Infrequent where found.

Scirpus acutus-type: (Figs. 46, 47). *Habitat:* In shallow water or wet areas around lakes, ponds, marshes, and flowing waters; also found in fens and marl flats. *S. validus* which has a similar achene grows in similar habitats. *Description:* Achenes (Fig. 46) well-preserved although bristles often lacking, black in color, tear-shaped in long section ending in a short pointed style, oval and compressed in cross section (Fig. 47); bristles bearing retrorsed teeth. *Stratigraphy:* Beginning at the transition from limnic sediments to marsh and fen sediments and may occur throughout the fen stratum. Generally absent from *Sphagnum* peat. *Chronology:* The oldest dated record is 12,590 ± 60 ybp (Aker Mastodont Locality). *Frequency:* 81%. *Abundance:* Variable from infrequent to frequent where found; extremely frequent at the Wilkinson Giant Beaver locality, Kosciusko County, Indiana.

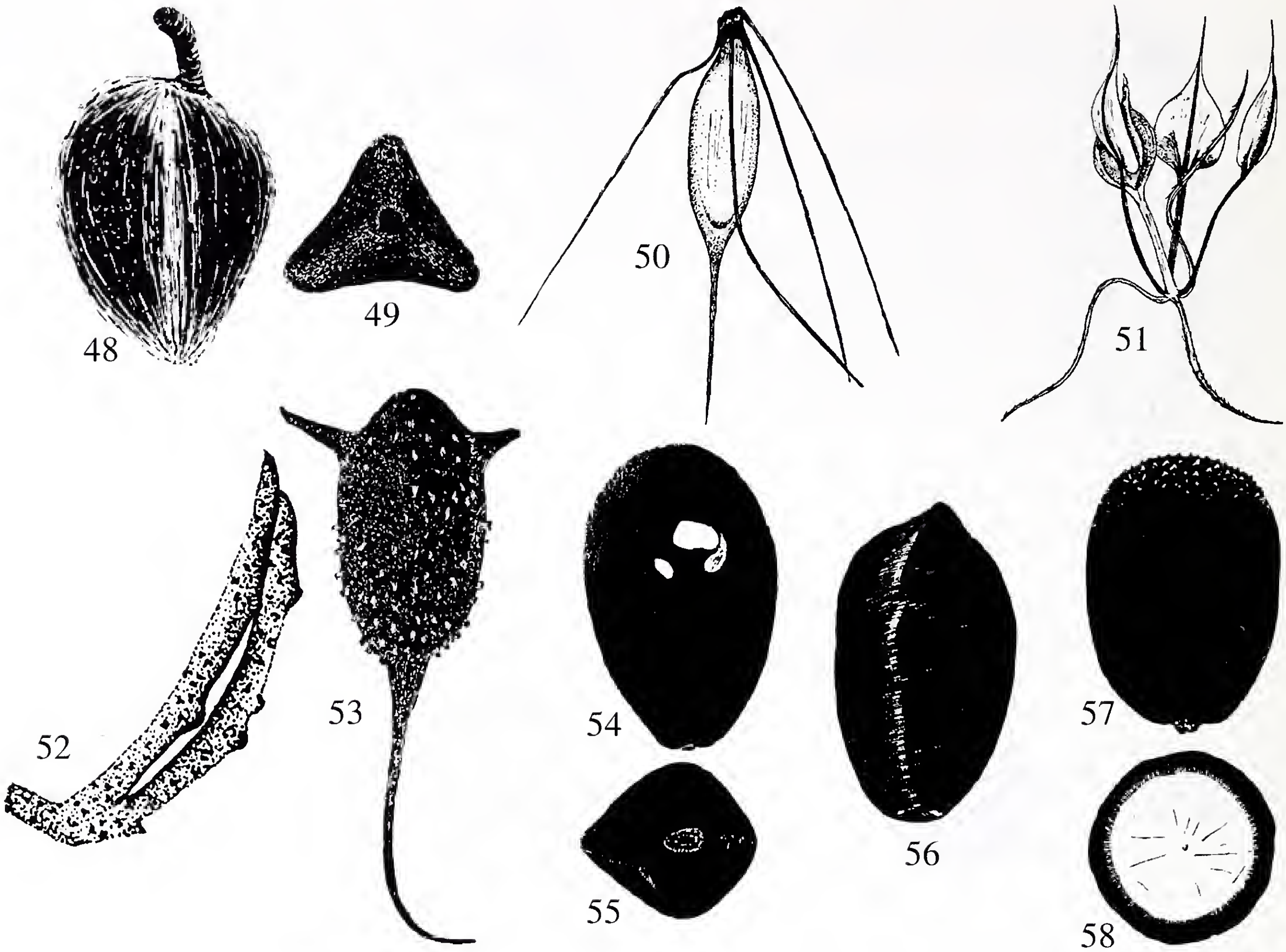
Carex cf. *pseudo-cyperus*: (Figs. 48, 49). *Habitat:* In shallow water or wet areas around lakes, ponds, marshes, and streams; also in swamps and bogs. *Description:* Achenes (Fig. 48) well preserved, lacking bristles, obovate in long section ending in a retrorsed cylindrical style, three-angled/triangular in cross-section (Fig. 49), surface somewhat alveolate. *Stratigraphy:* In sedge peat in Blueberry Bog, Elkhart County, Indiana. *Chronology:* The only dated record is 2190 ± 80 ybp (Blueberry Bog). *Frequency:* 6%. *Abundance:* Infrequent where found.

Dulichium arundinaceum: (Fig. 50). *Habitat:* Marshes, fens, and mineral-rich areas of bogs; often forming treacherous floating mats. *Description:* Achenes (Fig. 50) more or less fusiform, ending in a long narrow style, light brown in color, glabrous, somewhat translucent; bristles bend toward style and lack teeth. *Stratigraphy:* In fen strata. *Chronology:* The only dated record is 1850 ± 80 ybp (Little Chapman Bog). *Frequency:* 19%. *Abundance:* Rare where found.

Fuirena pumila: (Fig. 51). *Habitat:* Mud flats around lakes and ponds; floating mats of fens. *Description:* Fruits well preserved, light brown; Achenes (Fig. 51) more or less fusiform in long section, three-angled/triangular in cross section, stalked, ending in a short acute style; bristles three, bearing retrorsed teeth; bracts three, thickened, chordate with long, acuminate tips. *Stratigraphy:* In lower layers of *Sphagnum* peat, Yost Bog, Lagrange County, Indiana. *Frequency:* 6%. *Abundance:* Infrequent where found.

