2001. Proceedings of the Indiana Academy of Science 110:141–150

OCCURRENCE AND DISTRIBUTION OF FRESHWATER MUSSELS IN SMALL STREAMS OF TIPPECANOE COUNTY, INDIANA

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ABSTRACT. A mussel survey was conducted at 52 sites in 12 stream systems within Tippecanoe County, Indiana. The study did not include the Wabash River, the Tippecanoe River, or the Middle Fork of Wildcat Creek. Evidence of 28 mussel species was found during the survey; 17 species were found live. Of all live mussels, 58% were *Lampilis siliquoidea* (fatmucket). Mussel species richness in each stream system was significantly correlated with watershed area and fish species richness. However, the presence of potential host fish species did not entirely explain the mussel distribution.

Keywords: Headwater streams, mussel distribution, host fish

Surveys of freshwater mussels (unionids) in North America have documented declines of mussel species diversity and reduced distributional ranges (Meyer 1968; Dineen 1971; Cummings et al. 1992). Of 297 native freshwater mussel species in the United States and Canada, 71.7% are considered endangered, threatened, or of special concern (Williams et al. 1993). Changes in mussel populations may be a good indicator of stresses on the stream ecosystem caused by agriculture, industry, or urbanization (Dineen 1971).

The unionid's life cycle has the larval stage, the glochidium, parasitic on a fish host. The glochidium undergoes transformation into a juvenile mussel during this parasitic phase. The host-parasite relationship is specific in that only certain species of fish may serve as glochidial hosts for any given mussel species. When transformation is complete, the juvenile mussel detaches from the fish and begins life as an independent organism (McMahon 1991). The movement of fish bearing glochidia is the main mechanism of unionid dispersal. Whether a mussel can then survive in any given location therefore depends on immediate environmental conditions and chance events such as droughts, floods, and exposure to pollutants (Watters 1992).

Small streams are generally under-represented in mussel status reports because they are not included in most stream surveys and mussel populations are usually not assessed as part of most stream faunistic surveys which usually focus on fish and/or aquatic insects. Recent regional mussel surveys which did include small streams include the Sangamon River Basin, Illinois (Schanzle & Cummings 1991), the Big Darby Creek system, Ohio (Watters 1994) and a few selected tributaries of the Tippecanoe River, Indiana (Ecological Specialists, Inc. 1993).

Factors affecting whether or not a small stream will support mussels include presence of host fish species, size of watershed area, and suitability of habitat. Mussels thought to be typical headwater species include *Anodontoides ferussacianus, Alasmidonta viridis* and *Lasmigona compressa* (Cummings & Mayer 1992); but because of the lack of small stream mussel survey data, it is not known to what extent these streams might support additional species.

Tippecanoe County, located in west central Indiana, includes a variety of small streams as well as the confluence of the Tippecanoe with the Wabash River. Land use in Tippecanoe is primarily agricultural but is undergoing rapid urbanization. The Wabash River flows through the county from northeast to southwest; and all streams in the county, including the Tippecanoe River, are tributaries of the Wabash. The Tippecanoe and Wabash River watersheds contain a high diversity of unionid fauna (Goodrich & van der Schalie 1944; Cummings & Berlocher 1990). Recent mussel surveys in the middle Wabash drainage include the Wabash and Tippecanoe Rivers (Cummings et al. 1992), the Tippecanoe River (Ecological Specialists, Inc. 1993) and the Middle Fork of Wildcat Creek (Henschen 1990), and the present study did not include these waterways. Tippecanoe County is an especially good location to address these issues because of recent surveys of fish and large river mussels, and rapid changes in land use.

There are many potential variables controlling the occurrence and distribution of mussels, including water quality issues and physical habitat suitability. However, fundamental to the perpetuation of mussel life is the presence of host fish. The size of the watershed can influence fish populations and, therefore, mussel populations (Watters 1993). Because of this unique host-parasite relationship, the discussion of factors affecting mussel distribution will examine the effects of watershed size and fish diversity, and compare mussel distributions with host fish distributions.

The objective of this study was to determine the occurrence and distribution of mussels in 12 small stream systems. This distribution was correlated to the watershed areas and fish species richness of the stream systems to evaluate the relationship of these factors to mussel species richness. Host fish distributions were compared to the presence or absence of mussels in each stream system to determine the extent to which host fish availability limits mussel distribution. This study will serve as a baseline for future work with small stream mussel populations.

