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# Conservation of the freshwater gastropods of Indiana: Historic and current distributions

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**Abstract:** We surveyed Indiana collections of freshwater gastropods from 220 museum collection lots and found 39 species inhabiting Indiana historically. Collection dates of museum material ranged from 1900 to 2006, with a median date of 1986. We collected 17,593 gastropods at 123 sites, including 86 sites where museum material was previously collected. Our surveys were combined with recent literature surveys and indicate a total of 36 species are currently present in Indiana. The Indiana fauna is composed of three species that are apparently secure globally, and 36 species that are widespread, abundant, and globally secure, including two exotics. However, three species are locally extinct and many others are locally imperiled or vulnerable. The majority of freshwater gastropod taxa in Indiana are of local conservation concern. The causes of local gastropod extinctions are unknown but likely include agricultural impacts, hydrologic alterations from reservoirs, and pollution. We recommend thorough inventory, recognition, and protection of the aquatic gastropods in Indiana.

**Key words:** macroinvertebrates, endangered species, snails, distributions, biogeography

Freshwater gastropods inhabit all aquatic habitats in North America. However, relatively little information is available on species distributions and the ecological requirements of this group as a whole (Burch 1982, Thorp and Covich 2001, Stewart 2006). Although recent distributional studies exist for several states—*e.g.*, Iowa and New York (Jokinen 1992, Stewart 2006), large knowledge gaps remain for geographic distribution and species composition throughout much of North America. Aquatic gastropods are a large component of freshwater ecosystems, providing significant biomass as herbivores (Brown 2001, Brown *et al.* 2008). Freshwater gastropods are frequently used in water quality bioassessments because of the occurrence of several indicator species or groups that are sensitive to water quality and habitat alteration (Salanki *et al.* 2003). In addition, freshwater organisms are the most imperiled fauna in North America, and freshwater gastropods are a group that is at risk (Ricciardi and Rasmussen 1999, Brown *et al.* 2008).

Indiana's water resources are at risk because of a combination of agricultural, urban, and other human impacts. These effects result largely from patterns of human land use and subsequent effects on aquatic ecosystems (Allan 2004, Pyron *et al.* 2006). Although land use patterns are unlikely to change in the near future, identification and awareness of existing fauna can provide a baseline for further monitoring and conservation.

The earliest attempt to produce a guide to the aquatic gastropods of Indiana was by Goodrich and van der Schalie (1944), which included an identification key, habitat descriptions for each species, and brief descriptions of species distributions. However, most of the taxonomy used in this guide is out of date, and no other Indiana guides to aquatic gastropods have been published. Several more recent studies of Indiana aquatic gastropods provide presence/absence information for several taxa. Brown (1982) sampled aquatic gastropods of temporary ponds in northeast Indiana, to test for habitat overlap among species. He found six species that varied in abundances by pond type. Jokinen (2005) surveyed ponds of the Indiana Dunes National Park, to compare with a historic survey by Shelford (1913). Many of the ponds that Shelford (1913) surveyed have since been destroyed by industrial development. However, Jokinen (2005) found similar overall species richness for aquatic gastropods, due to a combination of species that appeared to be extinct and other species that were not found in Shelford's (1913) survey. Greenwood and Thorp (2001) studied the distributions and substrate selection of two caenogastropods in the Ohio River, upstream from Louisville, Kentucky. Both species, *Lithasia obovata* (Say, 1829) and *Pleurocera canaliculata* (Say, 1821), are large river specialists.

A current survey of Indiana snails is important because it provides information of local declines and extinctions that will require action from conservationists. Local extinctions may suggest problems with water quality or hydrologic alterations in the watershed, or other explanations for absence of gastropods at sites. Information on historical and current snail distributions throughout Indiana will thus be invaluable to future water quality managers and scientists. This study is such a survey of museum collections from Indiana, coupled with site visits to assess the current status of aquatic gastropods in the state.

## MATERIALS AND METHODS

### Study area

Indiana is in the mid-western United States, with physiography consisting primarily of glacial till plains (Visher 1922) and a total area of 94,000 km$^2$. The majority of the state is in the Central Lowland province with only local topographical relief. The southern limit of glaciation is a boundary line between the Central Lowland and the southern Low Plateau (~⅓ of the southern portion of the state). One fourth of the state along the north is in the Eastern Lake Section, with many moraine lakes formed from glacial drift. Two major watersheds drain the state: the Great Lakes are immediately north, and the remainder of the state is in the Mississippi River basin. The Illinois River watershed includes the Kankakee River to the northwest, the southern section of the state drains directly into the Ohio River, and the majority of the state is within the Wabash River watershed that drains to the Ohio River (Visher 1922).

The human footprint has been large in Indiana. About 98% of land is used for cropland, pasture, or development (GAP 1996). The northern 24% of the state was predominately wetland prior to European settlement, and 85% of these wetlands have been lost, with drainage for agriculture the primary cause (IDNR 1996). Water quality of Indiana streams was severely altered by humans (Gammon 1998). Nearly all Indiana streams that are within the Wabash River watershed (>70 % of the state) have hydrologic alterations (significant changes to the natural flow regime) caused primarily by agricultural effects and/or reservoir release (Pyron and Neumann 2008). The net result is a human-dominated landscape with habitat fragmentation and degradation, widespread pollution, and isolated plant and animal populations.

We used a two-step process for surveying aquatic gastropods of Indiana. The first step was to assess historical distributions using two natural history collections (Ohio State University Museum of Biological Diversity and University of Michigan Museum of Zoology) that contain aquatic gastropod material from Indiana. The second step was to return to sites where museum collections were taken and to re-survey the sites to determine if previously recorded species were still present. The modern surveys would also reveal any additional species not reported in earlier surveys. Museum visits included examining specimens and verifying identifications and recording location information and collection dates. No other Indiana guides to aquatic gastropods have been published, thus Burch's (1982) keys and notes are the primary reference for identification. Unless otherwise noted, nomenclatural taxonomy was from Turgeon *et al.* (1998) or Stewart (2006).

### Field sampling

We visited 123 sites of which 86 were historical sites, in the summers of 2006-2008 to collect aquatic gastropods (Fig. 1). The additional sites were in locations where historic samples were sparse. Methods consisted of sampling all available habitats at each site, primarily by hand collections in shallow water, on woody debris, on the undersides of stones, and on aquatic vegetation. Deeper areas and fine substrates were sampled with a net. Collection durations were the equivalent of one individual searching for 60 min. For example, two persons searched for 30 min (Brown *et al.* 1998). Gastropods were preserved in 70% ethanol and identified in the laboratory to the lowest possible taxonomic level, using Burch (1982). All specimens will be deposited at the Illinois Natural History Survey. We determined global conservation status for species using The Nature Conservancy designations (www.natureserve.org), and we described the Indiana status based on our collections.

## RESULTS

We found 220 lots of Indiana aquatic gastropods at the two museums, comprising 39 taxa at 86 sites. Museum ma-

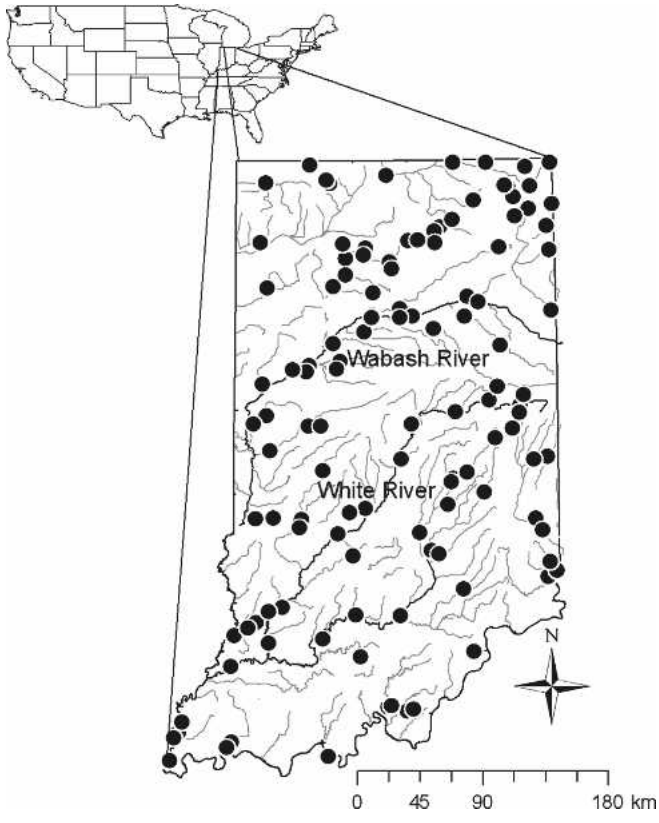


**Figure 1.** Sites sampled in 2006-2008. Coordinates are available from authors.

terial was collected between 1900 and 2006 with a median collection date of 1976. Our current survey of 123 sites yielded 17,593 individuals in 32 species (Figs. 2-17). Four additional taxa were included based on the survey by Jokinen 2005). Most taxa occurred at few sites—the average number of sites where an individual taxon occurred was 11 (range, 1-75; Figs. 2-17). The mean abundance of individuals collected at sites was 144 (range, 0-1463). The mean number of species per site was 3.3 (range, 0-8). Ten of the historic collection sites and five new sites had no gastropods. Seventeen of the 36 taxa we collected, or that were in Jokinen's (2005) collections, were not collected in previous surveys.