Class Dicotyledonaceae
Order Ranunculales
Family Ceratophyllaceae

Ceratophyllum demersum: (Figs. 52–53). *Habitat:* Submergent in quiet waters of lakes, ponds, sloughs, and streams. Prefers calcareous waters (Swink & Wilhelm 1994). *Description:* Leaves (Fig. 52) well preserved, light brown with dark brown spots, translucent, flattened from compression by sediment, often forked, bearing several teeth on lower margin; achenes (Fig. 53) oblong with two protruding spines and a long thin style, bearing many light brown scaly protrusions on main body. *Stratigraphy:* Restricted to the lower layers of limnic sediment; associated with *Najas flexilis* and occasionally with other aquatics such as *Potamogeton* spp. *Chronology:* The oldest dated record is 13,170 ± 170 ybp (Svoboda Fen). *Frequency:* 50%. *Abundance:* Leaves frequent to extremely frequent where found; achenes rare, not always present with leaves.



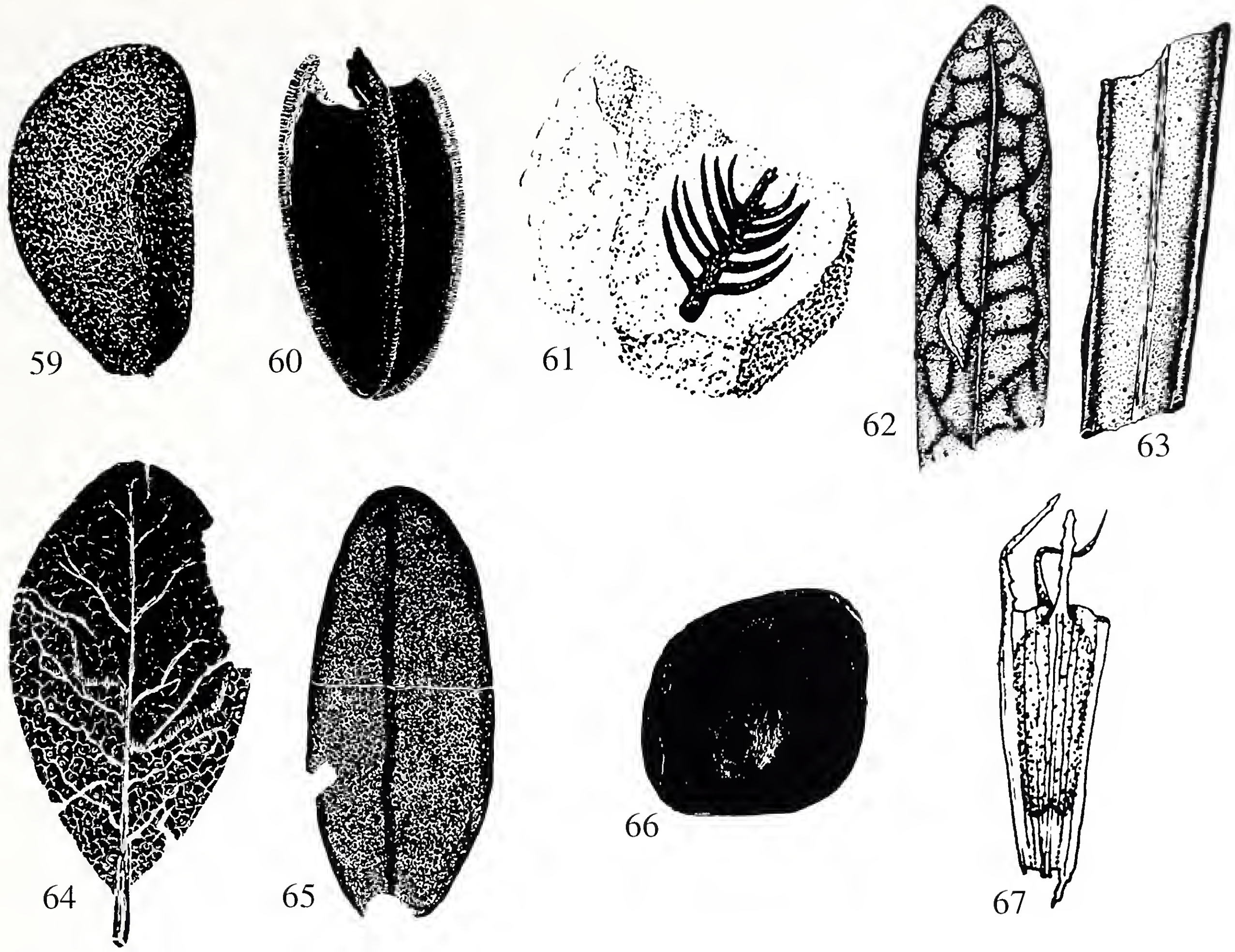
Figures 48–58.—48. *Carex* cf. *C. pseudocyperus* achene (3 mm); 49. *C. cyperus* achene (c.s.); 50. *Dulichium arundinaceum* achene with bristles (3 mm); 51. *Fuirena pumila* achene with bristles and bracts (3 mm); 52. *Ceratophyllum demersum* leaf (5 mm); 53. *C. demersum* achene (12 mm); 54. *Nuphar advena* seed (6 mm); 55. *N. advena* seed (end view); 56. *Nymphaea* cf. *N. odorata* seed (4 mm); 57. *Brasenia schreberi* seed (4 mm); 58. Cross-section of *B. schreberi* showing endosperm.

Family Nymphaceae

Nuphar advena: (Figs. 54, 55). *Habitat:* Emergent in quiet waters of lakes, ponds, rivers, and streams. Often associated with *Brasenia schreberi*, *Ceratophyllum demersum*, *Lemna minor*, *Nymphaea tuberosa*, and *Pontedaria cordata*. *Description:* Seeds (Fig. 54) obovate, usually black but occasionally brown, auburn, or yellowish in color, glossy, commonly bearing a slight "keel" (Fig. 55) but not as pronounced as in *Nymphaea odorata*. *Stratigraphy:* Transitional stratum between limnic sediments and fen peat; occasionally found well within fen and bog strata, presumably from remnant plants surviving within an advancing floating mat. *Chronology:* The oldest dated record is 11,990 ± 90 ybp (Wilkinson Giant Beaver Locality). *Frequency:* 50%. *Abundance:* Infrequent to rare where found.