METHODS

Description of study area.—A mussel survey was conducted at 52 sites in 12 watersheds in Tippecanoe County, Indiana (Fig. 1) in June–August 1995. These same sites were surveyed for fish in 1994 (Fisher et al. 1998). The characteristics of streams included in the study varied tremendously. Included were channelized agricultural ditches, unaltered small streams with forested riparian corridors, and a designated scenic waterway (Wildcat Creek) of moderate size. Stream orders at the sites varied from second (Site 7) to fifth (Site 34). The smallest stream was Bridge Creek, with a total watershed area of 16 km^2 and the largest was Wildcat Creek, with a total watershed area of 2085 km^2 (Hoggatt 1975).

Survey methodology.—Stream sites were surveyed once each by walking for a length of stream bed covering at least three riffle-pool sequences. Search efforts varied from a minimum of 2 person-hours at the smallest sites to at least 10 person-hours at the largest sites on Wildcat Creek. All types of habitat were visually searched, including banks, gravel bars, pools and riffles. Visible trails in the substrate were searched by hand digging to locate burrowed mussels. At each site, the number and species of live mussels and mussel shells were recorded. Specimens were classified as live, fresh shell or weathered shell. Fresh shells were categorized as having the hinge ligament unbroken or the periostracum largely intact. Live mussels were identified in the field and returned to the stream, with voucher specimens being collected from dead shells only. Identifications were made using the taxonomic references of Oesch (1984), Watters (1995) and Cummings & Mayer (1992), and by examination of specimens housed in the Indiana State Museum. Voucher specimens are located at Purdue University.

Data analysis.—Information on mussel species distributions was compared with fish species distributions for these sites (Fisher et al. 1998) and host fish species lists (Watters 1995). Regression analyses were done to evaluate the relationships between the number of mussel species versus the log of the watershed size, and between the number of mussel species present by stream system versus number of fish species (Table 1). The regression analyses included Tippecanoe County mussel data from the Wabash and Tippecanoe Rivers (Cummings et al. 1992), but excluded Big Shawnee Creek. Only one site was surveyed on the upstream portion of Big Shawnee Creek; however, the remainder of the stream which continues through Fountain County, Indiana was not surveyed.

RESULTS

Mussel distribution.—Twenty-eight species of mussels (Table 2) were found during the survey; and of these, 219 individuals of 18 species were found alive (Table 3). Three species (*Lampsilis siliquoidea, Anodontoides ferussacianus* and *Pyganodon grandis*) were the most common found alive, comprising 72.2% of the total. Uncommon species were *Strophitus undulatus, Alasmidonta marginata,*

