PLECOPTERA OR STONEFLIES (INSECTA) OF INDIANA: DIVERSITY AND CONSERVATION STATUS OF SPECIES

by

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Abstract. Stoneflies (Plecoptera) are indicators of water quality and have been lost in dramatic numbers from Midwest states, including Indiana. This study synthesizes over 5,000 specimen level records from museums and recent fieldwork to build a current species list, assess watershed level species richness, and calculate state level conservation assessments using NatureServe's Conservation Rank Calculator. Results include 1,050 positive occurrence records that yielded 92 species. Among these is one recently described species, a new species not yet described, and three previously described species new to Indiana. We have also found additional locations for rare species and confirmed the presence of a few species thought to be extirpated. United States Geological Survey Hierarchical Unit Code scale 6 (HUC6) drainages with the highest species richness values were the Patoka-White (73 species), Lower Ohio-Salt (60 species), and the Wabash River (57 species). The other seven drainages produced from five to 28 species, being limited by low gradient streams due to lake plain landscapes and by stream nutrient enrichment from agriculture. Eleven species were rated as extirpated or presumed extirpated, leaving 81 extant species. Of these, 17 were rated as critically imperiled (S1), 26 imperiled (S2), 25 vulnerable (S3), while only 13 species were rated as secure (S4 & S5). Watersheds and specific streams were discussed for their ability to support individual species or rich assemblages.

Keywords: Plecoptera, Indiana, conservation status, freshwater

INTRODUCTION

Stoneflies (Plecoptera) are an ancient order of insects whose fossil record extends 300 million years ago to the Pennsylvanian (Béthoux et al. 2011). A combination of external morphological characters distinguish stoneflies from other insect orders: most adults have two pairs of wings, larvae have two multi-segmented cerci, and the tarsus of both stages is composed of three segments, the distal segment bearing paired claws. The biology of stoneflies was recently reviewed by DeWalt et al. (2015). DeWalt et al. (2019) provide an up-to-date website for global nomenclature, literature, and distribution information for stoneflies.

Using the definition of Bybee et al. (2015), stoneflies exhibit a hemimetabolous (incomplete) metamorphosis consisting of egg, nymph or naiad (their preferred term), and adult life stages. Most stonefly researchers use nymph for the immature stage of stoneflies, we retain its use here. The aquatic nymphs grow gradually then transform to usually winged adults. Nymphs feed on decaying leaves and wood, encrusting algae, or on other invertebrates, and some species are known to undergo ontogenetic diet shifts (Miyasaka & Genkai-Kato 2009). Stoneflies utilize all stream sizes, inhabit high latitude or high elevation lakes, endure a wide range of thermal regimes, and have evolved to complete their life cycles under a broad range of stream permanence conditions (Bogan & Carlson 2018). Adults are almost exclusively terrestrial, and approximately half of the species feed during this stage to support maturation of eggs (Tierno de Figueroa & Sánchez-Ortega 1999, Smith & Collier 2000).

The highest species richness of stoneflies occurs in cool and coldwater streams draining mountains of temperate latitudes, but considerable diversity also occurs in high-quality, warm-water streams (Stewart & Stark 2002). Species reside on every continent except Antarctica and avoid areas of continuous ice cover and vast deserts (DeWalt et al. 2019).

In the United States stoneflies are rated by NatureServe as the third most imperiled group of freshwater aquatic organisms (Master et al. 2000). They stated that some 43% of USA stonefly species were regarded by state natural heritage programs as being at some level of imperilment (species ranked as extinct, critically imperiled, imperiled, and vulnerable). In Illinois, where adequate historical and contemporary specimens were available for study, 28.6% of 77 species known at the time were considered lost from the state, including the extinction of two endemics (DeWalt et al. 2005). Many species were widespread and abundant historically and those remaining have usually experienced considerable range loss. The study also reported that all regions of the state lost species, that the frequency of predatory feeding habits and long life cycles declined precipitously, and that wholesale shifts in assemblage structure occurred post-1950. Medium to large river habitats lost the highest proportion of the historic assemblage of species.

This loss is not just a USA problem as noted by Bojková et al. (2012) who studied 170 fixed sites in the Czech Republic for two time periods: pre-1960 and post-2006. Species with narrow specialization in protected habitats survived. Those with wider habitat and water quality tolerance, and were thus more widely distributed, were disproportionately lost. This was especially apparent in lowland agricultural and urban areas. Globally, Sánchez-Bayoa and Wyckhuysmeet (2019) suggest in a review article that within areas that are well studied, 35% of species are in decline, 29% are in threatened status, and 19% are experiencing local or regional extinction within the areas studied, with many species meeting IUCN criteria for inclusion in the Red List of Threatened Species.

Stonefly work in Indiana began with studies by Theodore H. Frison (1935, 1942) who utilized regional sampling to help understand the morphological variation of species he found in Illinois. Frison conducted much sampling in Turkey Run and Shades State Parks, many locations in the vicinity of Bloomington, the East Fork of the White River at Shoals and Rogers, the mainstem of the White River at Petersburg, and a host of other locations. Our historical knowledge of the richness of Indiana stoneflies is based on these published records and the specimens still at the Illinois Natural History Survey (INHS) that verifies the existence of several species.

The first published list of stoneflies of Indiana was written by Ricker (1945). He used a relatively small amount of material from Purdue University and teaching collections at Indiana University, supplemented with specimens at the INHS, to build a list of 38 species. Finni (1973) published on the life histories of four winter stoneflies from Little Pine Creek in Warren County. His work was one of the first to document the life cycles of winter emerging stoneflies. The next substantive work to document Indiana stoneflies was that of Bednarik & McCafferty (1977) and included much more extensive sampling. They reported 61 species from Indiana. Grubbs (2004), stonefly systematist from Western Kentucky University, sampled the unglaciated south of the state meticulously and critically examined borrowed material. His work resulted in the removal of five species corresponding to misidentifications or lack of verifying specimens in museums. He also added 17 more species to the state tally bringing the total to 76 species. DeWalt & Grubbs (2011), in an effort to reconstruct the stonefly fauna of the Midwest, examined all specimens borrowed from regional museums and conducted extensive collecting in more northern areas of Indiana. They added 13 more species to the tally for the state and removed one species, for a total of 87 species in Indiana. The authors also reported that at least 10 species (11.5%) of the total, could not found in the state any longer. Most of these losses were from the Wabash and White River drainages. Recently, Grubbs & DeWalt (2018) described *Perlesta armitagei* from Ohio and Indiana and added *P. xube* Stark & Rhodes, 1997.

The past century of work has built a strong foundation from which to assess the species the conservation status of stoneflies in Indiana. Assessment of conservation status requires knowledge of historical distributions (Shaffer et al. 1998). While printed works are useful for understanding historical distributions, the taxonomy of stoneflies changes constantly placing in doubt the identity of specimens examined in the past. The availability of large numbers of museum specimens ensures that re-examinations and re-identification of specimens to current taxonomic standards are possible. Conversely, extensive collecting of contemporary specimens is extremely important to assess the current occupancy of historic locations and to find new locations for a species.