Nymphaea odorata-type: (Fig. 56). *Habitat:* Emergent in quiet, shallow water of lakes, ponds, rivers and streams. Often associated with *Brasenia schreberi*, *Ceratophyllum demersum*, *Lemna minor*, *Najas flexilis*, *Nuphar advena*, and *Pontedaria cordata*. *Description:* Seeds (Fig. 56) oblong , slightly keeled, black in color, dull. *Stratigraphy:* Transitional stratum between limnic sediments and fen peat; occasionally found well within fen and bog strata, presumably from remnant plants surviving within an advancing floating mat. *Chronology:* The oldest dated record is 11,990 ± 90 ybp (Wilkinson Giant Beaver Locality). *Frequency:* 31%. *Abundance:* Infrequent to rare where found.

Brasenia schreberi: (Figs. 57, 58). *Habitat:* Quiet ponds and lakes, usually in soft, acid waters (Voss 1972); commonly associated with *Elodea canadensis*, *Lemna minor*, *Myriophyllum exalbescens*, *Nuphar advena*, *Nymphaea odorata*, *Polygonom amphibium*,



Figures 59–67.—59. *Sarracenia purpurea* seed (2 mm); 60. *Impatiens capensis* seed (5 mm); 61. *Myriophyllum exalbescens* embedded in silt clod (7 mm); 62. *Andromeda glaucophylla* upper side of leaf (30 mm); 63. *A. glaucophylla* lower side of leaf; 64. *Chamaedaphne calyculata* leaf (30 mm); 65. *Vaccinium macrocarpon* leaf (4.5 mm); 66. *Menyanthes trifoliata* achene (3 mm); 67. *Bidens* sp. achene (4.5 mm).

Pontedaria cordata, *Potamogeton pectinatus*, *Spirodela polyrhiza*, and *Utricularia vulgaris* (Swink & Wilhelm 1994). *Description:* Seeds (Fig. 57) oblong, bearing conspicuous micropyle at narrow end, opposite end is papillose; seed coat thick, woody, comprising nearly 20–25% of the diameter of the seed; empty individuals are dark brown to black in color, some specimens are reddish in color due to the reflectance of white endosperm within the seed; examination of endosperm from seeds shows cells intact; embryo present (Fig. 58); probably viable. *Stratigraphy:* Most common in the transitional marsh sediments between the limnic stratum and fen peat; usually with other emergents such as *Nuphar advena*; specimens bearing endosperm have been found to depths up to 6 m; as many as 20% of specimens contain endosperm in some deposits. *Chronology:* The oldest dated record is 11,240 ± 80 ybp (Wilkinson Giant Beaver Locality). *Frequency:* 56%. *Abundance:* Infrequent to rare, although it is not uncommon to find 40–50 seeds in a 300 cm^3 volume of sediment.

Order Sarraceniales
Family Sarraceniaceae

Sarracenia purpurea: (Fig. 59). *Habitat:* Bogs and fens. *Description:* Seeds (Fig. 59) poorly preserved, somewhat kidney shaped, brown in color, bordered on one side by a compressed "keel." *Stratigraphy:* In *Sphagnum* peat. *Chronology:* The only dated record is 1140 ± 90 ybp (Dutch Street Bog). *Frequency:* 6%. *Abundance:* Extremely rare; only one specimen found in Dutch Street Bog.

Order Sapindales
Family Balsaminaceae

Impatiens capensis: (Fig. 60). *Habitat:* Moist woods, swamps, floodplains, marshes, fens, lakeshores. *Description:* Seeds (Fig. 60) oblong in long section, compressed-oblong in cross section, black in color, bearing a narrow winged margin; seed bisected by a narrow ridge. *Stratigraphy:* In hemic peat of Svoboda Fen. *Frequency:* 6%. *Abundance:* Extremely rare; description based on a single specimen.

Order Myrtales
Family Haloragidaceae

Myriophyllum exalbescens: (Fig. 61). *Habitat:* Quiet, often calcareous waters of ponds and lakes; commonly associated with *Ceratophyllum demersum*, *Elodea canadensis*, *Lemna minor*, *Najas flexilis*, *Nuphar advena*, *Nymphaea odorata*, *Potamogeton foliosus*, *P. illinoensis*, *P. natans*, *P. pectinatus*, *P. zosteriformis*, *Ranunculus longirostris*, and *Vallisneria americana* (Swink & Wilhelm 1994). *Description:* Leaves brittle, dark brown in color, entire specimens rare, often evidenced only by carbonized imprints in silt (Fig. 61), leaf segments usually less than 12 pairs. *Stratigraphy:* In fine organic sediments of lower strata at the Shafer Mastodont Locality. *Chronology:* The only dated record is 15,540 ± 70 ybp (Shafer Mastodont Locality). *Frequency:* 6%. *Abundance:* Frequent where found.

Order Ericales
Family Ericaceae

Andromeda glaucophylla: (Figs. 62, 63). *Habitat:* Most common in leatherleaf (*Chamaedaphne calyculata*) bogs, but may also occur in fens. Associates include *Betula pumila*, *Chamaedaphne calyculata*, *Thelypteris palustris*, *Hypericum virginicum*, *Menyanthes trifoliata*, *Potentilla palustris*, *Sarracenia purpurea*, *Vaccinium macrocarpon*, and *V. oxycoccos*. *Description:* Leaves (Figs. 62, 63) brown, linear, entire, revolute; surface glabrous, covered with black flecks, veins furrowed; undersides (Fig. 63) dull with raised midrib. *Stratigraphy:* Beginning at the transition from fen peat to *Sphagnum* peat and extending well into the *Sphagnum* peat. *Chronology:* The oldest dated record is 2835 ybp (Ropchan Memorial Bog). *Frequency:* 31%. *Abundance:* Infrequent to rare where found.

Chamaedaphne calyculata: (Fig. 64). *Habitat:* Mature *Sphagnum* bogs; usually associated with *Vaccinium macrocarpon* and/or *Vaccinium oxycoccos*. *Description:* Leaves (Fig. 64) poorly preserved, obovate, entire, covered with a thick cuticle bearing pits, pits absent where cuticle has deteriorated. *Stratigraphy:* Upper layers of *Sphagnum* peat. *Chronology:* The oldest record is 4010 ± 80 ybp (Burket Bog). *Frequency:* 19%. *Abundance:* Infrequent to rare where found.

Vaccinium macrocarpon: (Fig. 65). *Habitat:* Bogs and fens; often associated with *Sphagnum*, *Chamaedaphne calyculata*, and *Sarracenia purpurea*. *Description:* Leaves (Fig. 65) well preserved, oblong, thick, dark brown to black in color, midrib visible, other veins inconspicuous, margins of leaf slightly revolute. *Stratigraphy:* Upper reaches of brown moss (fen) peat and extending through the lower layers of *Sphagnum* peat. *Chronology:* The oldest dated record is 4110 ± 100 ybp (Dutch Street Bog). *Frequency:* 44%. *Abundance:* Frequent where found.