Mean water hardness was 300 mg $CaCO_3$/L and ranged from 40 to 1200. Mean water conductivity was 550 μmhos and ranged from 101 to 1800. Mean pH was 8.2 and ranged from 6 to 9.6. Although we found variation in mean water chemistry parameters among species, overall variation among sites was relatively low. The majority of species had mean hardness values of 300 mg $CaCO_3$/L, conductivity of 500 μmhos, and pH of 8.0. Only one species occurred at sites with an exceptional mean water chemistry value: *Ferrissia fragilis* (Tryon, 1863) was found at 18 sites with a mean pH of 7.2. We will examine the influence of environmental variables on gastropod assemblages in detail in a separate study.

The following list of taxa is organized by family. Distribution maps include historical sites from archival material and current (2006-2008) collections. Not all museum material included specific site details or dates. We did not include information on maps if collections lacked site information.

**Family Valvatidae**

*Valvata bicarinata* (Lea, 1841). Goodrich and van der Schalie (1944) reported the species occurred likely in every county in Indiana. This species has apparently declined or disappeared, as in Iowa (Stewart 2006). We consider it to be extinct in Indiana and secure in the rest of the range.

*Valvata lewisi* (Currier, 1868). No historical collections were found. The species was historically present in lakes in Kosciusko and Marshall County (Goodrich and van der Schalie 1944). We collected this species only at Clear Lake, Steuben County. The habitat was silt substrate and submerged vegetation. This species occurs in southern Canada from Quebec to British Columbia and northern U.S. from New York to Minnesota (Burch and Tottenham 1980). Jokinen (1992) found only one site for this species in New York, and Stewart (2006) determined the species is extinct in Iowa. We categorized it as critically imperiled in Indiana but it is secure in the rest of the range.

*Valvata tricarinata* (Say, 1817). No historical or recent collections were found. Jokinen (2005) found this species in a pond at Indiana Dunes National Lakeshore in 1992-1993. We categorized it as critically imperiled in Indiana but secure in other parts of the range.

*Valvata sincera* (Say, 1824). No historical or recent collections were found. Burch and Tottenham (1980) reported the range as Maine west to Alberta, and south to South Dakota and Indiana. We consider it to be extinct in Indiana but secure in other parts of the range.

**Family Viviparidae**

*Viviparus georgianus* (Lea, 1834). No historical collections were found. Wright (1932) collected this species in Indiana at four sites on Maxinkuckee Lake and its outlet, the Tippecanoe River. The species was historically present in the Wabash River and numerous Indiana lakes (Goodrich and van der Schalie 1944). We collected this species at two sites: Clear Lake (Steuben County) and Lake Wawasee (Elkart County). Both lakes had submerged vegetation and either sand or silt substrates. This species is distributed across the midwest and eastern U.S. (Burch and Tottenham 1980). Jokinen (1992) found many sites with this species in New York. It appears to be critically imperiled in Indiana but secure in other parts of the range.

*Viviparus subpurpureus* (Say, 1829). This species was collected historically at four sites that were large rivers and one pond (Fig. 2). We did not collect this species. The three large river sites have reservoirs within their watersheds, and reservoir releases likely produce hydrologic alterations to natural flow regimes. This species has a range through out the Mississippi River watershed to Iowa, Illinois, and Kentucky and south to Louisiana (Burch and Tottenham 1980, Brown *et al.* 1989). Goodrich and van der Schalie (1944) reported the species as confined to larger streams such as the Mississippi, Ohio, and Wabash rivers. Populations appear to be possibly extinct in Indiana but secure in other parts of the range.

*Bellamya chinensis* (Reeve, 1863). No historical collections were found. We collected this species at four sites that were lakes and rivers in the northern third of the state (Fig. 2). The sites had submerged macrophytes and various substrates. This Asian snail is an exotic species that has been introduced and subsequently dispersed across North America (Stewart 2006).

*Bellamya japonica* (von Martens, 1861). No historical collections were found. We collected this species at four sites that were lakes and rivers in the northern third of the state (Fig. 2). The sites had submerged macrophytes and various substrates. This Asian snail is an exotic species that has been introduced and subsequently dispersed across North America (Jokinen 1992).

*Campeloma decisum* (Say, 1817). We mapped all of the *Campeloma* spp. records together, following Stewart (2006). However, we recognized our current collections as *C. de-*

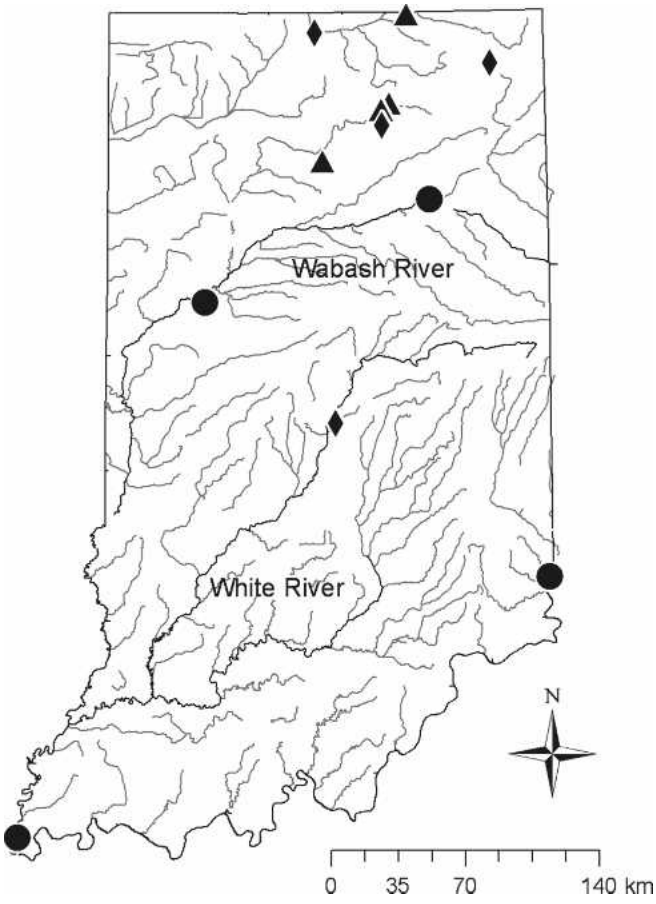


**Figure 2.** Distributions of historic *Viviparus subpurpureus* (circles), current *Bellamya chinensis* (triangles), and current *Bellamya japonica* (diamonds).

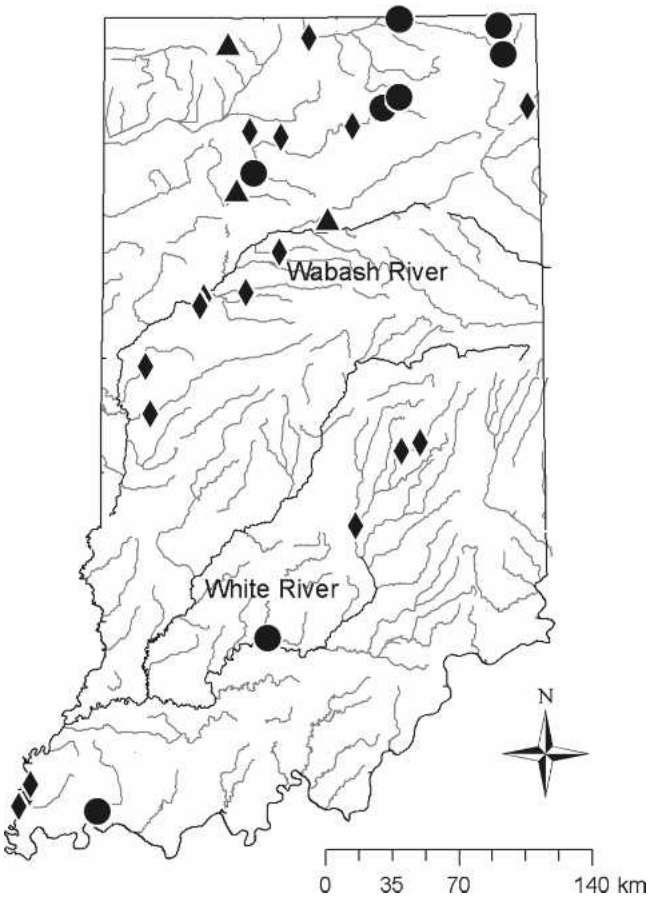


**Figure 3.** Distributions of historic (diamonds) and current *Campeloma decisum* (circles). Sites where historic and current collections occurred are triangles.

*cisum*. We found 20 historical collections and 11 current sites (Fig. 3). Habitats included macrophytes, woody debris, and various substrates of silt, sand, gravel, and cobble. *Campeloma* spp. occur in the Missouri and Mississippi watersheds (Stewart 2006 and references therein). They are common in lakes and rivers of Indiana and we classified them as secure.

**Family Hydrobiidae**

*Birgella subglobosus* (Say, 1825). No historical collections were found. We found the species at six sites (Fig. 4). Habitats included various substrate categories but lacked silt. The species was historically found throughout Indiana (Goodrich and van der Schalie 1944) with a range from Ohio west to Iowa, and from Michigan south to Alabama and Arkansas (Burch and Tottenham 1980). Jokinen (1992) collected the species in Lake Champlain, St. Lawrence watershed. We classified it as imperiled in Indiana but it is apparently secure in other parts of the range.