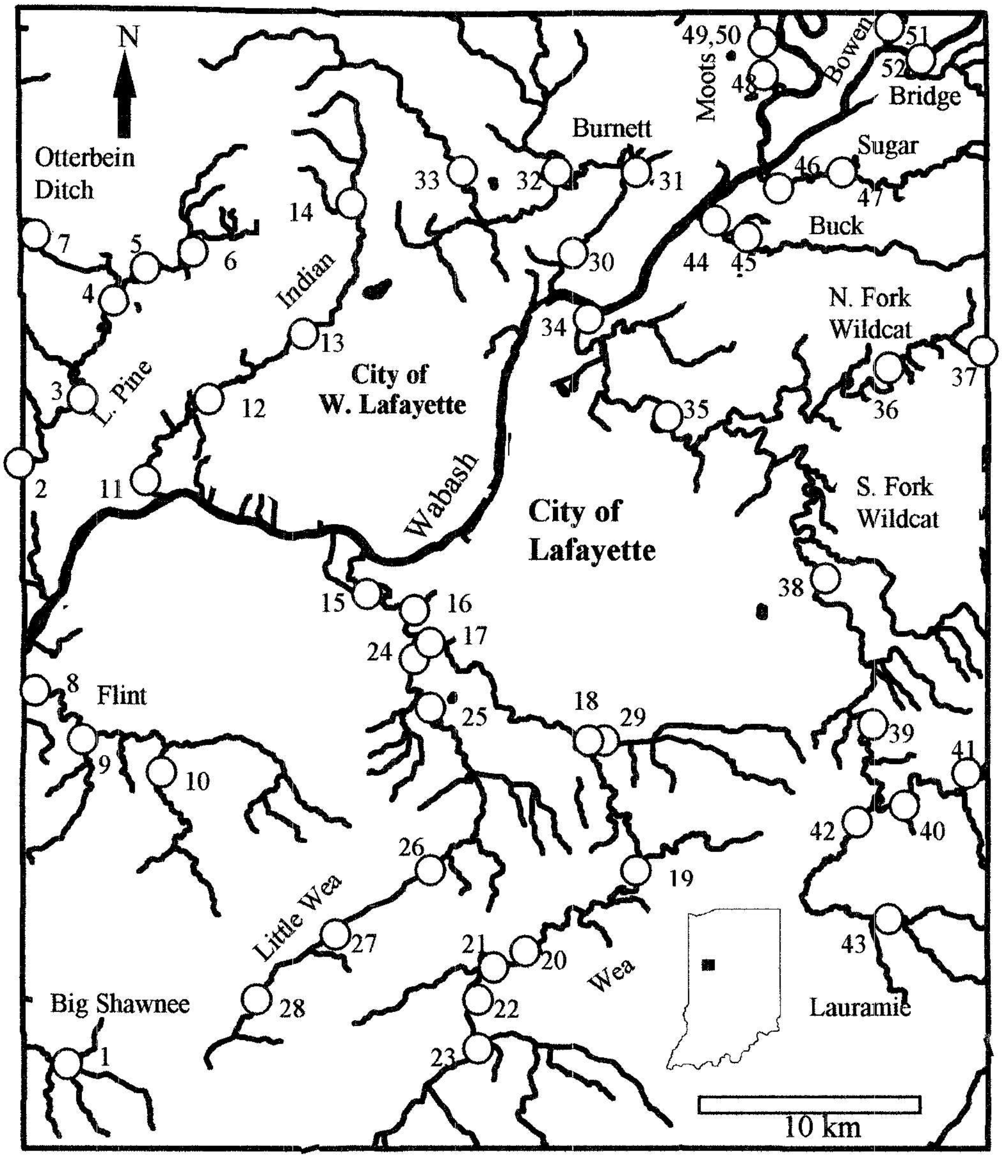

Figure 1.—Mussel sampling sites in Tippecanoe County, Indiana. Sampling sites are indicated with a circle (○) and are labeled with numbers. The cities of Lafayette and West Lafayette are located in the central part of the county, and are separated by the Wabash River.

Lampsilis teres, and *Ligumia recta,* each being represented by one live individual.

All stream systems surveyed, except Bridge Creek, showed evidence of unionid life, whether in the form of live individuals or shells. Only weathered shells were found in Indian Creek, Buck Creek, Flint Run (site 10), Dismal Creek (site 29), and Sugar Creek. Flint Run is a tributary of Flint Creek, and Dismal Creek is a tributary of Wea Creek. Only one weathered shell fragment of *Anodontoides ferussacianus* was found in Indian Creek at site 13, and one weathered valve of *Actinonaias ligamentina* was found in Buck Creek at site 44.

Of all live mussels found during the study, 58% were *Lampsilis siliquoidea.* They were found alive at five Wildcat Creek sites, and shells of this mussel were found at all Wildcat Creek sites. They were also found alive in Lauramie, Wea, and Little Pine Creeks.

Table 1.—Mussel and fish species richness in relation to watershed areas by stream system. Mussel species include live, fresh shells and weathered shells. Watershed areas are reported to the mouth of stream, except for the Wabash River, which shows the drainage area to Lafayette, Indiana. Superscripts represent: [a] Hoggatt 1975; [b] Fisher et al. 1998; [c] Cummings et al. 1992.