The stonefly fauna of Indiana and much of the region is largely governed by natural variables, key among these is glaciation history (DeWalt et al. 2012, DeWalt & Grubbs 2011). Indiana experienced at least two glacial events, the older Illinoisan age glaciation that ended some 150,000 yr ago and the Wisconsinan glaciation, which reached its southernmost extent about 18,000 yr ago (Wiggers 1997). The Illinoisan advanced the farthest south, leaving a flattened landscape around a triangular lobe of unglaciated, hilly land from Bloomington to the Ohio River (Fig. 1). The ice sheets wiped out most of the macrofauna in the region (Pielou 1991). The Wisconsinan did not extend as far southward as did the Illinoisan, but it again removed most macrofauna from the region. The unglaciated area of southern Indiana also survived this glacial advance and undoubtedly served as a refugium for some of the cold tolerant species. The Wisconsinan deposited a thick layer of outwash sand and gravel over top of the Illinoisan aged landscape, surround the unglaciated area with finer sediments. The area surrounding Indianapolis and northward was left a till plain, a flat area that produced many moderate gradient, cool to warmwater streams such as the Kankakee, Tippecanoe, and Wabash that matured to support many stonefly species specializing in large rivers. In the northwest corner of Indiana, the vast Kankakee Marsh developed on lake plain landscape that produced sluggish streams that were colonized by few stonefly species (DeWalt et al. 2016b). Beginning at Michigan City and going eastward to near Angola is an area of drift plain with higher gradient streams of sand, gravel, and cobble bottom that historically supported greater stonefly species richness than streams of the Kankakee Marsh. Another area of low gradient streams occurred from Angola eastward in the old Lake Erie lake plain. This area supported many fewer stoneflies than the nearby drift plain.

Using the INHS collections, those at the University of Purdue Entomological Research Collections (PERC), many other regional museums, and new sampling we will meet the following objectives.

1. Characterize the diversity of stoneflies in Indiana.
2. Analyze the distribution of each species across the state.
3. Assess the conservation status of each species based on historical vs. contemporary distributions and relative stability of habitat.

METHODS

Museum specimens. Museum specimens were obtained from 17 regional collections (Table 1). Each pin with a single specimen or vial with one or more specimens represents a collection object that was provided with a unique identifier (catalog number) that positively linked the object with a data record. The objects usually come with a location and one or more determination labels, the text of which were digitized into a custom database.

We also included specimens records from three border rivers in our data set from the Wabash (Illinois, 93 records), Ohio (Kentucky, 3 records), and Great Miami River (Ohio, 1 record). The Great Miami River is not an official border between Indiana and Ohio, but it meanders across the border four times in the space of 5 km upstream from its confluence with the Ohio River. Including these border river records in the data for Indiana assumes that if a species is found on one bank of the river, it also exists on the opposite bank.

New collections. Collecting in 2017 and 2018 focused on verifying the presence of rare, imperiled, or presumed extirpated species (from DeWalt & Grubbs 2011) at historical locations, increasing the number of known locations for rare species, and filling in gaps in coverage across the state. We focused our collection efforts on running waters and seeps since no Indiana species uses lakes. Adult specimens afforded the greatest likelihood of species identification; so much of our efforts focused on this life stage. We used beating sheets, sweepnets, hand picking from hard substrates and ultraviolet light trapping to collect adults. Nymphs were also collected and when they could not be identified to the species level, were reared to adulthood in an artificial stream in Champaign, Illinois. Methods for collecting nymphs included disturbing rocks, logs, and leaf packs in front of a rectangular dipnet. Stoneflies are known to exhibit a succession of species throughout the year (DeWalt & Stewart 1995) and required sampling across most months to obtain the full complement of species. Winter stoneflies (with representatives in several families) emerge November through March; there are also many spring and summer species, and one species that emerges into September. These specimens were identified to the most specific level possible and specimens stored separately in 95% EtOH. Each collection object was provided with a unique identifier (catalog number) that positively linked the object with a data record and all the label data (location and one or more determination labels) digitized into a custom database.

Georeferencing and locations. New sampling locations were georeferenced in the field using a DeLorme Earthmate PN-60 handheld GPS unit. These coordinates were verified in the laboratory by plotting them using Acme Mapper 2.1 (http://acme.mapper.com, datum WGS-84). Textual descriptions of locations for museum specimens were queried in Acme Mapper. Once a location was found, coordinates were copied into the database. All collector provide coordinates were also projected and adjusted to more closely match the textual description. An estimate of precision as a radius in meters was recorded based on: a stream with a bridge crossing = 10 m; a small town and nearby stream = 1,000 m; a large town with or without a stream name = 10,000 m; or a county-level record = 100,000 m.

Distribution maps. Duplicate locality records were eliminated using Excel’s remove duplicates function, followed by visual examination of location information. This resulted in 1,050 unique locations. These locations were mapped using ESRI ArcMap (version 10.6.1) and a distribution map plotted for all species in the data set.

Species Richness. A species list was compiled for Indiana. Using ESRI ArcMap (version 10.6.1), species distributions were layered over HUC6 drainages. Using the intersect function, a new layer was produced assigning each unique locality to a drainage. The number of the unique species was totaled for each HUC6, then set into an additional layer. To compare richness values between HUC6s, the highest HUC6 total was divided into five classes with breaks at multiples of

15, producing a color-coded HUC6 species richness map of the state. We examined the relative importance of families relative to species richness in chart format.

Conservation status. All assessments were performed at the subnational (S) level. Seven NatureServe Conservation status ranks exist: SX (Presumed extirpated), SH (Possibly extirpated), S1 (Critically imperiled), S2 (Imperiled), S3 (Vulnerable), S4 (Apparently secure), and S5 (Secure). Conservation status assessment was performed using NatureServe criteria via the NatureServe Rank Calculator (ver. 3.186, March 2015). The limited number of records for rare species and the lack of population estimates constrained our data input to the following variables: "range extent", "number of occurrences [all unique locations]", and the "number of occurrences with good viability/ecological integrity [post-1950]". Initial runs of the calculator produced no species with conservation status rankings of S5, although *Allocapnia granulata*, *A. recta*, *A. ricker*i, *A. vivipara* and *Taeniopteryx burksi* were each represented by over 100 unique locations across the state. For these species we reran the calculator adding the field of "intrinsic vulnerability", assigning them the lowest degree of vulnerability, which resulted in an S5 status for each species.

The calculator will not return a conservation status on species with zero recent occurrences. Therefore, researchers are left to their best judgment for assigning SX and SH statuses to species. We chose to assign SX to any species that has not been seen since 1950 when we know it has been looked for several times at historical locations. We manually assigned SH to any species with only one or two records since 1950 if we know the species has been sought several times since then. The date of 1950 is used as the divider between historical and contemporary records based on time series analysis of when stonefly species disappeared from Illinois (DeWalt et al. 2005).