*Cincinnatia integra* (Say, 1821). We found one historical collection of this species from Lake James and we collected this species at one site on the Eel River. The habitat at the Eel River was gravel and sand substrates and submerged vegetation. Shelford (1913) found this species in ponds at the Indiana Dunes National Lakeshore. However, Jokinen (2005) did not find the species at the same ponds in 1992-1993. This species occurs in the Ohio River and tributaries in Ohio, Indiana, Kentucky, and southeastern Illinois (Burch and Tottenham 1980). Jokinen (1992) did not collect this species in New York, but it was found there historically. The species was historically common in Iowa (Stewart 2006). We classified it as critically imperiled in Indiana but secure in other parts of the range.

*Pyrgulopsis lustrica* (Pilsbry, 1890). Three historical collections were found: Tippecanoe Lake (Elkhart County), Pine Lake (La Porte County), and Lake Michigan (Lake County). We found the species in Little Turkey Lake and Big Turkey Lake (Steuben County). The habitats were sand or

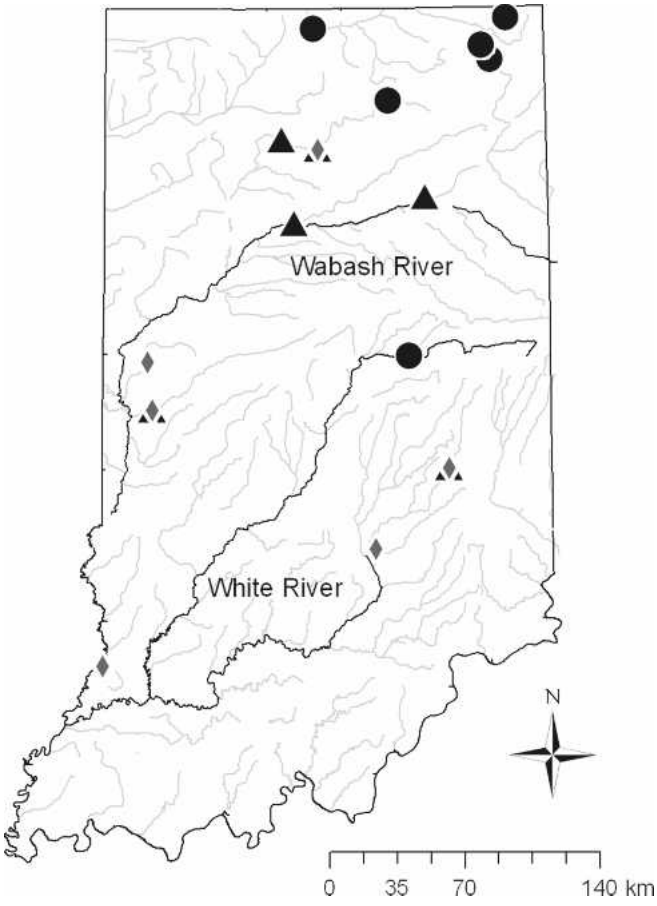


**Figure 4.** Distributions of current *Birgella subglobosus* (diamonds), current *Amnicola limosus* (circles), and *Pomatiopsis cincinnatiensis* (triangles).

silt substrates, woody debris, and emergent vegetation. This species occurs in southern Quebec and Ontario, and from Maine and New York west to Iowa and Minnesota (Burch and Tottenham 1980). Jokinen (1992) found this species at nine sites in New York. The species was found at several Iowa locations in 1979 (Stewart 2006). Goodrich and van der Schalie (1944) found this species was common in lakes, ponds, and streams that had heavy growths of macrophytes and algae. We classified its status as locally imperiled due to very few populations, but secure in other parts of the range.

*Amnicola limosus* (Say, 1817). No historical collections were found. We found the species at six sites (Fig. 4). Shelford (1913) found this species in ponds at the Indiana Dunes National Lakeshore. Jokinen (2005) found the species at one of the same ponds in 1992-1993. We found the species at six sites (Fig. 4). The species is imperiled in Indiana but secure in other parts of the range.

**Family Pomatiopsidae**

*Pomatiopsis cincinnatiensis* (I. Lea, 1850). This species is amphibious. No historical collections were found. We found the species at five sites (Fig. 4). The habitats were sand or silt substrates, and submerged or emergent vegetation. The river site had sand, gravel, and cobble substrates, and submergent vegetation. Goodrich and van der Schalie (1944) reported the historical distribution as Henry and La Porte Counties. The species is vulnerable in Indiana but it is apparently secure in other parts of the range.

**Family Pleuroceridae**

*Elimia livescens* (Menke, 1830). We included historical material that was misidentified as *Elimia semicarinata* (Say, 1829). We found 24 historical sites and 48 current sites (Fig. 5) of which five were lakes. The sites had various substrates including silt, sand, gravel, cobble, and boulders. This species occurs in the St. Lawrence River drainage from the Great

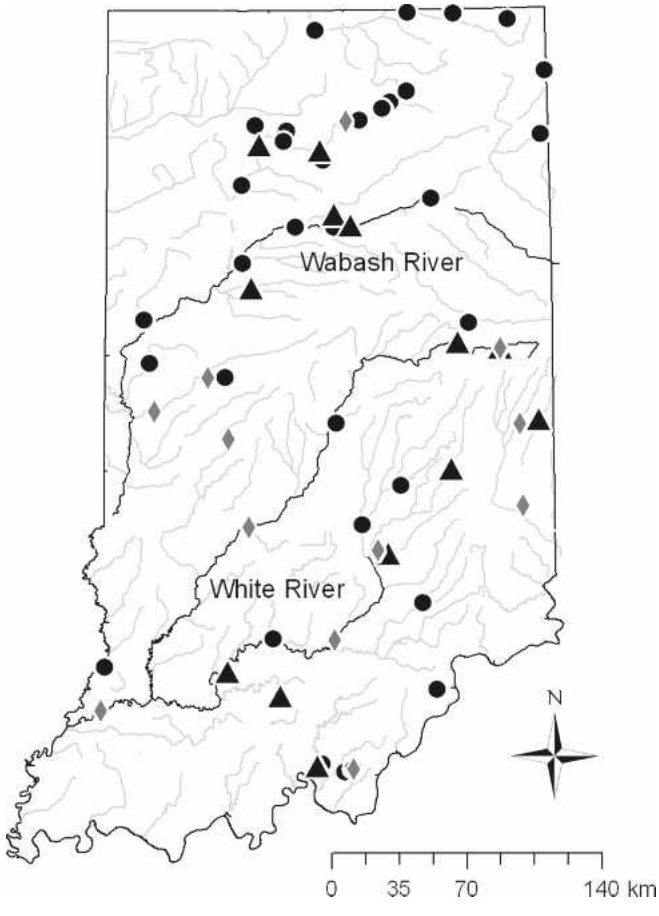


**Figure 5.** Distributions of historic (diamonds) and current *Elimia livescens* (circles). Sites where historic and current collections occurred are triangles.

Lakes to Lake Champlain and Quebec, east of the Scioto River in Ohio and west to the Illinois River (Burch and Tottenham 1980). The historic distribution was in the Wabash River watershed, the Maumee River watershed, the St. Joseph River watershed (Goodrich and van der Schalie 1944). The species was abundant in New York (Jokinen 1992). This is a common and abundant species in large rivers of Indiana with a secure status.

*Pleurocera acuta* (Rafinesque, 1831). We found 12 historical sites and 21 current sites for this species (Fig. 6) of which four were lakes. Habitat at the sites was varied with silt, sand, gravel, cobble, or boulder substrates and occasionally included macrophytes and/or woody debris. This species occurs in the Ohio River headwater streams and tributaries, the Great Lakes and tributaries, the Mississippi River watershed to Nebraska and Kansas, and the Cumberland and Duck rivers in Tennessee (Burch and Tottenham 1980). Goodrich and van der Schalie (1944) reported the historical distribution in Indiana as the upper Wabash River, tributaries, and lakes connected to the river, and the Maumee River and watershed. Stewart (2006) identified numerous collections in Iowa. Jokinen (1992) found the species at many New York locations. This species is common and abundant in Indiana with a secure status.

*Pleurocera canaliculata* (Say, 1821). We found 14 historical sites and two current sites on the Ohio River and White River (Fig. 7). Habitat at the Ohio River site was silt, sand, and riprap substrates with woody debris. The White River site had silt and riprap substrates. This species occurs in the Ohio River from Pittsburgh to Illinois, the Wabash River and its tributaries, aberrantly in the Tennessee River system, and to Omaha, Nebraska (Burch and Tottenham 1980). This species was found to be abundant in the Ohio River upstream from Louisville, Kentucky (Greenwood and Thorp 2001). Goodrich and van der Schalie (1944) listed the Indiana distribution as in the Wabash River above Lafayette downstream to the Ohio River, present in the White River

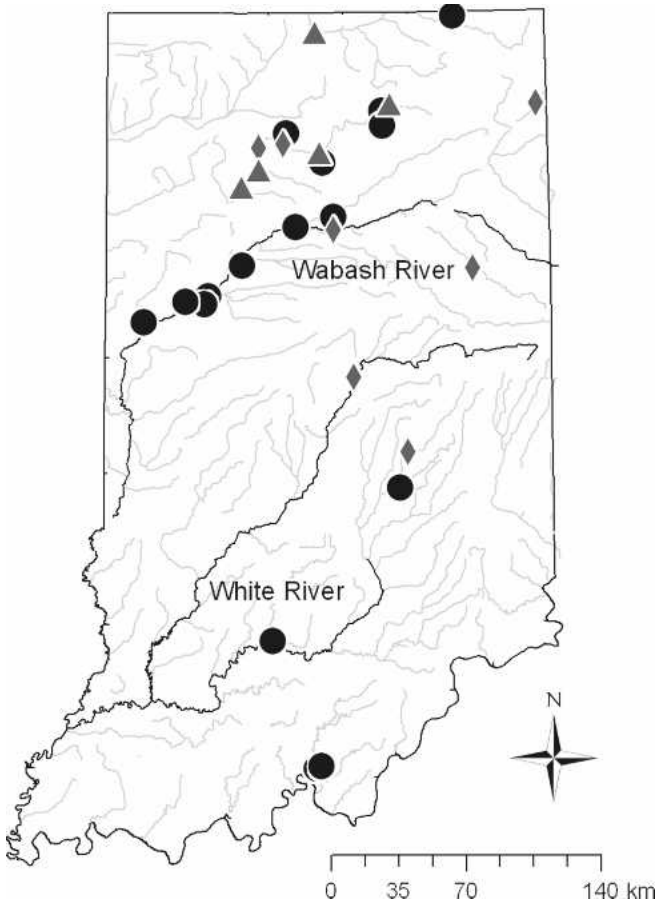


**Figure 6.** Distributions of historic (diamonds) and current *Pleurocera acuta* (circles). Sites where historic and current collections occurred are triangles.