Stream system	Watershed area (km^2)[a]	Number of mussel species	Number of fish species[b]
Bridge Creek	16	0	9
Bowen Ditch	22	1	9
Buck Creek	30	1	12
Sugar Creek	74	3	30
Indian Creek	77	1	21
Flint Creek	100	2	23
Moots Creek	133	3	39
Little Pine Creek	135	11	33
Burnett Creek	139	1	23
Big Shawnee Creek	167	1	15
Wea/Little Wea Creek	422	7	49
Wildcat Creek	2085	26	56
Tippecanoe River	5050	31[c]	55
Wabash River	19,397	43[c]	80

Anodontoides ferussacianus and *Alasmidonta viridis* were found in headwater areas during this study. Twenty-one live *Anodontoides ferussacianus* were found, representing 9.6% of the total live mussels, in Little Pine Creek, Wea Creek, and Moots Creek. Four live *Alasmidonta viridis* specimens, representing 1.8% of total live mussels, were found by digging with the hands at the end of visible mussel trails in Wea and Big Shawnee Creeks. Thirteen sites on Big Shawnee Creek, Wea Creek, Little Wea Creek, Little Pine Creek, Sugar Creek, South Fork Wildcat Creek and Flint Run yielded either live mussels or shells of *Alasmidonta viridis.*

Lasmigona compressa were also found in headwater areas. They were found live or as shells at sites in Little Pine Creek, Wea Creek, South Fork Wildcat Creek, Moots Creek, and Sugar Creek. Only two live individuals (sites 4 and 22) were found, representing 0.9% of total live mussels.

Three species found in both smaller streams and in the larger Wildcat Creek system were *Pyganodon grandis, Lampsilis cardium* and *Fusconaia flava.* Live *Pyganodon grandis* represented 9.6% of total live mussels, and were found as shells or live individuals in Little Pine Creek and Wildcat Creek. *Lampsilis cardium* was found in Wildcat Creek and Wea Creek, including a live mussel at Wea Creek site 19, and at Wildcat Creek sites 34, 36, 39 and 40. *Fusconaia flava* was found in Wea, Little Pine and Wildcat Creeks, including live individuals at Wea Creek sites 19 and 20.

Evidence of 26 species of mussels was found in the Wildcat Creek system, and of these, nine species were found alive. Species found only in the Wildcat Creek system, whether as live mussels or shells, were *Alasmidonta marginata, Amblema plicata, Cyclonaias tuberculata, Elliptio dilatata, Lampsilis teres, Lasmigona complanata, Lasmigona costata, Leptodea fragilis, Ligumia recta, Pleurobema clava, Potamilus alatus, Quadrula pustulosa, Quadrula quadrula, Tritogonia verrucosa* and *Truncilla truncata.* Mussel species that were found either as live individuals or shells only in the downstream portion (sites 34 and 35) of Wildcat Creek were *Quadrula quadrula, Leptodea fragilis, Potamilus alatus,* and *Truncilla truncata. Pleurobema clava* and *Cyclonaias tuberculata* were each represented by one weathered valve in North Fork Wildcat Creek.

Little Pine Creek contained 11 species of mussels, including two species not found in any other stream in the study. These were *Uniomerus tetralasmus* and the state species of special concern *Toxolasma lividus. Toxolasma lividus* was found at only one sampling site (Site 3) which had two live specimens and numerous fresh shells. All Little Pine Creek sites in Tippecanoe County supported live mussels except the most upstream site (site 6) and site 7 on the tributary stream Otterbein Ditch in the town of Otterbein, Tippecanoe County, Indiana.

Two species, *Toxolasma parvus* and *Uniomerus tetralasmus,* are new Tippecanoe County records. *Toxolasma parvus* was found in four streams (Bowen Ditch, Little Pine Creek, Wea Creek, and Wildcat Creek) and *Uniomerus tetralasmus* in one stream (Little Pine Creek).

Effects of watershed area and host fish.—The number of species per watershed was significantly correlated to the drainage area ($r^2 = 0.91$, $P < 0.01$) (Fig. 2). Correlation of the

Table 2.—Mussel species found during the study, categorized as live, fresh shells, or weathered shells. The numbers refer to sites listed in Figure 1.