RESULTS AND DISCUSSION

The data set. We examined specimens from 17 regional museums (Table 1), compiling 5,449 records. The INHS contributed >50% of the records, while 29% came from PERC. The remaining 15 collections produced only 17.7% of all stonefly records. Historical specimens, those with dates through 1950, contributed 1,022 (18.7%) records, while contemporary specimens, those beginning in 1951, contributed 4,427 records. Indianapolis Zoo/Indiana Department of Natural Resources funded fieldwork of 2017 and 2018 allowed us to contribute 757 (13.9%) records to the overall data set. Across all records, we found that 1,050 unique locations were sampled for stoneflies over the past century of work (Fig. 2).

Statewide and regional diversity. Our work has documented 92 species occurring in Indiana, including an undescribed species designated as *Perlesta* IN-5 (family Perlidae), occurring in several large rivers (Table 2). These 92 species belong to 8 of 9 North American families (Fig. 3). The family Perlidae contributed the greatest proportion to the total fauna and consists of many species that utilize larger, warmwater streams. Nymphs have large clusters of fingerlike-gills at the base of legs and other areas that provide increased surface area for oxygen diffusion into the body. Perlodidae were the next most species rich family. They lack gills found in the Perlidae and hence tend to live in cooler water temperature and are less tolerant of organic pollution. The Capniidae and Taeniopterygidae together comprise the "winter stoneflies" whose adults can be seen walking across the snow during winter. Together they contributed 20 species. Other families contributed from 2 to 7 species.

Of 10 HUC6 drainages in Indiana, the Patoka-White supported the greatest species richness of stoneflies at 73 species (Table 2, Fig. 4). The next most species rich drainages are the Lower-Ohio Salt with 60 and the Wabash drainage with 57. Five other drainages produced numbers in the 20s. The drainages with the fewest species were Western Lake Erie with ten species and Southwest Lake Michigan with five species. Unglaciated landscapes dominate both the Patoka-White and the Lower Ohio-Salt. In this region, stonefly assemblages have always been richer in species than unglaciated areas, unless the glaciated areas are adjacent, as in the Wabash River, and have varied habitats (DeWalt et al. 2016a). Two drainages are of exceptionally low species richness, Southwestern Lake Michigan and Western Lake Erie. Both drain glacial lake plain landscapes that at one time were extensive open marshes or wooded wetlands, respectively. These low gradient landscapes have always produced few stoneflies (DeWalt et al. 2012, 2016a, 2016b).

Conservation status assessment. One way to interpret the large numbers of species and the frequency in which they occur in an assemblage is in a species “prevalence” chart. In the Indiana stonefly assemblage, a relatively few species were known a large number of unique collecting events (Fig. 5). The inset of Fig. 5 demonstrates that only about 10 species were known from 100 or more unique collecting events. Most of the species are represented by an intermediate number of events. On the other end of the spectrum, there are a relatively large number of rare species. In our case, there are 12 truly rare species in the assemblage that are represented in the record by only one (singletons) or two (doubletons) collecting events.

It is useful to examine these kinds of visualizations by family. For instance, the family Capniidae in Indiana is composed of 13 species (Fig. 6). Four of these species are clearly under no threat, being known. They are known from over 100 unique collecting events and have been collected over 100 times each post-1950. Another 5 species are known from approximately 25 unique events and more than half of those events occurred post-1950. However, four species are clearly rare and one has not been collected since 1940 (*Nemocapnia carolina*), despite many attempts by multiple researchers to collect them. The Chloroperlidae, or Sallflies, are only represented by four species, only one of which is abundant and secure (Fig. 7). Two species appear at some lower level of imperilment, while one, *Alloperla hamata*, is known from only four recent events and appears to have a restricted range in Indiana.

The family Leuctridae is represented by 7 species in Indiana have 4 of them in need of protection (Fig. 8). Luckily we have collected all of the species recently. Only 2 of 6 Nemouridae appear to be imperiled (Fig. 9). Conversely, the family Perlidae appears to be in real trouble (Fig. 10). Of the 36 species, fully half are known from fewer than 10 unique locations and many of them have not been seen in many decades. Many of these are warmwater species, many from larger streams and big rivers. These are the types of running waters that cities and factories are built next to and that receive agricultural nutrients and pesticides from many tributary streams. The loss of stonefly species from these waterbodies is disproportionately large (DeWalt et al. 2005). The Perlodidae, spring emerging stoneflies, are in similar condition, but at about half the scale (Fig. 11). It appears that at least 4 species are feared lost from the state and another 6 are exceedingly rare.

Pteronarcyidae, the Salmonflies, are represented by 2 closely related species (Fig. 12). One species is secure, the other, *Pteronarcys dorsata*, may be experiencing a decline. The nymphs of these large stoneflies cannot reliably be identified to species and must be reared to adulthood for positive identification. Rearing of specimens from the St. Joseph River drainage might yield more specimens of *P. dorsata*. The family Taeniopterygidae, another winter emerging stonefly, is composed 7 species, four of which are rare and one (*Taeniopteryx parvula*) has not been collected in decades.

Of these 92 species, 8 are thought to be extirpated (SX), 3 possibly extirpated (SH), and another 17 are critically imperiled (S1). The remaining include 26 imperiled (S2) species, 25 vulnerable (S3) species, 8 apparently secure (S4), and only 5 secure (S5) species (Table 2, Table 3). Distribution maps for all 92 species have been prepared and organized alphabetically by family and species (Figs. 14-105).

Extirpated and Critically Imperiled Species

We have categorized a total of 28 species of stoneflies as extirpated, possibly extirpated, and critically imperiled in Indiana. For each of these species, we provide a more detailed description of the distribution and known records.

Capniidae

***Allocapnia illinoensis* Frison, 1935. S1.** This species was described from Clark County, Illinois and subsequently was lost from the state (DeWalt & Grubbs 2011). In Indiana it is known from two sites, a tributary to Lake Lonidaw in Pokagon State Park (Steuben Co.) and a tributary of Big Walnut Creek in Hall Woods Nature Preserve (Putnam Co.) (Fig. 16). It was last seen in Indiana in 2008.

***Nemocapnia carolina* Banks, 1938. SX.** A large river species of winter stonefly commonly associated with the coastal plain of the southern USA, this species was known from two sites on the East Fork of the White River (Pike County and Martin County) and one site on the Wabash at Grayville, Illinois (White Co., IL/Gibson Co. IN) (Fig. 25). It was last collected in 1940 at Rogers in Pike County. DeWalt and Grubbs (2011) consider it extirpated from both Illinois and Indiana.

***Paracapnia angulata* Hanson, 1961. S1.** This species was not reported from Indiana by DeWalt & Grubbs (2011). It is a new state record for Indiana. A single male was collected in 2010 from Allen's Creek of Monroe County (Fig. 26).

Leuctridae

***Leuctra alta* James, 1974. S1.** This species is commonly associated with small, hillside streams that dry before mid-summer (Grubbs 2005). These are habitats not well sampled by stonefly researchers, thus the distribution of the species may be underestimated. Its known Indiana localities include a tributary of Potato Run (Harrison Co.) and a tributary of Willow Creek (Ohio Co.) (Fig. 31). It was last collected in 2002.