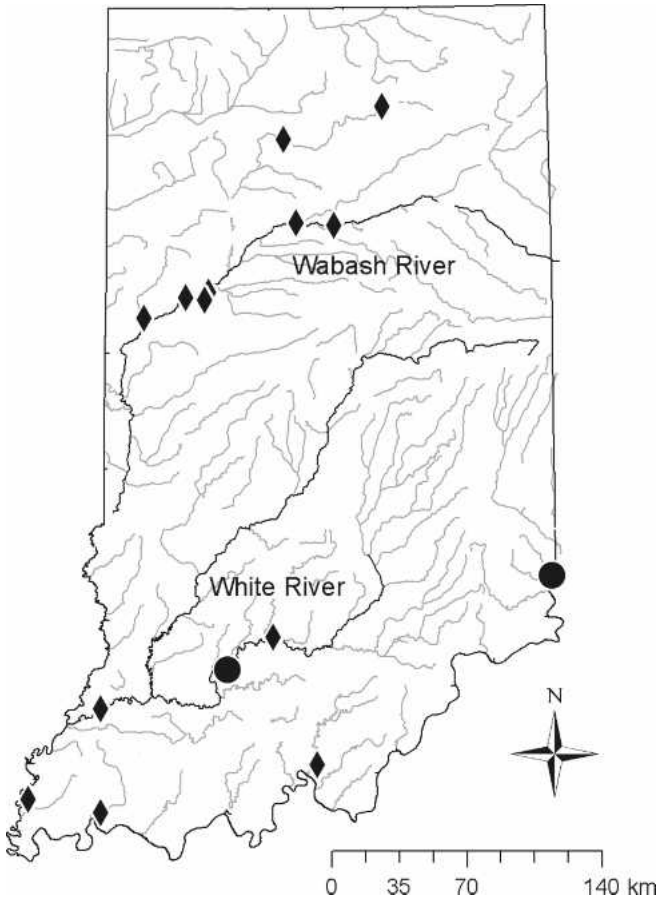


**Figure 7.** Distributions of historic (diamonds) and current *Pleurocera canaliculata* (circles).

and in the Ohio River. This is a rare species in Indiana but it is secure in other parts of the range.

*Leptoxis praerosa* (Say, 1821). No historical collections were found. We found the species at one site on the Blue River, Harrison County. The habitat was silt and riprap substrates with woody debris also present. Its range is the Ohio River below Cincinnati, Ohio to Elizabethtown, Illinois; the Cumberland River and tributaries; the Duck River, Tennessee; and the Tennessee River and tributaries (Burch and Tottenham 1980). Goodrich and van der Schalie (1944) reported the historical Indiana distribution as the Ohio River from Scioto County, Ohio to Pope County, Illinois, the Wabash River at Grand Chains, Posey County, and the Big Blue River, Crawford County. We categorized its status as critically imperiled in Indiana but it is secure in other parts of the range.

*Lithasia obovata* (Say, 1829). We found one historical collection from the Blue River in Harrison County, and one current site on the Eel River in Logansport. The habitat was silt, sand, and cobble substrates with emergent vegetation. This species was abundant in the Ohio River upstream from Louisville, Kentucky (Greenwood and Thorp 2001). This species occurs in the Ohio River and tributaries, in Pennsylvania, Ohio, Indiana, Illinois, Kentucky, and Tennessee (Burch and Tottenham 1980). Goodrich and van der Schalie (1944) reported this species present in the Wabash River downstream from Vincennes, in the Ohio River, the Big Blue River (Crawford County), and the Kentucky River in Kentucky. We categorized its status as critically imperiled in Indiana but it is apparently secure in other parts of the range.

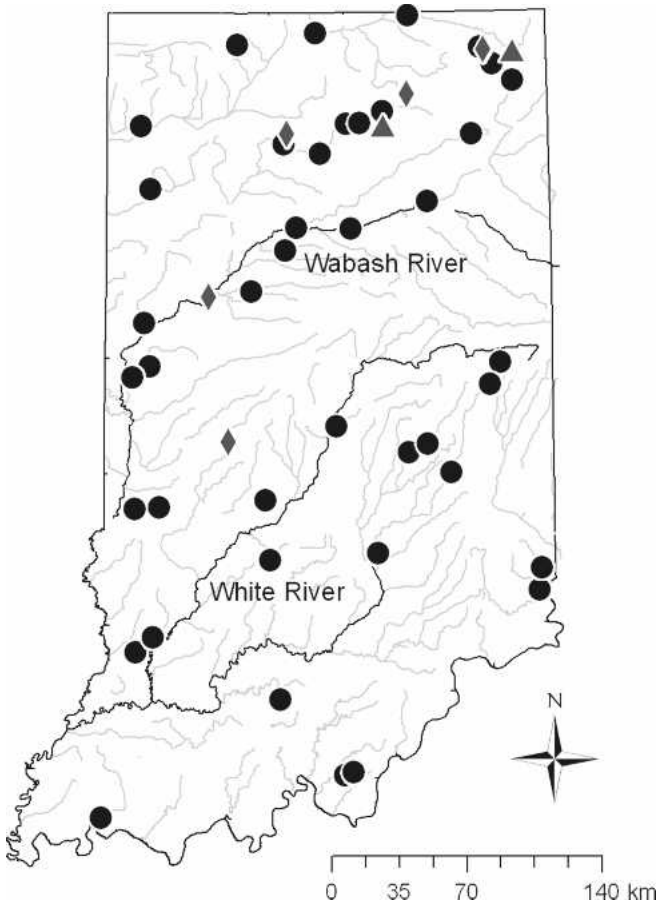


**Figure 8.** Distributions of historic (diamonds) and current *Fossaria* spp. (circles). Sites where historic and current collections occurred are triangles.

**Family Lymnaeidae**

*Fossaria* spp. (Say, 1822). Stewart (2006) attributes many currently confused taxa to this group. We found seven historical collections that were in lakes and the Wabash River, and at 43 of our current sites (Fig. 8) of which five were lakes. Substrates at the sites varied with silt, sand, gravel, cobble, or riprap substrates, and occasional woody debris and vegetation present. Brown (1982) found this taxon in ponds at the Crooked Lake Field Station at Fort Wayne. Goodrich and van der Schalie (1944) reported this taxon present in ponds, lakes, and brooks in Kosciusko, Starke, Steuben, and La Porte Counties. Shelford (1913) found this taxon in ponds at the Indiana Dunes National Lakeshore. Jokinen (2005) found the taxon at the same ponds in 1992-1993. Burch and Tottenham (1980) described the range of taxa in this group to include eastern North America west to Vancouver Island. These taxa appear to be common and abundant in Indiana and thus secure.

*Lymnaea stagnalis* (Linnaeus, 1758). No historical collections were found. We found the species at Bass Lake, Starke County. The habitat of the site was silt and sand substrates and emergent vegetation present. This species range is the Great Lakes–St. Lawrence River drainage area northwest to the Mackenzie and Yukon River drainage areas, west to the Rocky Mountains, south to Colorado, and in Illinois and Ohio in the Mississippi drainage (Burch and Tottenham 1980). The historical Indiana distribution was small lakes and streams of the northern part of the state, and in Lake Michigan (Goodrich and van der Schalie 1944). We categorized its status as critically imperiled in Indiana but it is secure in other parts of the range.

*Stagnicola catascopium* (Say, 1867). No historical collections were found. We found the species at one site, Fish Creek, Steuben County. The habitat of the site was silt and sand substrates and woody debris was present. Goodrich and van der Schalie (1944) reported the species was present in the Great Lakes and in other bodies of shallow water near Lake Michigan. The range is eastern Canada and Nova Scotia

west to North Dakota, Great Slave Lake south to northern Iowa, northern Ohio, and Maryland (Burch and Tottenham 1980). We categorized its status as critically imperiled in Indiana but it is secure in other parts of the range.

*Stagnicola caperata* (Say, 1829). One historical collection was found from the Maumee River. We did not find this species. Goodrich and van der Schalie (1944) suggested the species occurred in every county of Indiana. The range is Quebec and Massachusetts west to California, Yukon Bay, and James Bay south to Maryland, Indiana, Colorado, and California (Burch and Tottenham 1980). We categorized its status as critically imperiled in Indiana but it is secure in other parts of the range.