Species	Live	Fresh shells	Weathered shells
Actinonaias ligamentima	37	34–37	35, 37, 44
Alasmidonta marginata	37	36, 38	34, 36
Alasmidonta viridis	1, 20	3, 20, 21, 27	1, 10, 17–19, 21, 22 24, 36, 40, 46
Amblema plicata			35–37
Anodontoides ferussacianus	4, 22, 23, 50	3, 4, 20, 21, 23, 26, 32, 33, 40, 41, 43, 48	10, 13, 15, 18–22, 24, 26, 29–34, 37, 39, 40, 42, 46–50
Cyclonaias tuberculata			37
Elliptio dilatata		37	35
Fusconaia flava	19, 20	2, 3, 20, 36, 38	2, 19, 34–37, 40, 41
Lampsilis cardium	19, 34, 36, 39, 40	22, 34–36, 38, 40	17, 18, 20–22, 24, 34–41, 49
Lampsilis siliquoidea	2–4, 19–22, 34, 36, 37, 40–43	2–4, 20–22, 36, 39–41	2, 18–23, 34–41
Lampsilis teres	37	36	36
Lasmigona complanata	37	38	34–37
Lasmigona compressa	4, 22	3, 41, 49	46
Lasmigona costata		38, 40	36, 37, 40
Leptodea fragilis	34, 35	34, 35	35
Ligumia recta	34	36, 38	34–37, 39–41
Pleurobema clava			36, 37
Potamilus alatus	34	34	
Pyganodon grandis	3–5, 34, 36, 37	3, 4, 34, 36, 38	2, 36, 37
Quadrula pustulosa		36	35, 36
Quadrula quadrula		35	35
Strophitus undulatus	4, 37	36, 38, 40	34–37
Toxolasma lividus	3	3	
Toxolasma parvus	4	3, 20, 36, 51	4, 16, 18, 20
Tritogonia verrucosa		35	35–38
Truncilla truncata		34	
Uniomerus tetralasmus		3, 4	4
Utterbackia imbecillis	4	4	36

number of mussel species to the number of fish species was also highly significant ($r^2 = 0.80$, $P < 0.01$) (Fig. 3).

Comparisons were made by stream system for occurrences of mussels and host fish. For each mussel species found, host fish were documented for that stream system in all but two instances (Bowen Ditch and Buck Creek); however, host fish distributions exceeded mussel distributions.

DISCUSSION

Mussel distribution.—The small streams of Tippecanoe County are home to a diverse and widely-distributed mussel fauna, as demonstrated by 219 live individuals of 18 species found. However, the fact that only weathered shells were found in five streams implies that mussels existed in those streams in the past, but are unable to do so now.

Lampsilis siliquoidea is one of the most common mussels in Indiana (Goodrich & van der Schalie 1944). In a survey of the Eel River in Indiana, *Lampsilis siliquoidea* occurred at all sites where live mussels were found (Henschen 1987). Even this nearly ubiquitous species may have its limits of tolerance to habitat disturbance. *Lampsilis siliquoidea* appears to have declined in the Sangamon River drainage of Illinois, a watershed impacted by channelization, impoundment, and agricultural, industrial and municipal runoff (Schanzle & Cummings 1991). Because of the lack of historical data for the small streams in the present study, it is not known if a similar decline is occurring in Tippecanoe County.

Table 3.—Abundance of live mussels found in Tippecanoe County in this survey. The percentage of the total collection for hte county is also shown.

Species	Number of live mussels	Percentage
Lampsilis siliquoidea	127	58.0%
Anodontoides ferussacianus	21	9.6%
Pyganodon grandis	21	9.6%
Toxolasma parvus	11	5.0%
Utterbackia imbecillis	7	3.2%
Lampsilis cardium	5	2.3%
Fusconaia flava	4	1.8%
Alasmidonta viridis	4	1.8%
Leptodea fragilis	4	1.8%
Lasmigona complanata	3	1.4%
Actinonaias ligamentina	2	0.9%
Lasmigona compressa	2	0.9%
Toxolasma lividus	2	0.9%
Potamilus alatus	2	0.9%
Strophitus undulatus	1	0.46%
Alasmidonta marginata	1	0.46%
Lampsilis teres	1	0.46%
Ligumia recta	1	0.46%