Order Gentianales
Family Gentianaceae

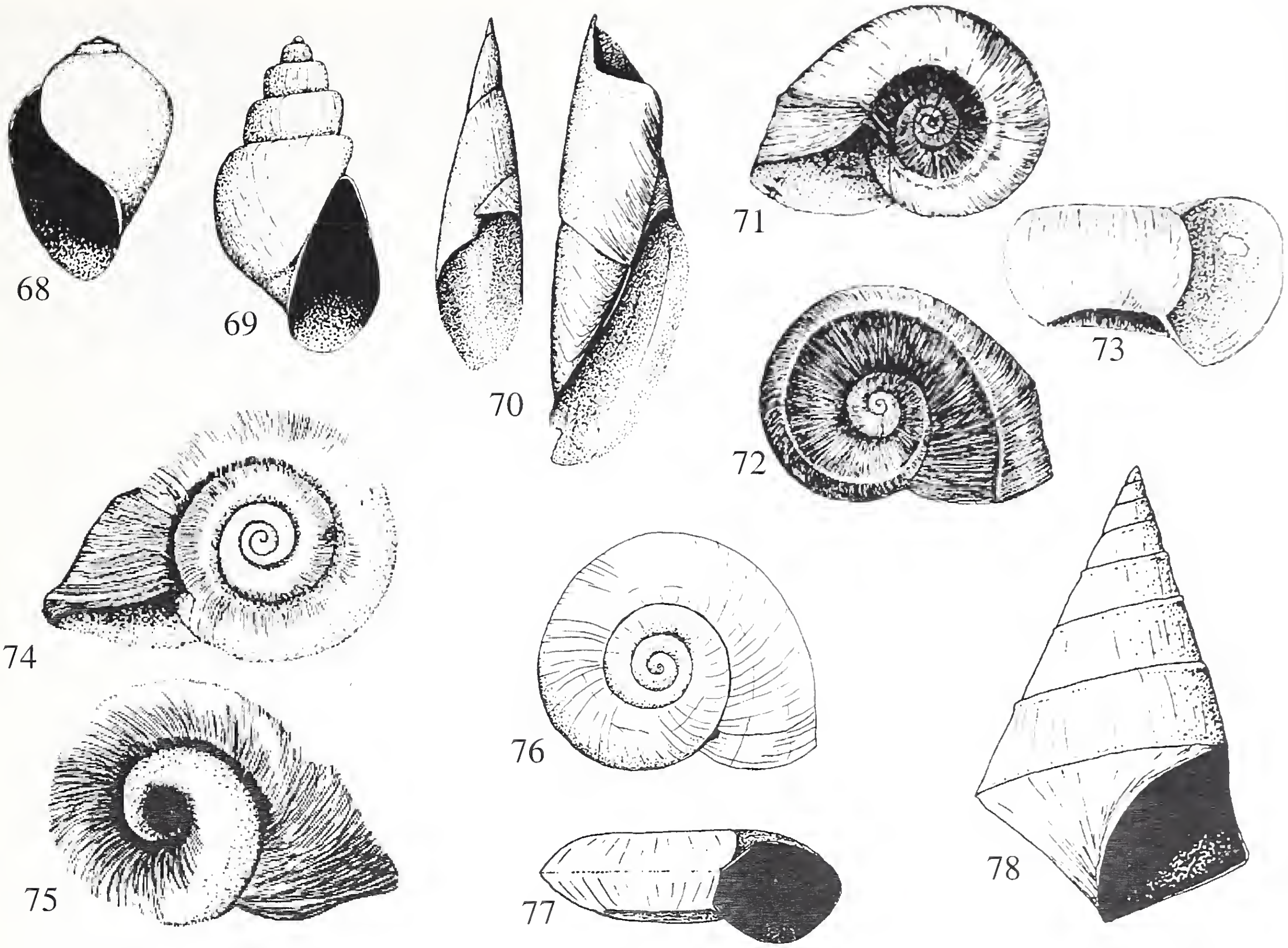
Menyanthes trifoliata: (Fig. 66). *Habitat:* Open, wet areas of neutral fens and mineral-rich *Sphagnum* bogs. *Description:* Achenes (Fig. 66) well preserved, shiny, dark brown to black in color, irregularly shaped, bearing concave depressions. *Stratigraphy:* Beginning in the uppermost portions of fen peats and extending into the early portions of *Sphagnum* peat. *Chronology:* The oldest dated record is 4010 ± 80 ybp (Burket Bog). *Frequency:* 31%. *Abundance:* Infrequent where found.

Order Campanulales
Family Asteraceae

Bidens sp.: (Fig. 67). *Habitat:* Wetlands. *Description:* Achenes (Fig. 67) poorly preserved, light brown in color, elongate-tapering, bearing four bristles. *Stratigraphy:* Fen peat in Little Chapman Bog. *Chronology:* The only dated record is ~1850 ± 80 ybp (Little Chapman Bog). *Frequency:* 6%. *Abundance:* Extremely rare where found.

Kingdom Animalia
Phylum Mollusca
Class Gastropoda
Subclass Pulmonata
Order Basommatophora
Family Physidae

Physa sayii: (Fig. 68). *Habitat:* This species is common to still, shallow waters (0.3–0.8 m) in open areas. It prefers moderate vegetation



Figures 68–78.—68. *Physa sayii* (4 mm); 69. *Lymnaea humilus* (7 mm); 70. *Lymnaea haldemani* fragments (portion of shell showing aperture: 15 mm); 71. *Helisoma anceps*, lateral view, side 1 (15 mm); 72. *H. anceps*, lateral view, side 2; 73. Ventral view of *H. anceps*, showing aperture; 74. *Helisoma campanulata*, lateral view, side 1 (apical) (12 mm); 75. *H. campanulata*, lateral view, side 2; 76. *Gyraulus parvus* apical view (7.5 mm); 77. Ventral view of *G. parvus*, showing aperture; 78. Apical portion of shell of *Pleurocera acuta* (6 mm).

and well-aerated water (Zimmerman 1960). While Zimmerman (1960) reports that *P. sayii* prefers protected areas, Harmen & Berg (1971) found that it was most common in exposed areas. Goodrich & van der Schalie (1944) note that it can sometimes be found on wave battered shores. *Description:* Shell (Fig. 68) well-preserved when found but extremely fragile, sinistral, thin, globose, spire obtuse-conical, body whorl extremely inflated (Harmen & Berg 1971); subfossils lacking periostracum. *Chronology:* The oldest dated record is 11,990 ± 90 ybp (Wilkinson Giant Beaver Locality). *Stratigraphy:* Found throughout the marl stratum in Kiser Lake Fen. In moderate to deep marls in the Wilkinson Giant Beaver Locality. *Frequency:* 13%. *Abundance:* Infrequent to rare where found.