*Stagnicola elodes* (Say, 1821). No historical collections were found. We found this species at 17 sites (Fig. 9) of which four were lakes. The habitats varied with substrates of silt, sand, gravel, cobble, or hardpan and woody debris and/or vegetation occasionally present. Goodrich and van der Schalie (1944) reported this species was expected in ditches, ponds, and shallow parts of lakes with heavy vegetation. Brown (1982) found this species was abundant in ponds at the Crooked Lake Field Station at Fort Wayne. Shelford (1913) found this species in ponds at the Indiana Dunes National Lakeshore. Jokinen (2005) found the species at the same ponds in 1992-1993. It is common and abundant in Indiana and is secure.

*Stagnicola exilis* (I. Lea, 1838). No historical collections were found. We found this species at Brown Ditch, Newton County. The habitat was silt substrate with submerged macrophytes. Goodrich and van der Schalie (1944) found this species to occur in temporary aquatic habitats. We categorized its status as critically imperiled in Indiana but it is secure in other parts of the range.

*Pseudosuccinea columella* (Say, 1817). No historical collections were found. We found 16 current stream sites (Fig. 10) of which seven were lakes or ponds. Habitats varied with substrates of silt, sand, gravel, or cobble and woody debris and/or vegetation occasionally present. The range is eastern North America generally west to Minnesota and eastern Kansas, south to central Texas and Florida (Burch and Tottenham 1980). Goodrich and van der Schalie (1944) re-

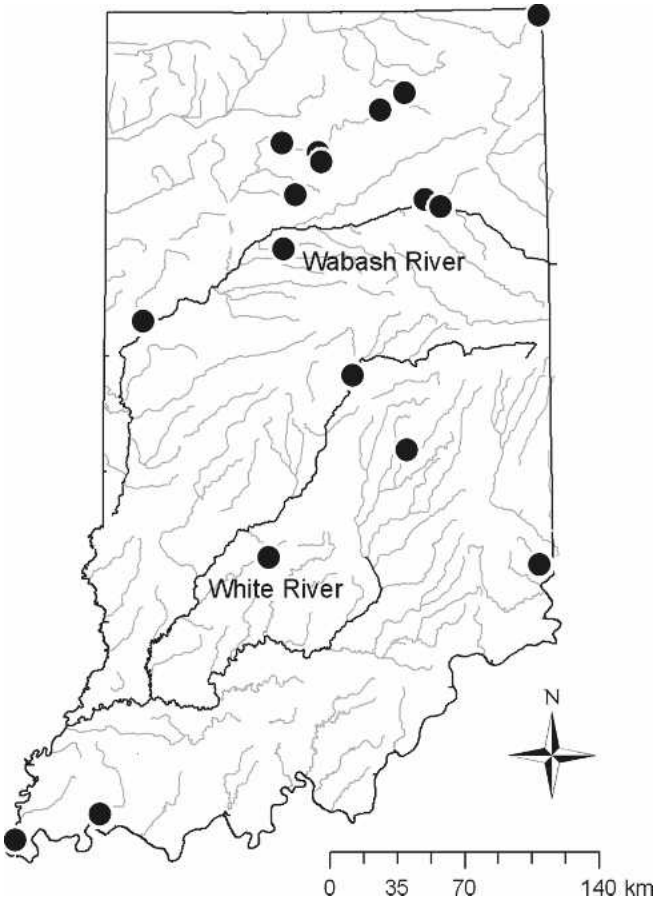


**Figure 9.** Distribution of current *Stagnicola elodes*.

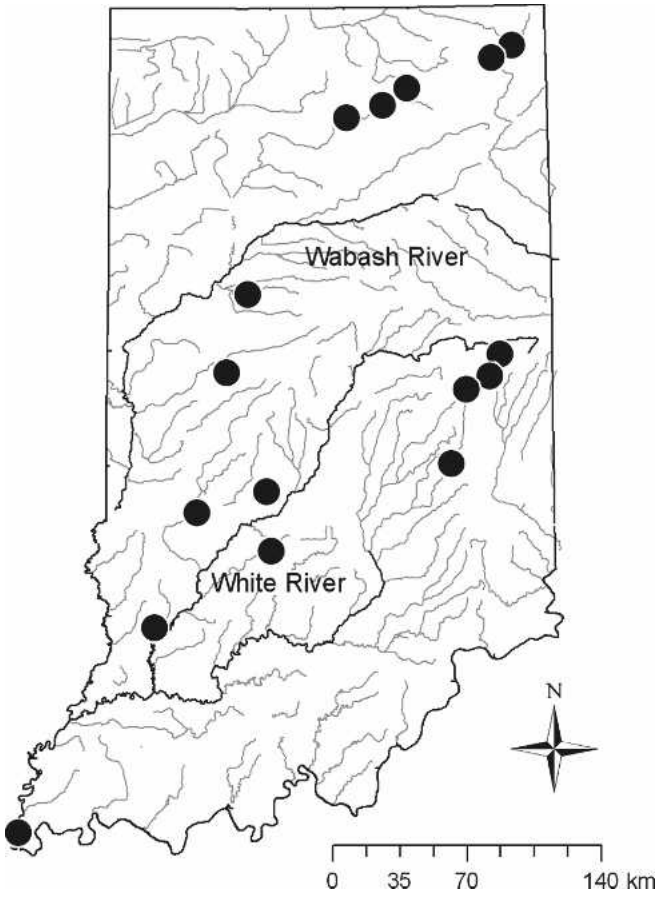


**Figure 10.** Distribution of current *Pseudosuccinea columella*.

ported this species present in northern Indiana counties. The species is common in New York (Jokinen 1992). It appears to be common in Indiana and is secure.

**Family Physidae**

*Physella gyrina* (Say, 1821). We found 22 historical sites and eight current sites (Fig. 11) of which one was a lake. Habitats varied with silt, sand, gravel, or cobble substrates and woody debris and/or vegetation present. Brown (1982) found this species was abundant in ponds at the Crooked Lake Field Station at Fort Wayne. Shelford (1913) found this species in ponds at the Indiana Dunes National Lakeshore. Jokinen (2005) found the species at the same ponds in 1992-1993. The species appears to be common and abundant and is secure.

*Physella acuta* (Draparnaud, 1805). We found 17 historical sites and 94 current sites (Fig. 12). Habitats varied with substrates of silt, sand, gravel, riprap, or cobble and woody debris and/or vegetation occasionally present. This species occurs throughout North America (Burch and Tottenham 1980) and is abundant in Indiana. We consider it to be secure in Indiana.

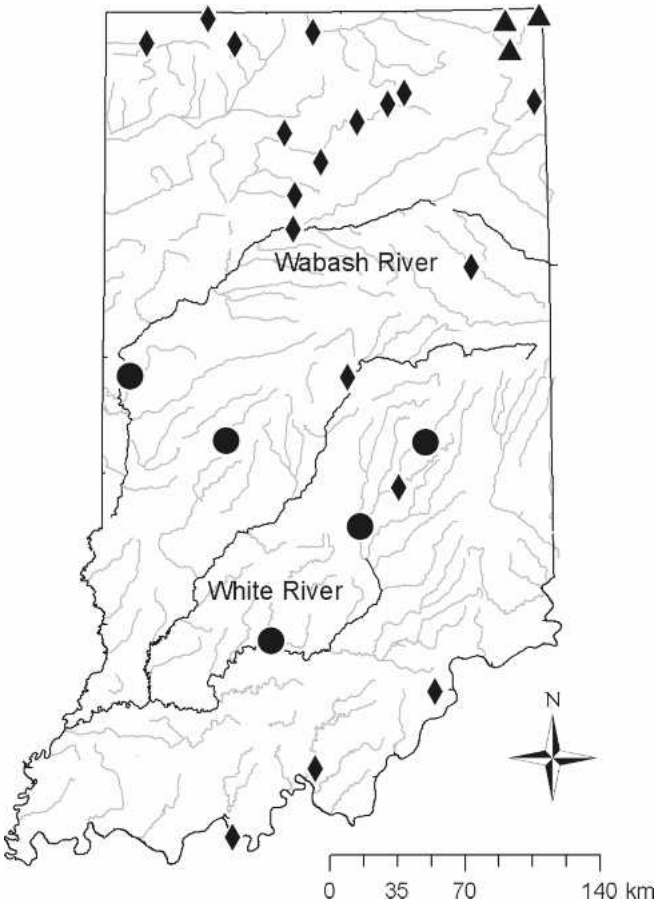


**Figure 11.** Distributions of historic (diamonds) and current *Physella gyrina* (circles). Sites where historic and current collections occurred are triangles.

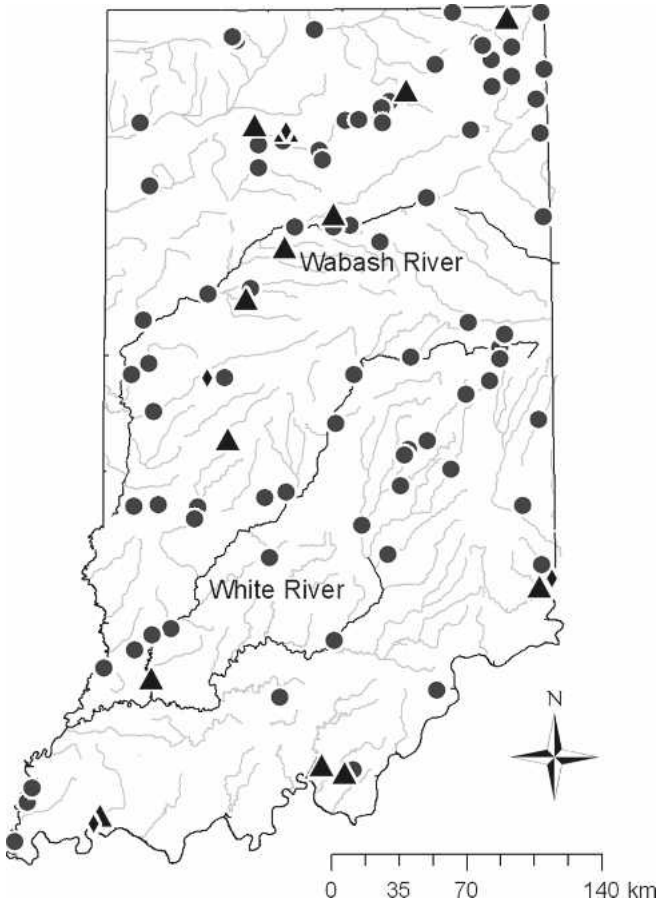


**Figure 12.** Distributions of historic (diamonds) and current *Physella acuta* (circles). Sites where historic and current collections occurred are triangles.