Several species of mussels are considered to be typical of headwater streams: *Anodontoides ferussacianus, Alasmidonta viridis,* and *Lasmigona compressa* (Cummings et al. 1992). *Anodontoides ferussacianus* was common and widespread in the present study. Schanzle & Cummings (1991) found *Anodontoides ferussacianus* in the upstream portions of the Sangamon River and its tributaries in sufficient numbers to constitute 2% of their total sample; and Ecological Specialists, Inc. (1993) called it one of the most common species collected in tributaries. Ecological Specialists, Inc. (1993) found *Alasmidonta viridis* distributed in tributary streams, although it was rare. *Alasmidonta viridis* is known to burrow in the substrate (Watters 1995) and may be easily missed. Ecological Specialists, Inc. (1993) also found that the small size of this unionid reduced chances of finding it alive. In the present study *Lasmigona compressa* individuals were widely scattered and never present in great numbers. Ecological Specialists, Inc. (1993) found *Lasmigona compressa* to be

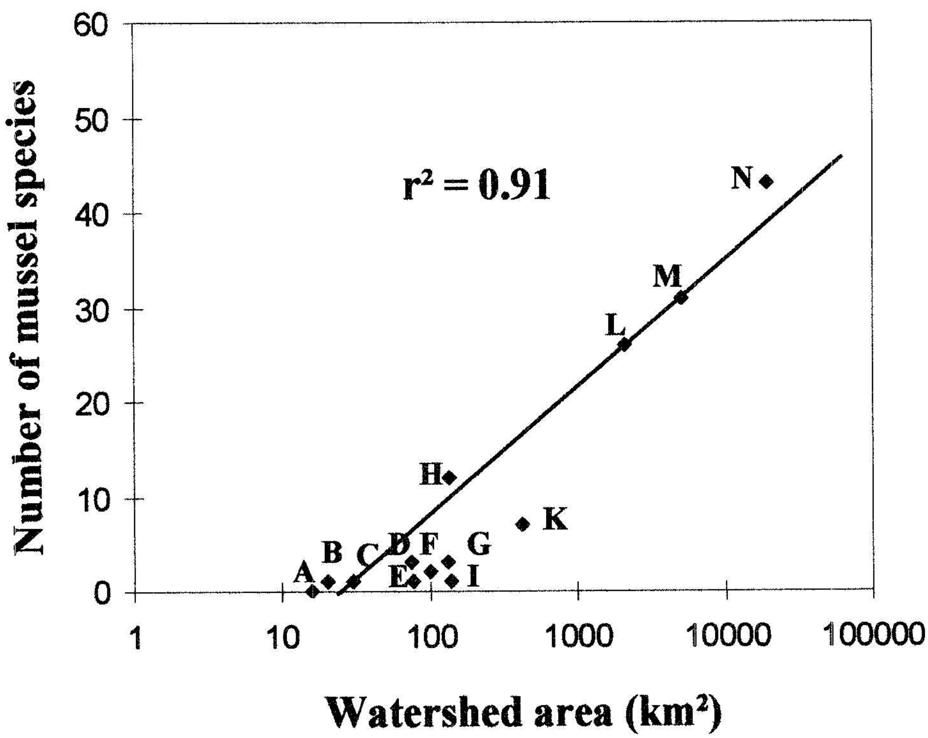

Figure 2.—Mussel species richness in relation to log of watershed area by stream system. (A = Bridge Creek; B = Bowen Ditch; C = Buck Creek; D = Sugar Creek; E = Indian Creek; F = Flint Creek; G = Moots Creek; H = Little Pine Creek; I = Burnett Creek; J = Big Shawnee Creek; K = Wea/Little Wea Creek; L = Wildcat Creek; M = Tippecanoe River; N = Wabash River).