Family Lymnaeidae

Lymnaea humilis: (Fig. 69). *Habitat:* Harmen & Berg (1971) report this species as inhabiting exposed mud flats, where they forage between the gravels with their shells partially exposed to the air. Goodrich & van der Schalie (1944) also report this species as inhabiting mud flats. *Description:* Shell (Fig. 69) well-preserved, up to 15 mm in length but more commonly less than 10 mm, dextral, relatively thick; spire acute-conical, bearing up to 7 whorls, sutures deeply impressed; growth lines inconspicuous, worn; aperture tear-shaped (Harmen & Berg 1971); subfossils lack periostracum. *Stratigraphy:* Marl. *Chronology:* The oldest dated record is 12,070 ± 50 ybp (Aker Mastodont Locality). *Frequency:* 25%. *Abundance:* Infrequent to frequent where found.

Lymnaea haldemani: (Fig. 70). *Habitat:* Common in shallow waters (0.3–1 m) of larger lakes in abundant vegetation. It prefers sheltered bays, and is commonly found on floating vegetation and on the undersides of water-lilies (Zimmerman 1960). It has also been found on rotting *Typha* leaves (Harmen & Berg 1971). This species is always found in limited numbers (Zimmerman 1960). It has not been recorded in Indiana in recent times. *Description:* Shell (Fig. 70) dextral, thin, up to 25 mm; spire extremely acute-conical, elongate; sutures impressed, up to 5 loosely coiled whorls, growth lines inconspicuous (Harmen & Berg 1971); subfossils extremely fragile, lack periostracum. *Stratigraphy:* Marl. *Chronology:* The youngest dated record is 11,240 ± 80 ybp (Wilkinson Giant Beaver Locality), and the oldest dated record is 12,070 ± 50 ybp (Aker Mastodont Locality). *Frequency:* 13%. *Abundance:* Extremely rare to rare where found.

Family Planorbidae

Helisoma anceps: (Figs. 71–73). *Habitat:* Common in shallow waters (<1 m) with abundant vegetation. While Reynolds (1959) reports that it prefers exposed habitats of open lakes, Harmen & Berg (1971) found it most commonly on inorganic substrates in protected areas of ponds as well as quiet pools of small streams. *Description:* Shell (Figs. 71–73) up to 15 mm, planospiral, about 3.5 loosely coiled whorls that are angulated above and below, spire deep, depressed on both sides; sutures shallow; growth lines conspicuous, crowded; aperture broadly lunate, sharply shouldered below and extending beyond plane of spire, inflated and rugose in mature specimens (Harmen & Berg 1971); subfossils well-preserved, but lack periostracum. *Stratigraphy:* Marl. *Chronology:* The oldest dated record is 12,070 ybp (Aker Mastodont Locality). *Frequency:* 19%. *Abundance:* Frequent to abundant where found.

Helisoma campanulata: (Figs. 74, 75). *Habitat:* Occurs in shallow waters of varying substrates in both protected and wave battered areas (Zimmerman 1960). Harmen & Berg (1971) found it mostly on inorganic substrates of small marshy lakes. They rarely found it associated with other *Helisoma* spp., with the exception of *H. anceps* and *H. trivolvis*. Dexter (1950) found the species to be common in *Chara*/*Myriophyllum*, *Nymphaea*/*Pontedaria*, and *Decodon* zones of a basic bog lake in Ohio. *Description:* Shell (Figs. 74, 75) up to 15 mm, sinistral, planospiral, with 4.5 tightly coiled whorls; sutures deep; growth lines conspicuous, evenly spaced, aperture broadly lunate, inflated on mature specimens (Harmen & Berg 1971); subfossils well-preserved, lack periostracum. *Stratigraphy:* Marl. *Chronology:* The oldest dated record is 12,070 ybp (Aker Mastodont Locality). *Frequency:* 19%. *Abundance:* Infrequent where found.

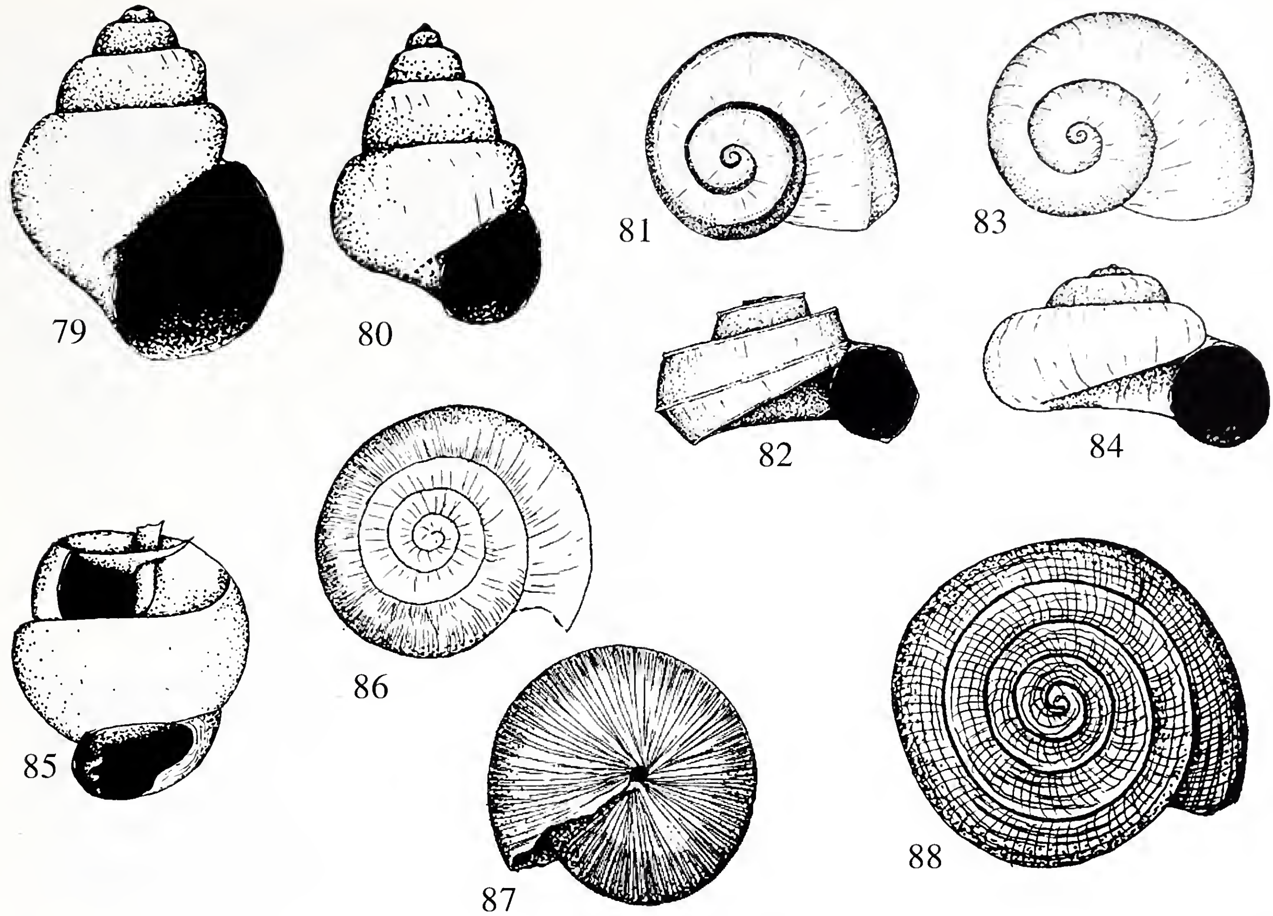
Gyraulus parvus: (Figs. 76, 77). *Habitat:* Occurs in small, shallow, protected waters (Zimmerman 1960), especially in ponds and backwaters with dense aquatic vegetation (Harmen & Berg 1971). Dexter (1950) found it to be restricted to the *Potamogeton* zone. *Description:* Shell (Figs. 76, 77) up to 7 mm, but mostly less than 4 mm, planospiral, 3.5 whorls; spire depressed; sutures deeply impressed; aperture broadly lunate, deflected downward (Harmen & Berg 1971); subfossils well-preserved, lack periostracum. *Stratigraphy:* Marl, rarely in limnic or hemic peat. *Chronology:* The oldest dated record is 12,590 ± 60 ybp (Aker Mastodont Locality). *Frequency:* 31%. *Abundance:* Extremely abundant to abundant where found.