*Aplexa elongata* (Say, 1821). Two historical collections were found: Tippecanoe Lake (Elkhart County) and the Elkhart River (Noble County). We did not find this species. Brown (1982) found this species was abundant in ponds at the Crooked Lake Field Station at Fort Wayne. Jokinen (2005) found the species in temporary aquatic habitats in the Indiana Dunes National Seashore in 1992-1993. Its range is Ontario to Saskatchewan, Canada, and Alaska (Burch and Tottenham 1980). We categorized its status as imperiled in Indiana but it is secure in other parts of the range.

**Family Planorbidae**

*Gyraulus circumstriatus* (Tryon, 1866). We found one historical collection from Rock Creek, Carroll County, and

none in our collections. Goodrich and van der Schalie (1944) reported the species present in Lake James, Lake Maximkuckee, and Webster Lakes in northern Indiana. This species occurs from Connecticut north to Quebec, west to Alberta, and south in the Rocky Mountains to New Mexico (Burch and Tottenham 1980). Jokinen (1992) found the species in New York collections but commented that it appears to be intolerant to low pH and low calcium, as are most snails. The species appears to be extinct in Indiana but secure in other parts of the range.

*Gyraulus deflectus* (Say, 1824). No historical collections were found although Shelford (1913) found this species in ponds at the Indiana Dunes National Lakeshore. Jokinen (2005) did not find them during 1992-1993 surveys of the same ponds. We found the species at 10 sites (Fig. 13). Habitats varied with substrates of silt, sand, gravel, or cobble and woody debris and/or vegetation occasionally present. We consider the species to be vulnerable in Indiana but it is secure in other parts of the range.

*Gyraulus parvus* (Say, 1817). We found nine historical sites and nine current sites (Fig. 14). Habitats varied with substrates of silt, sand, gravel, cobble, or boulder and woody debris and/or vegetation occasionally present. Shelford (1913) found this species in ponds at the Indiana Dunes National Lakeshore. Jokinen (2005) found the species at the same ponds in 1992-1993. Brown (1982) found this species was abundant in ponds at the Crooked Lake Field Station at Fort Wayne. Its range is all of North America (Burch and Tottenham 1980). Jokinen (1992) found the species at many sites in New York. Goodrich and van der Schalie (1944) comment that the species was "doubtless present in every county." The species appears to be common and abundant and is secure.

*Helisoma anceps* (Menke, 1830). No historical collections were found. Shelford (1913) found this species in ponds at the Indiana Dunes National Lakeshore. Jokinen (2005) did not found the species at the same ponds in 1992-1993. We found six current sites in lakes and streams (Fig.

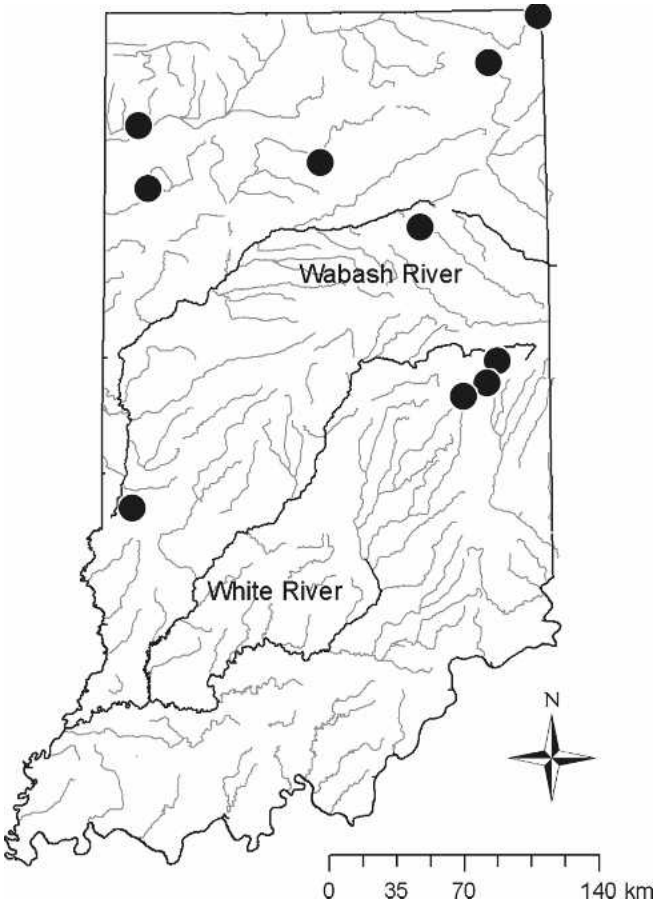


**Figure 13.** Distribution of current *Gyraulus deflectus.*

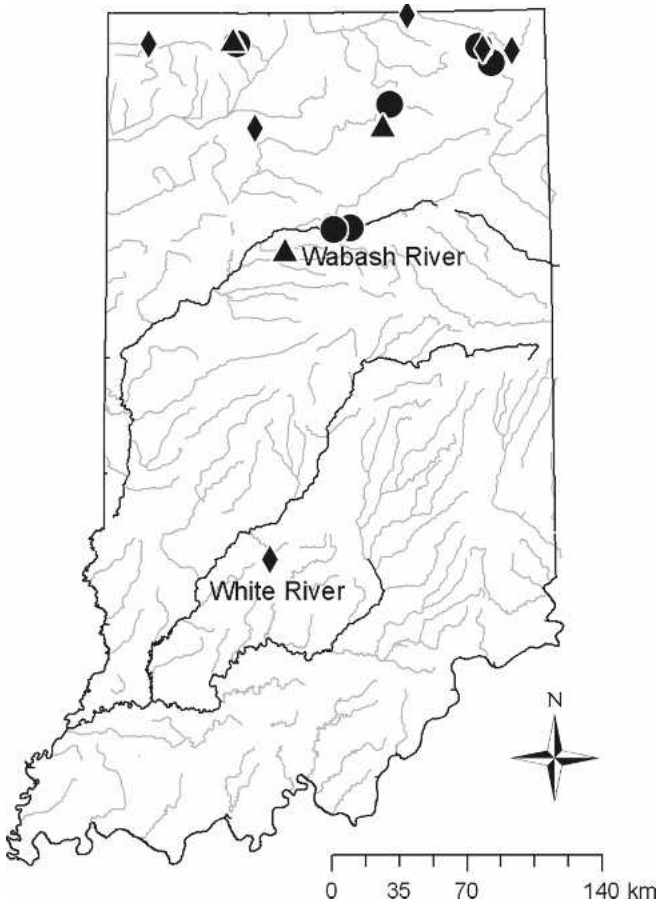


**Figure 14.** Distributions of historic (diamonds) and current *Gyraulus parvus* (circles). Sites where historic and current collections occurred are triangles.

15). Habitats varied with substrates of silt, sand, gravel, or cobble and vegetation occasionally present. The range is throughout North America from James and Hudson Bays south to Georgia, Alabama, Texas, and northwestern Mexico, west to southwestern Northwest Territories (Burch and Tottenham 1980). The species is widespread across New York (Jokinen 1992). Goodrich and van der Schalie (1944) reported the species was probably in every part of Indiana. We consider the species to be imperiled in Indiana but it is secure in parts of the range.

*Planorbella campanulata* (Say, 1821). No historical collections were found. We found one current site in Lake Wawasee. The habitat was sand and riprap substrate and submergent macrophytes. Shelford (1913) found this species in ponds at the Indiana Dunes National Lakeshore. Jokinen (2005) did not find the species at the same ponds in 1992-1993. The range is Vermont west to North Dakota, south to Ohio and Illinois, northward to Great Slave Lake (Burch and Tottenham 1980). The species was common in New York (Jokinen 1992). Goodrich and van der Schalie (1944) report that the species is most likely limited to the lakes area of Indiana, and the species is intolerant of domestic sewage. We consider the species to be imperiled in Indiana but it is secure in parts of the range.