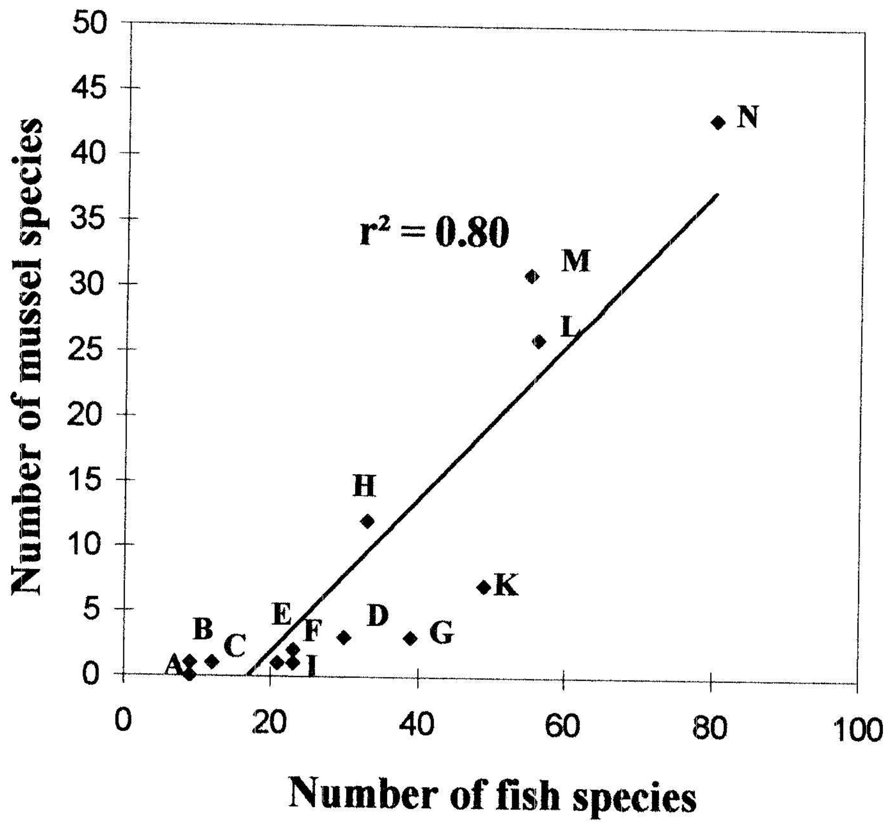

Figure 3.—Mussel species richness in relation to fish species richness by stream system. (A = Bridge Creek; B = Bowen Ditch; C = Buck Creek; D = Sugar Creek; E = Indian Creek; F = Flint Creek; G = Moots Creek; H = Little Pine Creek; I = Burnett Creek; J = Big Shawnee Creek; K = Wea/Little Wea Creek; L = Wildcat Creek; M = Tippecanoe River; N = Wabash River).

rare and scattered in the tributaries of the Tippecanoe River, as did Schanzle & Cummings (1991) in the tributaries of the Sangamon River. The present study shows that the typical headwater species *Alasmidonta viridis* and *Lasmigona compressa* are present in small streams, but their ranges may be underestimated due to difficulties in locating them.

Three species, *Pyganodon grandis, Lampsilis cardium,* and *Fusconaia flava* were widespread in their distribution. These three species are able to inhabit smaller streams such as Little Pine Creek and Wea Creek, moderate size streams such as Wildcat Creek, and large rivers such as the Wabash or Tippecanoe Rivers (pers. obser.).

Exceptional streams.—The Wildcat Creek system was exceptional in its mussel diversity in that it showed evidence of 26 mussel species. The four species found only in the downstream portion are more typical riverine species that are common in the Wabash River. A troubling observation was that the federally-endangered *Pleurobema clava* and the uncommon *Cyclonaias tuberculata* were found only as weathered shells in the North Fork Wildcat. This is similar to the finding of Henschen (1987) in which the Eel River, a stream with a similar watershed size to Wildcat Creek, yielded only shells of *Pleurobema clava* and *Cyclonaias tuberculata*. These species are disappearing from much of their former ranges, and Wildcat Creek may be no exception to this trend.

Little Pine Creek supports 11 mussel species, including the only known Tippecanoe County population of *Uniomerus tetralasmus*. This species is uncommon (Cummings & Mayer 1992) and was found in only one tributary of the Big Darby Creek system of Ohio (Watters 1994). The state species of special concern *Toxolasma lividus* individuals in Little Pine Creek are isolated from others of the same species. Previous county records of *Toxolasma lividus* include one live individual in the Tippecanoe River near the mouth (Cummings et al. 1992). These populations in Little Pine Creek are vulnerable to local extirpation from events such as ditching to facilitate agricultural drainage.

The discovery of two mussel species that are new county records emphasizes the importance of studying small streams. Many of these streams are subject to habitat modification, non-point source pollution, and land-use changes. Without baseline data on the biota of these streams, we may never know the magnitude of these impacts.