Family Pleuroceridae

Pleurocera acuta: (Fig. 78). *Habitat:* Rivers and unprotected shores of lakes associated with rivers (Harmen & Berg 1971). *Description:* Shell (Fig. 78) dextral, up to 30 mm, thick, elongate and acute-conical, 7–14 whorls, apical whorls bearing 1–3 carinae; body whorl shouldered at outer periphery, striate below; aperture angulate, lacrimate, canaliculate (Harmen & Berg 1971); growth lines inconspicuous; subfossils usually fragmented, lack periostracum. *Stratigraphy:* Marl. *Frequency:* 6%. *Abundance:* Rare where found.

Family Hydrobiidae

Amnicola limosa: (Fig. 79). *Habitat:* Common in protected areas of shallow lakes and muddy bays in 0–3 m of water (Zimmerman 1960). It is also found in marshes, ponds, temporary stream pools, creeks and rivers (Harmen & Berg 1971). Reynolds (1959) reports that it has been found in brackish water as well as freshwater and prefers sandy sub-



Figures 79–88.—79. *Amnicola limosa* (5 mm); 80. *Amnicola lustrica* (3.5 mm); 81. *Valvata tricarinata*, apical view (4 mm); 82. Ventral view of *V. tricarinata*, showing aperture; 83. *Valvata sincera*, lateral view (4 mm); 84. Ventral view of *V. sincera*, showing aperture; 85. *Gastrocopta* sp. shell fragment (1.5 mm); 86. *Retinella* sp., apical view (2.5 mm); 87. *Retinella* sp., ventral view; 88. *Helicodiscus parallelus* (3.5 mm).

strates with dense beds of *Chara*, *Potamogeton*, *Vallisneria*, and *Elodea*. Dexter (1950) reports it from the *Chara/Myriophyllum*, *Nymphaea/Pontedaria*, and *Decodon* zones. Zimmerman (1960) states the most important limiting factor for this species is vegetation (preferably abundant) and protection from exposure. He also reports that this species can endure long periods of emergence as long as it remains moist, but unusually high water temperatures can rapidly exterminate it from a waterbody. *Description:* Shell (Fig. 79) up to 5 mm, dextral; spire slightly elevated; apex truncated; sutures deep; whorls rounded, inflated, up to 4.5 in number; aperture broadly lacrimate (Harmen & Berg 1971); growth lines inconspicuous; subfossils well-preserved, lack periostracum. *Stratigraphy:* Marl. *Chronology:* The oldest dated record is 12,590 ± 60 ybp (Aker Mastodont Locality). *Frequency:* 19%. *Abundance:* Extremely abundant to abundant where found.

Amnicola lustrica: (Fig. 80). *Habitat:* This species is less common than *A. limosa*, although it occupies similar habitats (Harmen & Berg 1971). It prefers shallow (0–2 m), highly vegetated waters, where it often inhabits filamentous algae (Zimmerman 1960). *Description:* Shell (Fig. 80) dextral, elevated, acute-conical; sutures deep; aperture lacrimate (Harmen & Berg 1971); growth lines inconspicuous; subfossils well-preserved, lack periostracum. *Stratigraphy:* Marl. *Chronology:* The oldest dated record is 12,590 ± 60 ybp (Aker Mastodont Locality). *Frequency:* 25%. *Abundance:* Frequent to infrequent where found.

Family Valvatidae

Valvata tricarinata: (Figs. 81, 82). *Habitat:* Inhabits a wide variety of conditions but is most common in lakes. Harmen & Berg (1971) report that most specimens from lotic conditions are depauperate. Dexter (1950) found it to be common in the *Chara/Myriophyllum*, *Potamogeton*, *Nymphaea/Pontedaria*, and *Decodon* zones. Reynolds (1959) reports that the species is partial to firm bottoms and is usually associated with *Oedogonium*, *Cladophora*, and *Vaucheria*. *Description:* Shell (Figs. 81, 82) dextral, up to 5 mm, turreted; sutures deep; spire low; whorls 4, angulate, top, middle and bottom, each bearing a carina; aperture circular (Harmen & Berg 1971); growth lines somewhat conspicuous; subfossils well-preserved, lack periostracum. *Stratigraphy:* Marl. *Chronology:* The oldest dated record is 12,590 ybp (Aker Mastodont Locality). *Frequency:* 25%. *Abundance:* Extremely abundant where found.