***Leuctra tenuis* Pictet, 1841. S1.** Adults are usually reported from permanent ravine streams in late summer after most other stonefly species have finished emergence. Because of their phenology, they may have been overlooked and have a more extensive range. It is known from Mill Creek (Montgomery Co), two tributaries of Sugar Creek (Parke Co.), and a tributary of the

West Fork of Mosquito Creek (Harrison Co.) (Fig. 34). It was last collected in 2009 from Mill Creek.

Perlidae

***Acroneuria covelli* Grubbs & Stark, 2004. S1.** This is a large-river species known from two localities on the Ohio River (Clark Co., 2003; Gallatin Co., KY/Switzerland Co., IN, 1942) and a third imprecise location in Washington County in 1938 (Fig. 45). Large river habitats are notoriously difficult to effectively sample, hence it may be more widely distributed in the Ohio River than currently known.

***Acroneuria filicis* Frison, 1942. SH.** This species is known from three sites, one from the Tippecanoe River (Tippecanoe Co., 1969), an unknown location in Monroe County in 1961, and an unknown location in Washington County in 1938 (Fig. 47).

***Acroneuria hitchcocki* Kondratieff & Kirchner, 1988. S1.** A species described from the Outer Bluegrass region of Northern Kentucky (Kondratieff & Kirchner 1998). In Indiana, it is known from only one site on the West Fork of the Whitewater River in Fayette Co. (Fig. 49). Some time has been spent searching for new records of this species without success, but we have left this species ranked S1 as we think more collection attempts are necessary to conclude that it is extirpated. It was last collected in 1987.

***Acroneuria lycorias* Newman, 1839. S1.** This is a new state record for Indiana. We collected 1 male and 20 exuviae in 2018 from the confluence of the Elkhart and St. Joseph Rivers in Elkhart (Fig. 51). This is a large species, adults measuring to near 3 cm length, yet it remained undetected for over a century. We believe this species is from the Elkhart River, not the St. Joseph. Within the past month, a few additional specimens have been donated to the INHS from upstream of the confluence, suggesting that continuous population inhabits the river for at least 10 km upstream of the confluence.

***Acroneuria ozarkensis* Poulton & Stewart, 1991. S1.** This too is a new state record and again a large species. We collected six males at Hindostan Falls (Martin Co.) in 2017 using an ultraviolet light trap (Fig. 52). It was previously known only from the Ozark region of Arkansas and Missouri (Poulton & Stewart 1991). It is a cryptic species, being extremely similar to *A. perplexa* that occurs at the same location.

***Agnetina annulipes* Hagen, 1861. S1.** This species had not been collected for several decades in Indiana. We collected a few females from two locations on the Blue River in Harrison County (Fig. 54) in 2018.

***Attaneuria ruralis* Hagen, 1961. SX.** This species was once widely found in large prairie streams across the Midwest. It once inhabited the Wabash River (Tippecanoe Co.) and the White River (Monroe Co.) (Fig. 57), both last collected in 1944. DeWalt & Grubbs (2011) reported it as extirpated from Indiana and Illinois.

***Neoperla coosa* Smith & Stark, 1998. S1.** This species has only been found at two locations on the Blue River, both in Harrison County (Fig. 60). It was last recorded in 2018.

***Neoperla occipitalis* Pictet, 1841. SX.** This stonefly is known from one record listed only as Warren County in 1935 (Fig. 62).

***Neoperla osage* Stark & Lentz, 1988. S1.** A single male was recorded from the Ohio River at Leavenworth in Harrison County (Fig. 63), collected in 2002.

***Neoperla robisoni* Poulton & Stewart, 1986. SH.** The species is known from a single location on the Tippecanoe River in White County (1978), the Blue River in Harrison County (1972), and from Mount Carmel, Illinois (Wabash Co. IL/Gibson Co. IN, 1906) (Fig. 64). All were adults, and the dates of collection were in late July and August. This is much later than most stonefly emergence, so later collections at large rivers may produce more specimens.

***Paragnetina kansensis* Banks, 1905. SX.** Records come from five large-river localities across the state. This species is represented by our oldest specimens, dating to July 1879 at Nineveh Creek in Bartholomew County (now part of Camp Atterbury). Other sites include the East Fork of the White River in Pike County (1936), the main stem of the White River also in Pike County (1936), an unknown location in Monroe County (1909), and the Wabash River in Tippecanoe County (1944) (Fig. 66).

***Perlesta golconda* DeWalt & Stark, 1998. S1.** This large river species is known from only four locations: the Wabash River in Knox County (1993), the White River in Greene County (1901), the St. Joseph River in Elkhart County (1947), and a 2018 collection from a 5-10 m wide stream called Arnold Creek in Ohio County (Fig. 72). The latter record probably represents a specimen from the Ohio River just a few kilometers away. Its distribution stretches from Nebraska to Ohio (Grubbs & DeWalt 2008, DeWalt & Grubbs 2011, Grubbs et al 2013).

***Perlesta shawnee* Grubbs, 2005. S1.** This species is known from two sites in the East Deer Creek drainage of Perry County (2003, 2018) in the upper drainage is part of the German Ridge Recreation Area of Hoosier National Forest (Fig. 76). This species has been collected from Alabama north to unglaciated parts of southern Illinois, and east to Virginia (Grubbs & DeWalt 2008).

***Perlesta xube* Stark & Rhodes, 1997. S1.** This species is known from two mid-sized streams, Leatherwood Creek in Lawrence County (2009) and Darroch Hunter Ditch, a tributary of the Iroquois River in Newton County (1972) (Fig. 78).

Perlodidae

***Helopicus nalatus* Frison, 1942. SX.** This species is known from mid-sized, swift streams from Oklahoma and Kansas east to Indiana and Michigan. In Indiana, it has only been collected Crawford (1947) and Harrison Counties (1949) on the Blue River (Fig. 83).

***Isogenoides varians* Klapálek, 1912. S1.** This species was once thought to be extirpated from Indiana and much of the Midwest (DeWalt & Grubbs 2011) until exuvia were collected from the Wabash River at Attica in 2010. Other collections are much older: Wabash River in Tippecanoe

County (1959), Wabash River in Wabash Co. IL/Gibson Co. (1939), and Pike Co. in the White River mainstem and East Fork of the White River in 1936 (Fig. 86).

***Isoperla frisoni* Illies, 1966. S1.** This species is commonly found throughout much of the Great Lakes region. In Indiana, it has been collected from Trail Creek in LaPorte County (1957, 2007, 2018), from Pigeon Creek in LaGrange County (1972), and from the Yellow River in Starke County (1937) (Fig. 91).

***Isoperla marlynia* Needham & Claassen, 1925. SX.** This large river species ranges from the Great Plains east to New Jersey and northward into Canada. It has declined throughout much of its range, including Indiana (DeWalt & Grubbs 2011). It is only known from two sites, the East Fork of the White River at Rogers in Pike County (1942) and the St. Joseph River at Elkhart (Elkhart Co., 1906) (Fig. 92).

***Isoperla namata* Frison, 1942. SX.** This species is known from a single verified collection, that of McCormick's Creek, in McCormick's Creek State Park, Owen County (1938) (Fig. 94).