*Planorbella trivolvis* (Say, 1817). Two historical collections were found in Half Moon Pond and Bass Lake. We found it at 16 sites (Fig. 16) of which five were lakes. Habitats varied with substrates of silt, sand, gravel, cobble, or boulder and woody debris and/or vegetation occasionally present. The species was not found at either historical site. Shelford (1913) found this species in ponds at the Indiana Dunes National Lakeshore. Jokinen (2005) found the species at the same ponds in 1992-1993. Brown (1982) found this species was abundant in ponds at the Crooked Lake Field Station at Fort Wayne. The range is Atlantic coast and Mississippi River drainages, northward to Arctic Canada and Alaska, and southward to Tennessee and Missouri (Burch and Tottenham 1980). The species is widespread and abundant in New York (Jokinen 1992). The species was histori-

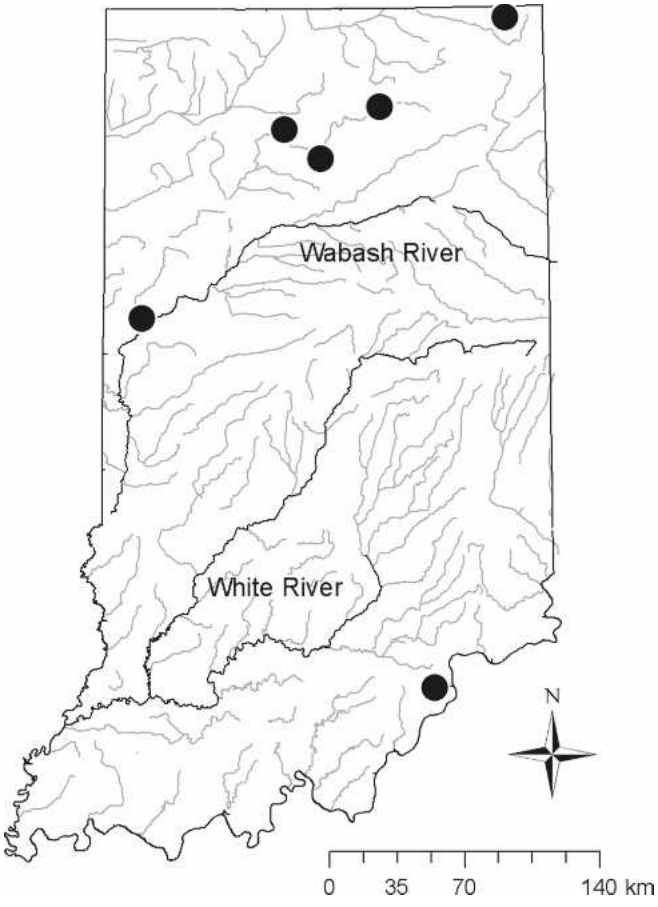


**Figure 15.** Distribution of current *Helisoma anceps.*

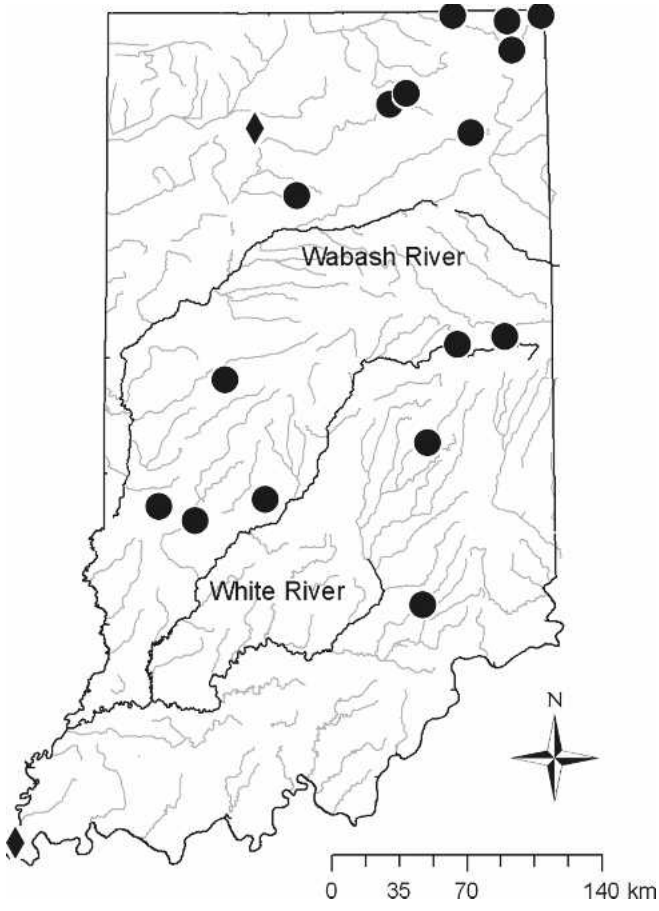


**Figure 16.** Distributions of historic (diamonds) and current *Planorbella trivolvis* (circles).

cally common in lakes and likely present throughout Indiana (Goodrich and van der Schalie 1944). We categorized the status of this species as locally and globally secure.

*Planorbula armigera* (Say, 1821). No historical collections were found and we did not find them in our collections. However, Shelford (1913) found this species in ponds at the Indiana Dunes National Lakeshore. Jokinen (2005) found the species at the same ponds in 1992-1993. Historical locations in Indiana were lakes in Lake, La Porte, Steuben, Marshall, and Kosciusko Counties (Goodrich and van der Schalie 1944). We categorized its status as critically imperiled in Indiana but it is secure in other parts of the range.

*Promenetus exacuous* (Say, 1821). No historical collections were found. We found the species at two lakes in Steuben County, Clear Lake and Pleasant Lake. Habitats were silt substrates with submerged vegetation at Clear Lake, and silt and sand substrates with emergent vegetation at Pleasant Lake. Shelford (1913) found this species in two ponds at the Indiana Dunes National Lakeshore. Jokinen (2005) found the species at one of the ponds in 1992-1993. The species was assumed to occur throughout Indiana by Goodrich and van der Schalie (1944). We categorized its status as critically imperiled in Indiana but it is secure in other parts of the range.

**Family Ancylidae**

*Ferrissia fragilis* (Tryon, 1863). No historical collections were found. We found three current stream sites: Clear Creek (Huntington County), Coal Creek (Fountan County), and the Tippecanoe River (Kosciusko County). Habitats varied with substrates of silt, sand, gravel, cobble, or boulder and woody debris occasionally present. The range is New York to Michigan, California, and Texas (Burch and Tottenham 1980). Stewart (2006) found that the species has not been observed in Iowa since 1912. However, he mentioned that the species is tiny and easily overlooked. In New York, the species is fairly common (Jokinen 1992). The historical locations that were published in Indiana were Clear Lake and a pond in La Porte County (Goodrich and van der Schalie 1944). We categorized its status as imperiled in Indiana but it is secure in other parts of the range.

*Ferrissia parallelus* (Haldeman, 1841). No historical collections were found and we did not collect this species. Shelford (1913) found this species in ponds at the Indiana Dunes National Lakeshore. Jokinen (2005) also found the species in ponds at the Indiana Dunes National Lakeshore in 1992-1993. The only other historical location in Indiana was Lake Maxinkuckee (Goodrich and van der Schalie 1944). The species appears to be extinct in Iowa (Stewart 2006) and rare in Indiana. We categorized its status as critically imperiled in Indiana but it is secure in other parts of the range.

*Ferrissia rivularis* (Say, 1817). No historical collections were found. We found 18 current sites (Fig. 17) of which four were lakes. Habitats varied with substrates of silt, sand, gravel, cobble, or boulder and woody debris and/or vegetation occasionally present. The range is most of North America: northward into the Hudson Bay lowlands and northwestward to Saskatchewan, south to North Carolina and New Mexico, west to California and Oregon (Burch and Tottenham 1980). The species is fairly common in New York (Jokinen 1992). The historical distribution in Indiana was Lake Knox and Henry Counties (Goodrich and van der Schalie 1944). The species appears to be widely distributed in Indiana, except that it is easily overlooked. It is common, widespread, and secure.

*Laevapex fuscus* (C. B. Adams, 1841). No historical collections were found. We found one current site, the Eel River at Logansport. The habitat was silt and riprap substrates and woody debris was present. Jokinen (2005) found the species in one pond at the Indiana Dunes National Lakeshore in 1992-1993. Historical locations in Indiana were lakes in Marshall and La Porte Counties, and Grassy Creek, Kosci-

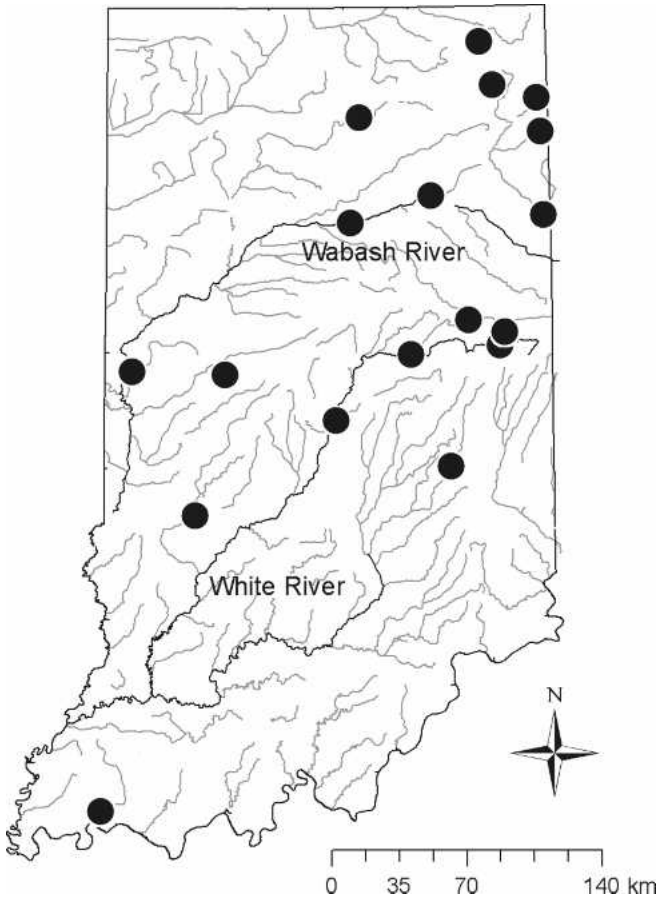


**Figure 17.** Distribution of current *Ferrissia rivularis.*

**Table 1.** Summary of aquatic gastropods of Indiana by current taxa (from Stewart 2006), synonyms from Goodrich and van der Schalie (1944), historic sites based on museum material, current sites where we collected the species, and observation status using The Nature Conservance global ranking system (www.natureserve.org). GS refers to species that are presumed extinct, GH are possibly extinct, G1 are critically imperiled, G2 are imperiled, G3 are vulnerable, G4 are apparently secure, and G5 are secure.