Valvata sincera: (Figs. 83, 84). *Habitat:* This species is reported as being primarily from deep water (5– 6 m), usually below 3 m in depth, of cold lakes with limited vegetation (Zimmerman 1960). Harmen & Berg (1971) found it at a depth of 5 m. *Description:* Shell (Figs. 83, 84) dextral, up to 4 mm, turreted; sutures deep; spire low; whorls 2.5, circular, acarinate; aperture circular (Harmen & Berg 1971); growth lines somewhat conspicuous to inconspicuous; subfossils well-preserved, lack periostracum. *Stratigraphy:* Marl. *Chronology:* The oldest dated record is 15,910 ± 90 ybp (Celery Bog). *Frequency:* 25%. *Abundance:* Infrequent to rare where found.

Order Ophistobranchia
Suborder Stylommatophora
Family Pupillidae

Gastrocopta sp.: (Fig. 85). *Habitat:* Terrestrial. *Description:* Shell (Fig. 85) ovate, smooth, aperture bearing large, blunt teeth; subfossil shells fragile. *Stratigraphy:* A few shells were found in the earliest sediments of the peat stratum of Kiser Lake Fen. *Chronology:* The oldest dated record is 4360 ± 100 ybp (Kiser Lake Fen). *Frequency:* 6%. *Abundance:* Infrequent to rare.

Family Zonitidae

Retinella sp.: (Figs. 86, 87). *Habitat:* Terrestrial. *Description:* Shell (Figs. 86, 87) thin, smooth, lustrous, depressed with four to six whorls, well-preserved. *Stratigraphy:* A few specimens in sandy marl of Kiser Lake Fen. *Chronology:* The oldest dated record is 4360 ± 100 ybp (Kiser Lake Fen). *Frequency:* 6%. *Abundance:* Rare.

Family Endodontidae

Helicodiscus parallelus: (Fig. 88). *Habitat:* Terrestrial. Goodrich & van der Schalie (1944) report this species as being most common to flood plains. *Description:* Shell (Fig. 88) disc-shaped, bearing parallel, raised, lines; spire flat; umbilicus broad, shallow. *Stratigraphy:* One specimen from the uppermost marl stratum of the Wilkinson Giant Beaver Locality, Whitley County, Indiana. *Chronology:* The oldest dated record is 11,240 ± 80 ybp (Wilkinson Giant Beaver Locality). *Frequency:* 6%. *Abundance:* Extremely rare.

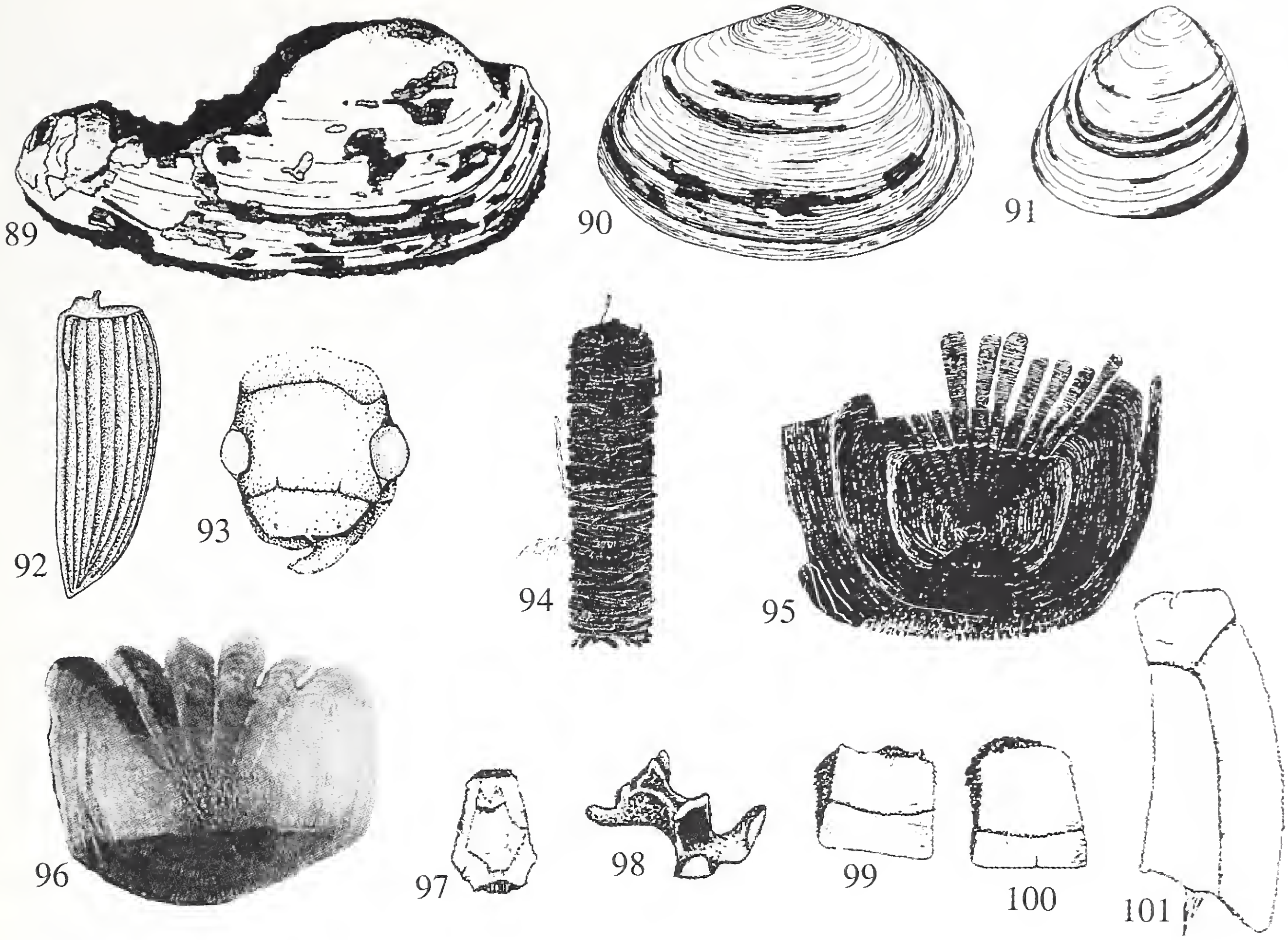
Class Bivalvia
Order Prionodesmacea
Family Unionidae

cf. *Elliptio dilatata*: (Fig. 89). *Habitat:* Lakes, ponds, and limnic waters with fish communities. *Description:* Valves (Fig. 89) very poorly preserved, powdery and brittle, periostracum present. *Stratigraphy:* Marl. *Chronology:* The oldest dated record is 11,240 ± 80 ybp (Wilkinson Giant Beaver Locality). *Frequency:* 6%. *Abundance:* Extremely rare.