***Isoperla richardsoni* Frison, 1935. SX.** This species is known from Iowa east to Connecticut. DeWalt & Grubbs (2011) listed it as extirpated from both Indiana and Illinois, but it was recently rediscovered in Pope Co., Illinois (2006), probably originating from the Ohio River. In Indiana, it is known from two sites in the White River drainage near Bloomington in Monroe County (1938) and Rogers in Pike County on the East Fork of the White River (1936) (Fig. 96). Due to the recent collection in Illinois, it may well reside in the Ohio River bordering Indiana.

Pteronarcyidae

***Pteronarcys dorsata* Say, 1823. S1.** A cool water species, this insect is known only from northern parts of the state. It is still found in the St. Joseph and Elkhart Rivers in and around Elkhart (Elkhart Co., 2018, 1993). It was once found in the Wabash River at Lafayette (Tippecanoe Co.), but the most recent record we have there is from 1915 (Fig. 97). West Lafayette is well collected due to the presence of Purdue University. We do not believe that it still inhabits the Wabash River.

Taeniopterygidae

***Taeniopteryx parvula* Banks, 1918. SH.** This is a species that has a generally northern distribution but seems to have been a glacial relict in a southern Indiana refugium. All known locations are in the White River drainage. Three are from the East Fork of the White: at Rogers in Pike County (1938), Shoals in Martin County (1936), and Haysville in DuBois County (1960). Another site includes a tributary of the East Fork at Medora in Jackson Co. (1938). Other sites include Boggs Creek (Martin Co. 1938), Beanblossom Creek (Monroe Co., 1950), Richland Creek and Plummer Creek in Greene Co. (1963) (Fig. 105). It seems unlikely that this species remains in Indiana.

Focal Drainages

Several drainages have in history and some continue to support important species or assemblages of stoneflies. We provide a discussion of several of these drainages.

East Fork of the White River. The East Fork of the White River begins in glacial till plain as a number of rivers east of Indianapolis including the Big Blue, Flatrock, and Driftwood rivers. These streams unite at Columbus in Bartholomew County forming the East Fork of the White River. This part of its drainage consists of slowly meandering streams with sandy, gravel, and silty substrates. Downstream of Columbus, the East Fork flows through a wide floodplain surrounded by hills that were last glaciated in the Illinoian period, here it is joined by the Muscatatuck River on the border of Jackson and Washington Counties. Upstream of this confluence the river is not rich in stoneflies.

As the East Fork continues westward it enters the unglaciated part of the state. Stream gradients increase, the bottom substrates become coarser, and more groundwater enters the drainage. This section, roughly from the point the river enters Lawrence County until it exits Martin County near Haysville has historically been rich in stoneflies and still supports a relatively rich fauna. Downstream of Hindostan Falls, the river again flows through areas glaciated during the Illinoian period. Historically, many species have been found downstream as far as its confluence with the West Fork of the White River and further to near Petersburg, but stonefly diversity appears to have dropped significantly since the 1930s and 1940s.

At least 35 species are have been recorded from the East Fork of the White River, with many more from its tributaries. Of the 35 species, five are believed to have been eliminated from the state, *Isoperla marlynia* (SX), *Isoperla richardsoni* (SX), *Nemocapnia carolina* (SX), *Paragnetina kansensis* (SX), and *Taeniopteryx parvula* (SH). *Agnetina flavescens* (S2) and *Isogenoides varians* (S1) has not been collected from the East Fork since 1936, and have likely been extirpated from this system. In 2018, we collected *Acroneuria ozarkensis* (S1) at a UV light near Shoals in Martin County, a new state record. There are an additional seven S2 ranked taxa with records from the East Fork, including *Acroneuria abnormis*, *Acroneuria evoluta*, *Hydroperla fugitans*, *Perlesta* IN-5, *Perlesta ouabache*, *Taeniopteryx lita*, and *Taeniopteryx maura*.

Sugar Creek and Tributaries. This mid-sized tributary of the Wabash in Parke and Montgomery Counties holds a number of species that are either relatively rare in the state or are species more commonly associated with regions that have undergone fewer than two glacial events. Parts of this drainage are made up of sandstone bluffs and canyons, leading to high stream gradients in numerous ravines. Many of these streams are protected as part of Turkey Run and Shades State Parks. Sugar Creek itself holds many significant taxa including S2 ranked *Hydroperla crosbyi*. *Leuctra tenuis* (S1), *Paraleuctra sara* (S2), *Sweltsa hoffmani* (S2), *Isoperla montana* (S2), and *Allocapnia nivicola* (S3) are all known from small tributaries of Sugar Creek.

St. Joseph (Southeastern Lake Michigan drainage), Elkhart, and Pigeon Rivers. The St. Joseph River begins in south-central Michigan and is already a large river by the time it enters Indiana north of Bristol. The Elkhart River starts in LaGrange and Noble Counties and flows generally northwest to its confluence with the St. Joseph River in Elkhart. The Pigeon River begins as Pigeon Creek south and east of Angola, flowing northwest into Michigan, meeting the St. Joseph about one kilometer north of the Indiana/Michigan border.

The glacial drift plain of this far northern part of the state has significant groundwater close to the surface and a cooler climate than most of the state. These, combined with higher stream gradients, and the relatively intact riparian zones of the Elkhart and Pigeon Rivers provide some excellent habitat for many Plecoptera species.

Prostoia completa (S2), *Acroneuria internata* (S3), *Acroneuria lycorias* (S1), *Agnetina capitata* (S2), *Paragnetina media* (S2), *Isoperla dicala* (S2), *Isoperla frisoni* (S1), *Pteronarcys dorsata* (S1), and *Taeniopteryx nivalis* (S3) are all species with northern distributions that occur in the St. Joseph River and tributaries. In addition, *Allocapnia illinoensis* (S1) is found in a small Pokagon State Park stream that flows into this drainage.

Blue River (Lower Salt-Ohio drainage). The Blue River is a mid-sized river in unglaciated Indiana where it flows through karst geology. The river flows generally southwest through Washington, Harrison, and Crawford counties where it benefits from large groundwater input, high stream gradients, and a heavily forested watershed that supports *Agnetina annulipes*, *Neoperla coosa*, *Agnetina capitata*, and *Acroneuria internata*. Some species, such as *Allocapnia indianae* (S3) are found in the mainstem of this river when it usually inhabits much smaller streams.

Two species are believed extirpated from this stream: *Neoperla robisoni* (SH) and *Helopicus nalatus* (SX). Other species known to inhabit this stream include *Agnetina annulipes* (S1) and *Neoperla coosa* (S1), *Acroneuria abnormis* (S2), *Agnetina capitata* (S2), *Agnetina flavescens* (S2), *Neoperla catharae* (S2), *Neoperla stewarti* (S2), *Isoperla burksi* (S2), and *Taeniopteryx maura* (S2).

Allen's Creek. This small stream in Monroe County flows directly into Lake Monroe in Hoosier National Forest. Eight species are known from this stream, including the only locality of *Paracapnia angulata* (S1) and *Taeniopteryx metequi* (S2). An *Ostrocerca* nymph was taken here and may represent *Ostrocerca truncata* (S2). Five other species are present with rank S3 or S4.