Effects of watershed area and fish diversity.—The effect of watershed area shows increasing unionid diversity with greater watershed area. The stream with the smallest watershed area, Bridge Creek (16 km^2) is probably too small to support mussels. Bowen Ditch, with a watershed area of 20 km^2, yielded one mussel species. The habitat quality of Bridge Creek was as least as good as that of Bowen Ditch and both supported nine fish species, implying that the minimum watershed size needed for mussels is approximately 20 km^2. Unionid diversity is not solely a consequence of the drainage area, but is also related to the fish diversity (Watters 1992). In small systems, the number of unionids is related to the drainage area, while in larger systems unionid diversity is related to both drainage area and fish diversity (Watters 1992).

Regression between number of mussel species and number of fish species is a linear function ($r^2 = 0.80$). A similar analysis by Watters (1993) gave an r^2 of 0.92, indicating the species numbers of fishes and unionids are highly correlated. The ratio of fish diversity to unionid diversity is essentially a constant, and this ratio may be used to predict an expected unionid diversity (Watters 1993). Deviations from expected unionid diversity based on fish diversity may be attributed to several causes such as fish mobility, presence of exotic fish species, and the persistence of unionid shells many years after the death of the animal (Watters 1992).

Comparison with host fish distributions.—Host fish were documented for observed mussels in all but two instances. This apparent anomaly is undoubtedly a result of the transient nature of fish communities at any given location. No dams that would limit fish movement are present on any of the streams.

For some mussel species, distributional ranges corresponded closely with those of known host fish. Examples include *Potamilus alatus, Leptodea fragilis* and *Truncilla truncata* inhabiting the downstream portion of Wildcat Creek along with their host fish, *Aplodinotus grunniens* (freshwater drum). Another example is the host fish for *Uniomerus tetralasmus, Notemigonus crysoleucas* (golden shiner) that was found in only Little Pine Creek and in the Wabash River during a Tippecanoe County fish survey (Fisher et al. 1998); and the only known Tippecanoe County population of *Uniomerus tetralasmus* is in Little Pine Creek. For most other mussel species, the ranges of the host fish greatly exceeded the ranges of the mussels. Hosts for *Toxolasma lividus* are *Lepomis cyanellus* (green sunfish) and *Lepomis megalotis* (long ear sunfish) which are widely distributed throughout the county, but this mussel was limited to one site. This concurs with the findings of Bauer et al. (1991) that the distribution pattern of hosts does not explain the distribution pattern of the mussels. The role of host fish in mussel distribution is an essential one, but other environmental factors limit whether a particular species can survive past the post-parasitic stage.

In some cases where the habitat preferences of a mussel species is known, it may be concluded that this, rather than the presence of host fish, is the determinant for mussel success. For example, *Alasmidonta marginata* usually occurs in clear flowing streams of moderate size (Watters 1995). *Alasmidonta marginata* was present only in Wildcat Creek, which also contains the host species *Ambloplites rupestris* (rock bass), *Moxostoma macrolepidotum* (shorthead redhorse), *Hypentelium nigricans* (northern hogsucker), and *Catostomus commersoni* (white sucker). However, these fish were widely-distributed throughout the county. Strayer (1983) states that in addition to stream size, surface geology is also a factor in defining mussel species habitats, and that hydrological variability associated with surface geology is probably an important factor in determining unionid distributions.

CONCLUSIONS

The distribution of mussels in Tippecanoe County indicated a total of 28 species in 12 watersheds. Of these, some species are typical of headwater areas, others inhabit moderate size streams such as Wildcat Creek, and others are widely-distributed throughout the county. The mussel species richness was significantly correlated with fish species richness, but the pattern of host fish distribution did not entirely explain the patterns of mussel distribution. Since mussels are not routinely included in small stream water quality surveys, many of the factors influencing mussel distribution, such as habitat requirements, are not well known. Because of the recent decline in mussel populations, this merits further study.

ACKNOWLEDGMENTS

The authors would like to thank Laurie Hatton and Brant Fisher for assistance with field work. We would also like to thank Dr. G. Thomas Watters of The Ohio State University and Ron Richards of the Indiana State Museum for taxonomic assistance. A review of an earlier version of this manuscript by Dr. Jon Harbor was greatly appreciated.

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Manuscript received 11 November 2000, revised 10 September 2001.