Order Teleodesmacea
Family Sphaeriidae

Sphaerium sp.: (Fig. 90). *Habitat:* Lakes, ponds, marshes, swamps, sloughs, slow rivers and streams. *Description:* Valves (Fig. 90) up to 20 mm, nearly equal in morphology, symmetrical, nearly as long as broad, relatively thin; surface bearing eccentric ridges; subfossils moderately to poorly preserved, larger shells usually broken, surface often has remnants of periostracum. *Stratigraphy:* Marl. *Chronology:* The oldest dated record is 11,990 ± 90 ybp (Wilkinson Giant Beaver Locality). *Frequency:* 13%. *Abundance:* Abundant to frequent where found.

Pisidium sp.: (Fig. 91). *Habitat:* Lakes, ponds, marshes, swamps, sloughs, slow rivers and streams. *Description:* Valves (Fig. 91) up to 6 mm but usually 3–4 mm, laterally assymetrical; surface more or less smooth but eccentric growth rings visible; subfossils well-preserved, bearing remnants of the periostracum. *Stratigraphy:* Marl, rarely in limnic or sapric sediments. *Chronology:* The oldest dated record is 12,590 ybp (Aker Mastodont Locality). *Frequency:* 38%. *Abundance:* Extremely abundant to rare where found.



Figures 89–101.—89. *Elliptio dilatata* (100 mm); 90. *Sphaerium* sp. (12 mm); 91. *Pisidium* sp. (5 mm); 92. Coleoptera elytron (6 mm); 93. Coleoptera head capsule (2 mm); 94. Larval case of cf. *Micrasema* sp. (Trichoptera) (20 mm); 95. *Lepomis* cf. *macrochirus* scale (5 mm); 96. *Perca flavescens* scale (4 mm); 97. *Sternotherus odoratus* cranial bone (9 mm); 98. Vertebra of *S. odoratus* (7 mm). 99. Peripheral plate of *S. odoratus* (9 mm). 100. Peripheral plate of *S. odoratus* (10 mm); 101. Costal plate of *S. odoratus* (31 mm).

Phylum Arthropoda
Class Insecta
Order Coleoptera

Unidentified appendages: (Figs. 92–93). *Habitat:* Mostly terrestrial. *Stratigraphy:* Restricted mostly to peat strata. *Frequency:* 63%. *Abundance:* Abundant.

Order Trichoptera
Family Brachycentridae

cf. *Micrasema* sp.: (Fig. 94). *Habitat:* Weed-choked, lotic environments. *Description:* Case (Fig. 94) more or less cylindrical, open at both ends, constructed from *Ceratophyllum demersum* stems. *Stratigraphy:* A single specimen from basal aquatic sediments of Svoboda Fen. *Frequency:* 6%. *Abundance:* Extremely rare.

Phylum Chordata
Class Osteichthyes
Family Centrarchidae

Lepomis cf. *macrochirus*: (Fig. 95). *Habitat:* All of the sunfish species prefer relatively warm waters generally found in mesotrophic to eutrophic waters of lakes and ponds; also found in lotic waters. The natural range of the family is from southern Canada to the Gulf of Mexico (Page & Burr 1991). *Description:* Scales (Fig. 95) ctenoid, subquadrate with 8–15 primary anterior radii that converge at the focus; radii crenate at scale margin; antero-lateral corners square, postero-lateral corners rounded; focus located in posterior half of scale (Daniels 1996). *Stratigraphy:* Limnic sediments and marls of Kiser Lake Fen, Little Chapman Bog, and Little Arethusa Bog.

Chronology: The oldest dated record is >4360 ybp (Kiser Lake Fen). *Frequency:* 19%. *Abundance:* Infrequent where found. Appear sporadically throughout limnic sediments.

Family Percidae

Perca flavescens: (Fig. 96). *Habitat:* Freshwater lakes, ponds, and quiet areas of streams and rivers in the Atlantic, Arctic, Great Lakes, and Mississippi River Basins (Page & Burr 1991). *Description:* Scales (Fig. 96) ctenoid, with 4–8 primary radii in anterior field only; radii deeply cleft at scale margin; focus located on posterior third of scale (Daniels 1996). *Stratigraphy:* Limnic sediments of Celery Bog. *Chronology:* The oldest dated record is >9530 ± 90 ybp (Celery Bog). *Frequency:* 6%. *Abundance:* Somewhat frequent where found.

Class Reptilia
Order Chelonia
Family Kinosternidae

Sternotherus odoratus: (Figs. 97–101). *Habitat:* Rivers, lakes, ponds, marshes, swamps, and sloughs. Prefers slow current and soft organic bottom or marl (J.A. Holman pers. comm.). *Stratigraphy:* Five bones (Figs. 97–101), presumably of a single animal, were found in the limnic sediment of Little Chapman Bog, Koscisuko County. *Chronology:* The only dated record is 3680 ± 80 ybp (Little Chapman Bog) (Swinehart & Holman 1999). *Frequency:* 6%. *Abundance:* Extremely rare.

CONCLUSIONS

Although not exhaustive, the present paper characterizes the macroscopic subfossil taxa common to wetland deposits in northern Indiana, and should provide useful information to other investigators working on the palaeoecology of wetlands in the southern Great Lakes region. Macrofossil surveys are a necessary complement to pollen data, especially when reconstructing local ecosystems. For example, although many pollen profiles show *Picea* as being abundant to within 8000 ybp, no macrofossils of *Picea* less than about 11,000 ybp have been recovered in Indiana. This suggests that macrofossil data may be more accurate for local or even regional reconstructions. Radiocarbon dating of macroscopic subfossils has indicated that many of the taxa which are common to temperate, eutrophic waters colonized aquatic environments as early as the late-Pleistocene, suggesting that conditions may have become favorable to these species earlier than previously thought.

Although the percent frequency determined for each taxon (based on 16 sites) is helpful, it is biased by the site selection methods. Most of the sites are peatland deposits that attracted the author because of their unique, boreal flora. Other sites were studied because of the discovery of ice-age mammal remains. Further investigations of different wetland types, such as emergent marshes and extant lakes, would add to the understanding of late-glacial and post-glacial biogeography. Additional radiocarbon dates will help further document the dates and rates of the colonization of various taxa after glacial retreat. Furthermore, use of scanning electron microscopy in the examination of small, obscure seeds is recommended. This will greatly increase the number of identifiable taxa.

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