Arnold Creek. Arnold Creek is a small, swift stream in Ohio County in southeastern Indiana. It flows northeast into the Ohio River near Rising Sun. There are only records for five species from this site, but they are all from a single UV light collection in May of 2018. *Perlesta golconda* (S1) was found here, but this large river species likely flew in from a location on the Ohio River. Further collections from this stream in other seasons will likely add species.

East Deer Creek. This small stream is mostly contained within the German Ridge Recreation Area of Hoosier National Forest in Perry County. It arises in sandstone hills and flows west to its confluence with the main stem of Deer Creek, a tributary of the Ohio River whose mouth is flooded due to a downstream navigation dam. This protected stream at the southern edge of the state hosts 19 species. Two species have very limited ranges north of the Ohio River. Ranked as S1, *Perlesta shawnee* is known only from two sites in this drainage. Of the six recorded localities of *Allocapnia smithi* (S2) from Indiana, three are from this stream or its tributaries. Another S2 species, *Ostrocerca truncata,* is also known from this drainage.

Otter Creek. This system in southern Crawford County is known to contain 19 species. Much of Otter Creek itself is lined with pasture and cropland, but many tributaries start in the steep sandstone hillsides, cliffs, and box canyons. We have no records for the mainstem of Otter Creek. However, two protected areas, Hemlock Cliffs and Yellow Birch Ravine Nature Preserve have been collected. Five S2 ranked species have been found there, including Indiana’s northernmost record of *Allocapnia smithi,* as well as *Sweltsa hoffmani*, *Ostrocerca truncata, Paraleuctra sara,* and *Leuctra sibleyi.* Nine other species are ranked as S3.

CONCLUSIONS

This work takes advantage of a large data set of stonefly records accumulated to reconstruct the stonefly assemblage of the Midwest. It was begun due to the disappointing outcome of a review of the conservation status of stoneflies in Illinois (DeWalt et al. 2005). It appears that 11 of 92 species, nearly 12% of all stonefly species known from Indiana, can no longer be collected in the state, compared to 28.6% in Illinois (DeWalt et al. 2005). This leaves a confirmed 81 species extant in the state. A depressing concept is that 68 of 81 extant species (84%) qualify for S1, S2, and S3 status. Only 13 species, 16% of the extant stonefly fauna appear to be secure.

We have identified imperiled species, but we have also added six species to the state's list: *Paracapnia angulata*, *Acroneuria lycorias*, *A. ozarkensis*, *Perlesta armitagei*, *P. xube*, and an undescribed *Perlesta* IN-5. We have also found some species that have not been seen in decades, *Agnetina capitat*a and *Ag. annulipes* are examples. This demonstrates that more discoveries are likely in Indiana. Our work has also found several drainages that warrant additional protection due to their rich fauna.

Currently funded mayfly (Ephemeroptera) projects and one proposed for caddisflies (Trichoptera) should yield some important and surprising discoveries. It will confirm that imperilment of other aquatic insects has taken place in Indiana and that similar habitats and waterways important to stonefly conservation will be so for mayflies and caddisflies as well.

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Table 1. Regional museums providing stonefly specimen records.		
Institution Code	**Description**	**Records**
CNC	Canadian National Collection, Ottawa	308
FMNH	Field Museum of Natural History, Chicago	6
EIU	Eastern Illinois University, Charleston	8
SIUC	Southern Illinois University Carbondale	1
UWIRC	University of Wisconsin Insect Research Collection, Madison	1
BYU	Brigham Young University, Provo	17
PERC	Purdue University Entomological Research Collection, West Lafayette	1592
UMMZ	University of Michigan Museum of Zoology, Ann Arbor	8
UMSP	University of Minnesota, St. Paul	2
CINC	Cincinnati Museum of Natural History	1
DEBU	University of Guelph, Ontario	1
OBS-INHS	Ohio Biological Survey, now INHS	12
OSUC	Ohio State University Insect Collection, Columbus	10
Notre Dame	University of Notre Dame, South Bend	29
ISIC	Iowa State University Insect Collection, Ames	10
INHS	Illinois Natural History Survey, Champaign	2895
WKUC	Western Kentucky University Insect Collection, Bowling Green	548
		5449

Table 2. Species of stoneflies known from Indiana and characteristics. Conservation status, Number of localities by HUC6, Habitat information. Estimated stream permanence: A= permanent; B=Semi permanent, stream may go dry some years; C=ephemeral, stream goes dry nearly every year. Additional information about each species may be found at Plecoptera Species File (DeWalt et al. 2019).

				HUC6 Unique Localities										**Habitat information**		
Taxa	**Conservation status**	**Year last collected**	**Unique locations**	**SW Lake Michigan**	**SE L. Michigan (St. Joseph R.)**	**W L. Erie (Maumee R.)**	**Up. Illinois (Kank. R.)**	**Wabash**	**Patoka-White**	**Gr. Miami (Whitew. R.)**	**M. OH-L. Miami (Laugh. Cr.)**	**L. Ohio-Salt (Blue R.)**	**L. Ohio (Anderson R.)**	**Stream width (m)**	**Thermal regime**	**Stream permanence**
Capniidae																
Allocapnia forbesi	**S3**	2018	25						6		3	8	8	<10	cool	A, B, C
Allocapnia granulata	**S5**	2018	167		14	2	2	92	46	5		5	1	>5	warmwater	A
Allocapnia illinoensis	**S1**	2008	2		1				1					<10	cool	A, B
Allocapnia indianae	**S3**	2018	31						20		1	5	5	3-30	cool	A, B
Allocapnia mystica	**S3**	2018	19					2	10	2		3	2	3-15	cool	A, B
Allocapnia nivicola	**S3**	2018	29					13	10	1	1	4		3-30	cool	A, B
Allocapnia ohioensis	**S3**	2018	20						18			2		3-10	cool	A, B
Allocapnia recta	**S5**	2018	102					54	21	5	1	14	7	>1	warmwater	A, B
Allocapnia rickeri	**S5**	2018	135					12	72	8	9	25	9	>1	cool	A, B, C
Allocapnia smithi	**S2**	2018	6									1	5	3-10	cool	B, C
Allocapnia vivipara	**S5**	2018	226		4	2	5	103	78	14	8	8	4	>1	warmwater	A, B
Nemocapnia carolina	**SX**	1940	3					1	2					>30	warmwater	A
Paracapnia angulata	**S1**	2010	1						1					1-10	cool	A
Chloroperlidae																
Alloperla caudata	**S3**	2018	18						6			9	3	3-20	cool	A, B
Alloperla hamata	**S2**	2018	5						1			3	1	3-20	cool	B
Haploperla brevis	**S3**	2018	46					19	12	1		2	12	>1	cool	A, B, C
Sweltsa hoffmani	**S2**	2018	13					4	5		1	3		1-10	cool/cold	A
Leuctridae																
Leuctra alta	**S1**	2002	2								1	1		1-2	cool	C
Leuctra rickeri	**S3**	2018	36					1	10	1	5	9	10	1-15	cool	A, B, C
Leuctra sibleyi	**S2**	2018	6						3		1	2		1-10	cool	A
Leuctra tenuis	**S1**	2009	3					2				1		1-10	cool	A, B
Paraleuctra sara	**S2**	2018	4					2				2		1-10	cool	A