| Current taxa | Synonyms | Historic sites | Current sites | Conservation status |
|---|---|---|---|---|
| Valvatidae | | | | |
| *Valvata bicarinata* (Lea, 1841) | | 0 | 0 | G5 |
| *Valvata lewisi* (Currier 1868) | *Valvata lewisii* | 0 | 1 | G5 |
| *Valvata tricarinata* (Say, 1817) | | 0 | 0[a] | G5 |
| *Valvata sincera* (Say, 1824) | | 0 | 0 | G5 |
| Viviparidae | | | | |
| *Viviparus georgianus* (Lea, 1834) | *Valvata contectoides* | 0 | 2 | G5 |
| *Viviparus subpurpureus* (Say, 1829) | | 4 | 0 | G5 |
| *Bellamya chinensis* (Reeve, 1863) | | 0 | 4 | Exotic |
| *Bellamya japonica* (von Martens, 1861) | | 0 | 4 | Exotic |
| *Campeloma decisum* (Say, 1817) | *Campeloma* spp. | 20 | 11 | G5 |
| Hydrobiidae | | | | |
| *Birgella subglobosus* (Say, 1825) | *Somatogyrus subglobosus* | 0 | 6 | G4 |
| *Cincinnatia integra* (Say, 1821) | | 1 | 1 | G5 |
| *Pyrogulopsis lustrica* (Pilsbry, 1890) | *Amnicola lustrica* | 3 | 2 | G5 |
| *Amnicola limosus* (Say, 1817) | *Amnicola limosa, Amnicola parva* | 0 | 6[a] | G5 |
| Pomatiopsidae | | | | |
| *Pomatiopsis cincinnatiensis* (I. Lea, 1850) | | 0 | 6 | G4 |
| Pleuroceridae | | | | |
| *Elimia livescens* (Menke, 1830) | *Goniobasis livescens* | 24 | 48 | G5 |
| *Pleurocera acuta* (Rafinesque, 1831) | | 12 | 21 | G5 |
| *Pleurocera canaliculata* (Say, 1821) | | 14 | 2 | G5 |
| *Leptoxis praerosa* (Say, 1821) | *Anculosa praerosa* | 0 | 1 | G5 |
| *Lithasia obovata* (Say, 1820) | | 1 | 1[b] | G4 |
| Lymnaeidae | | | | |
| *Fossaria* spp. (Say, 1822) | *Lymnaea humilis, Lymnaea dalli, Lymnaea parva* | 7 | 43[a] | G5 |
| *Lymnaea stagnalis* (Linnaeus, 1758) | | 0 | 1 | G5 |
| *Stagnicola catascopium* (Say, 1867) | *Lymnaea catascopium* | 0 | 1 | G5 |
| *Stagnicola caperata* (Say, 1829) | *Lymnaea caperata* | 1 | 0 | G5 |
| *Stagnicola elodes* (Say, 1821) | *Lymnaea palustris, Lymnaea reflexa* | 0 | 17[a] | G5 |
| *Stagnicola exilis* (I. Lea, 1838) | *Lymnaea exilis* | 0 | 1 | G5 |
| *Pseudosuccinea columella* (Say, 1821) | *Lymnaea columella* | 0 | 16 | G5 |
| Physidae | | | | |
| *Physella gyrina* (Say, 1821) | *Physella heterostropha, Physella sayii, Physella ancillaria* | 22 | 8[a] | G5 |
| *Physella acuta* (Draparnaud, 1805) | *Physella heterostropha, Physella integra, Physella walkeri* | 17 | 94 | G5 |
| *Aplexa elongata* (Say, 1821) | *Aplexa hypnorum* | 2 | 0[a] | G5 |
| Planorbidae | | | | |
| *Gyraulus circumstriatus* (Tryon, 1866) | | 1 | 0 | G5 |
| *Gyraulus deflectus* (Say, 1824) | *Gyraulus hirsutus* | 0 | 10 | G5 |
| *Gyraulus parvus* (Say, 1817) | | 9 | 9[a] | G5 |
| *Helisoma anceps* (Menke, 1830) | *Helisoma antrosum* | 0 | 6 | G5 |
| *Planorbella campanulata* (Say, 1821) | *Helisoma campanulatum* | 0 | 1 | G5 |
| *Planorbella trivolvis* (Say, 1817) | *Helisoma trivolvis* | 2 | 16[a] | G5 |
| *Planorbula armigera* (Say, 1821) | | 0 | 0[a] | G5 |
| *Promenetus exacuous* (Say, 1821) | *Menetus exacuous* | 0 | 2[a] | G5 |
| Ancylidae | | | | |
| *Ferrissia fragilis* (Tryon, 1863) | *Gundlachia meekiana* | 0 | 3 | G5 |
| *Ferrissia parallelus* (Haldeman, 1841) | *Ferrissia parallela* | 0 | 0[a] | G5 |
| *Ferrissia rivularis* (Say, 1817) | *Ferrissia tarda* | 0 | 18 | G5 |
| *Laevapex fuscus* (C. B. Adams, 1841) | *Ferrissia fusca* | 0 | 1[a] | G5 |

[a] Refers to taxa that were collected in Indiana by Jokinen (2005). [b]Refers to taxa that were collected on the Ohio River main stem by Greenwood and Thorp (2001).

usko County (Goodrich and van der Schalie 1944). We categorized its status as critically imperiled in Indiana but it is secure in other parts of the range.

## DISCUSSION

Our historical surveys of museum records and literature search indicated 39 species present historically in Indiana. Our 2006-2008 survey and literature search resulted in 36 species of aquatic gastropods, including two exotics. Three species are apparently locally extinct in the state (*Valvata bicarinata, Valvata sincera,* and *Gyraulus circumstriatus*) but globally secure. Our species richness estimates are similar to species estimates for other states (Stewart 2006). For example, states with published aquatic gastropod species richness values are: Connecticut (35 species; Jokinen 1983), Maine (45 species; Martin 1999), New York (61 species; Jokinen 1992), Virginia (53 species; Stewart and Dillon 2004), Kentucky (29 species; Branson *et al.* 1987), and Iowa (49 species; Stewart 2006). The conservation status of Indiana's gastropods is: three taxa that are apparently secure globally and 36 taxa that are widespread, abundant, and globally secure, including two exotics (Table 1). However, three taxa are locally extinct and many others appear locally imperiled or vulnerable.

Of three Indiana species presumed to be locally extinct, only *Valvata bicarinata* was collected in Indiana by Goodrich and van der Schalie (1944) and it appears to be declining elsewhere (Stewart 2006). Whether *Valvata sincera* was ever collected in Indiana is an open question. *Gyraulus circumstriatus* is likely locally extinct due to water quality degradation, as it is intolerant to low pH and calcium (Jokinen 1992).

Only 31 of the sites where the museum material was collected had the same species present in our collections at those sites. Our interpretation is that these species are likely no longer present at the majority of historic sites. Our collection technique may have missed individuals, but the probability of missing species that were historically abundant seems unlikely. Explanations for local species extinctions include extensive habitat degradation throughout the state from agricultural impacts, hydrologic alteration by reservoirs, and pollution. The majority of Indiana watersheds have hydrologic alterations due to reservoir release and/or channelization for agriculture drainage (Pyron and Neumann 2008). Watersheds that are upstream from reservoirs are also negatively impacted by the reservoir (Pringle 1997).

Conservation of aquatic gastropods should be considered as important as conservation of other aquatic organisms, if only for preservation of phylogenetic diversity. In Alabama, 65% of gill-breathing endemic freshwater snails are extinct, endangered, threatened, or of special concern (Lydeard and Mayden 1995). Although the southeastern U.S. has the highest diversity of freshwater organisms on the continent, all freshwater fauna of North America are facing similar losses of biodiversity (Ricciardi and Rasmussen 1999). Ricciardi and Rasmussen (1999) projected future extinction rates for freshwater organisms in North America at 4% per decade. This is a similar depletion rate as for tropical forests. Additional protection besides the current approach to conservation of aquatic invertebrates is obviously necessary.

A first step toward conservation of aquatic gastropods is an accurate inventory (Lydeard and Mayden 1995). Efforts toward inventory of aquatic invertebrates in the U.S. have lagged behind inventories of vertebrates although some statewide surveys of aquatic gastropods are appearing (Jokinen 1992, Stewart 2006). Accurate inventory of aquatic gastropods will also encourage studies of the taxonomic, ecological, and general biology of the group (Neves *et al.* 1997). For example, studies of macro-ecological patterns of freshwater gastropods are rare compared with macro-ecological studies of vertebrates. These endeavors have lagged behind other taxa largely because of a lack of descriptive and distributional natural history studies.

Indiana currently lists the conservation status for vertebrate and invertebrate taxa (www.in.gov/dnr/). However, there is currently no specific conservation recognition or protection plan for aquatic gastropods in the state. We recommend such a thorough inventory, recognition, and protection plan for the aquatic gastropods in Indiana. A better understanding of freshwater gastropod ecology demands conservation and further study to protect this valuable natural resource.

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