Zealeuctra claasseni	**S3**	2018	46					6	14	3	3	10	10	1-20	cool	A, B, C
Zealeuctra fraxina	**S3**	2018	18						11			3	3	1-10	cool	A, B, C
Nemouridae																
Amphinemura delosa	**S4**	2018	73	1			1	14	25	5	6	15	6	2-40	cool	A, B
Amphinemura varshava	**S4**	2018	50		1			14	13	3	5	9	5	2-40	warmwater	A, B
Ostrocerca truncata	**S2**	2018	7						2			4	1	3-10	cool	A, B, C
Prostoia completa	**S2**	2009	11		1			1	5	1		2	1	>5	cool	A
Prostoia similis	**S3**	2018	39					19	15	3			2	>2	cool	A
Soyedina vallicularia	**S3**	2017	23					14	7	1		1		<2	cool	A
Perlidae																
Acroneuria abnormis	**S2**	2018	19				4	7	7			1		>5	warmwater	A
Acroneuria covelli	**S1**	2003	3								1	2		>30	warmwater	A
Acroneuria evoluta	**S2**	2007	9					1	8					>30	warmwater	A
Acroneuria filicis	**SH**	1969	3					1	1			1		>30	warmwater	A
Acroneuria frisoni	**S4**	2018	71			2		9	36	4	2	18		5-40	cool	A, B
Acroneuria hitchcocki	**S1**	1987	1							1				>30	warmwater	A
Acroneuria internata	**S3**	2018	17		9		1	2	1			4		>10	cool	A
Acroneuria lycorias	**S1**	2018	1		1									>30	cool	A
Acroneuria ozarkensis	**S1**	2017	1						1					>30	warmwater	A
Acroneuria perplexa	**S3**	2017	20					3	15			1	1	>30	warmwater	A
Agnetina annulipes	**S1**	2018	3						1			2		>30	cool	A
Agnetina capitata	**S2**	2018	4		2		1					1		>30	cool	A
Agnetina flavescens	**S2**	2010	20					3	10	1		6		>10	warmwater	A
Attaneuria ruralis	**SX**	1944	3					2	1					>30	warmwater	A
Neoperla catharae	**S2**	2000	5					2	2			1		>30	warmwater	A
Neoperla clymene	**S3**	2018	17					5	10			2		>30	warmwater	A
Neoperla coosa	**S1**	2018	2									2		>30	warmwater	A
Neoperla gaufini	**S2**	2001	7						3		1	3		>10	cool	A
Neoperla occipitalis	**SX**	1935	1					1						>30	cool	A
Neoperla osage	**S1**	2002	1									1		>30	warmwater	A
Neoperla robisoni	**SH**	1978	3					2				1		>30	warmwater	A
Neoperla stewarti	**S2**	2018	6					1	1			4		>30	warmwater	A
Paragnetina kansensis	**SX**	1944	5					1	4					>30	warmwater	A
Paragnetina media	**S2**	2018	8		8									>20	cool	A
Perlesta adena	**S3**	2010	15						7		3	4	1	< 10	warmwater	A, B
Perlesta armitagei	**S3**	2018	14		1			2	6	1		4		>20	warmwater	A
Perlesta decipiens	**S4**	2018	46		6	1	8	17	11	2		1		>10	warmwater	A

Perlesta ephelida	**S3**	2018	31		8	1	4	10	6	2				>5	cool	A
Perlesta golconda	**S1**	2018	4		1			1	1		1			>10	warmwater	A
Perlesta IN-5	**S2**	2018	4					1	2	1				>30	warmwater	A
Perlesta lagoi	**S3**	2018	40	5		3	4	5	16	1	2	4		>1	warmwater	A, B
Perlesta ouabache	**S2**	2017	12				1	1	10					>30	warmwater	A
Perlesta shawnee	**S1**	2003	2										2	3-10	cool	B
Perlesta teaysia	**S2**	2010	13						9			4		3-10	cool	A, B
Perlesta xube	**S1**	2009	2				1		1					3-10	cool	A, B
Perlinella drymo	**S3**	2018	40		3	1	1	12	17		1	5		>3	warmwater	A
Perlinella ephyre	**S3**	2018	25		3		2	5	11	2		2		>3	warmwater	A
Perlodidae																
Clioperla clio	**S4**	2018	86	1				40	27	6	2	9	1	>1	cool	A, B
Diploperla robusta	**S3**	2018	36					6	13	3	1	9	4	>2	cool	A
Helopicus nalatus	**SX**	1949	2									2		>20	warmwater	A
Hydroperla crosbyi	**S2**	2018	11					7	4					>10	warmwater	A
Hydroperla fugitans	**S2**	2010	11					7	4					>30	warmwater	A
Isogenoides varians	**S1**	2010	5					3	2					>30	warmwater	A
Isoperla bilineata	**S4**	2018	58		3		3	24	19	1	1	3	4	>5	warmwater	A
Isoperla burksi	**S2**	2010	7						4		1	2		5-20	cool	A
Isoperla decepta	**S4**	2018	80					3	29	6	9	18	15	2-20	cool	A, B
Isoperla dicala	**S2**	2018	11		7	1	1	1				1		>20	cool	A
Isoperla frisoni	**S1**	2018	5	3	1		1							5-30	cool	A
Isoperla marlynia	**SX**	1940	2		1				1					>30	warmwater	A
Isoperla montana	**S2**	2010	11					8	2			1		2-30	cool	A, B
Isoperla namata	**SX**	1938	1						1					2-10	cool	A
Isoperla nana	**S3**	2018	26		8		2	8	7		1			>1	warmwater	A, B
Isoperla richardsoni	**SX**	1938	2						2					>30	warmwater	A
Pteronarcyidae																
Pteronarcys dorsata	**S1**	2018	4		3			1						>30	cool	A
Pteronarcys pictetii	**S3**	2018	18		3		3	6	6					>10	warmwater	A
Taeniopterygidae																
Strophopteryx fasciata	**S4**	2018	56		2		2	25	21		1	5		>5	cool	A
Taeniopteryx burksi	**S5**	2018	183	1	11	4	13	80	63	2	1	3	5	>2	warmwater	A, B
Taeniopteryx lita	**S2**	2018	14					1	12				1	>5	warmwater	A
Taeniopteryx maura	**S2**	2018	8						4			4		>10	warmwater	A
Taeniopteryx metequi	**S2**	2010	6						6					1-20	cool	A
Taeniopteryx nivalis	**S3**	2018	23		14	1	2	6						>5	cool	A

Taeniopteryx parvula	**SH**	1963	8						8					>10	cool	A
Total number species			**92**	**5**	**25**	**10**	**21**	**57**	**73**	**28**	**28**	**60**	**28**			

Table 3. Summary of the number of stonefly species in conservation status categories in Indiana.

Category	**Status**	**Number of species**
SX	Presumed Extirpated	8
SH	Possibly Extirpated	3
S1	Critically Imperiled	17
S2	Imperiled	26
S3	Vulnerable	25
S4	Apparently Secure	8
S5	Secure	5

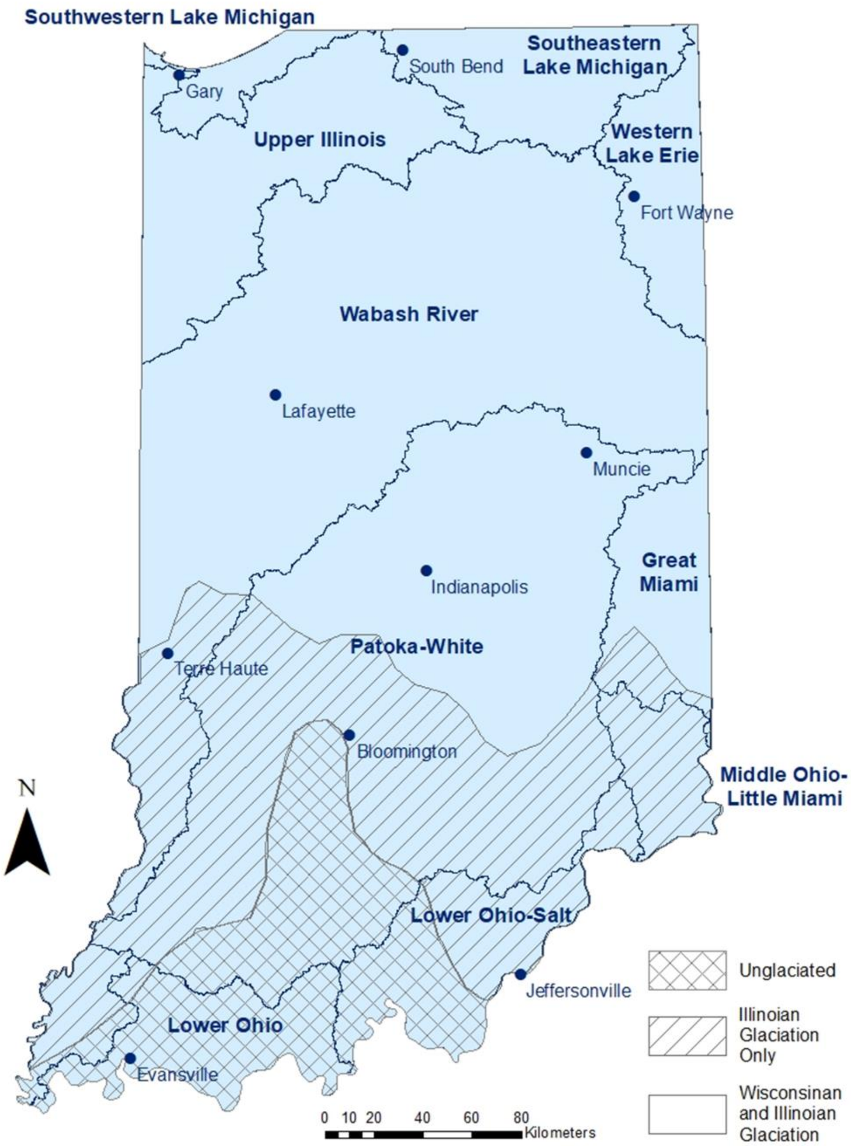

Figure 1. Glacial history, HUC6 drainages, and regional cities of Indiana.

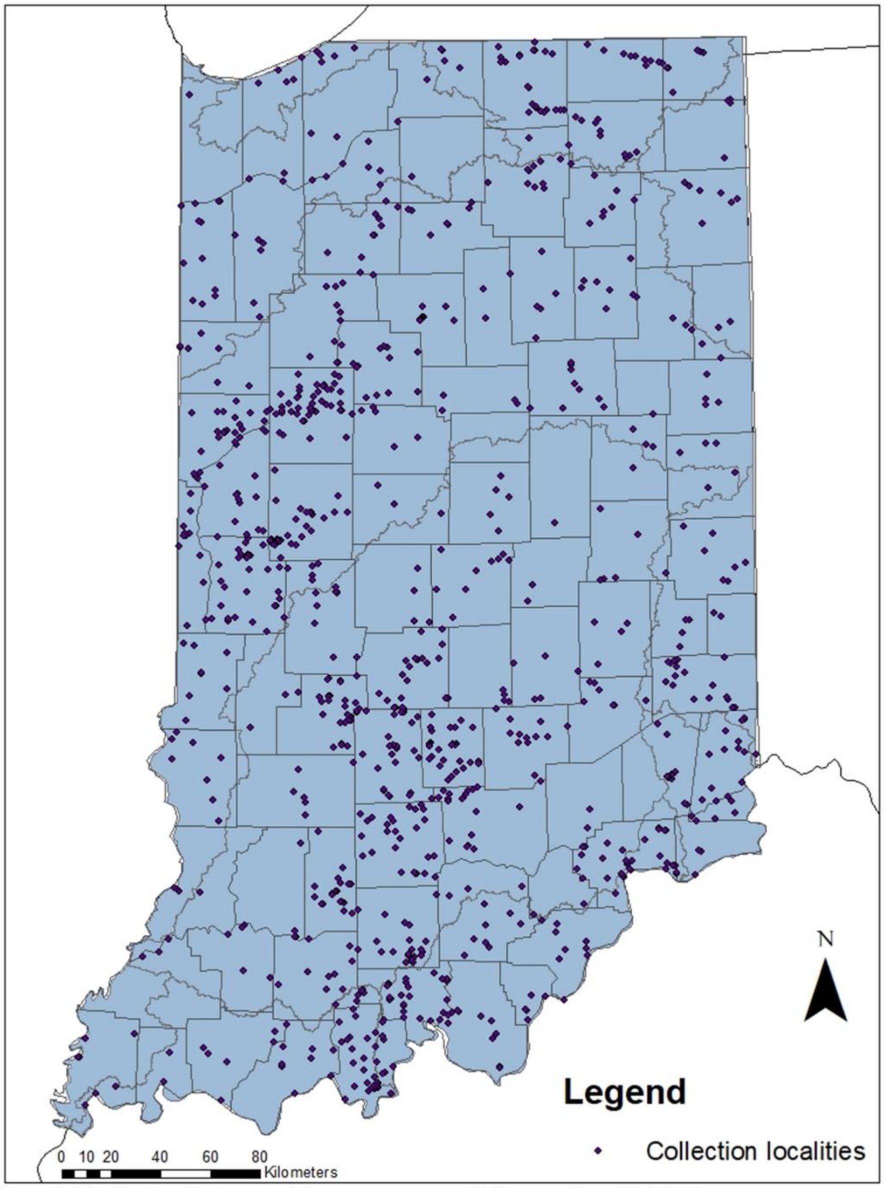

Figure 2. Distribution of unique positive occurrence records for stoneflies within Indiana.

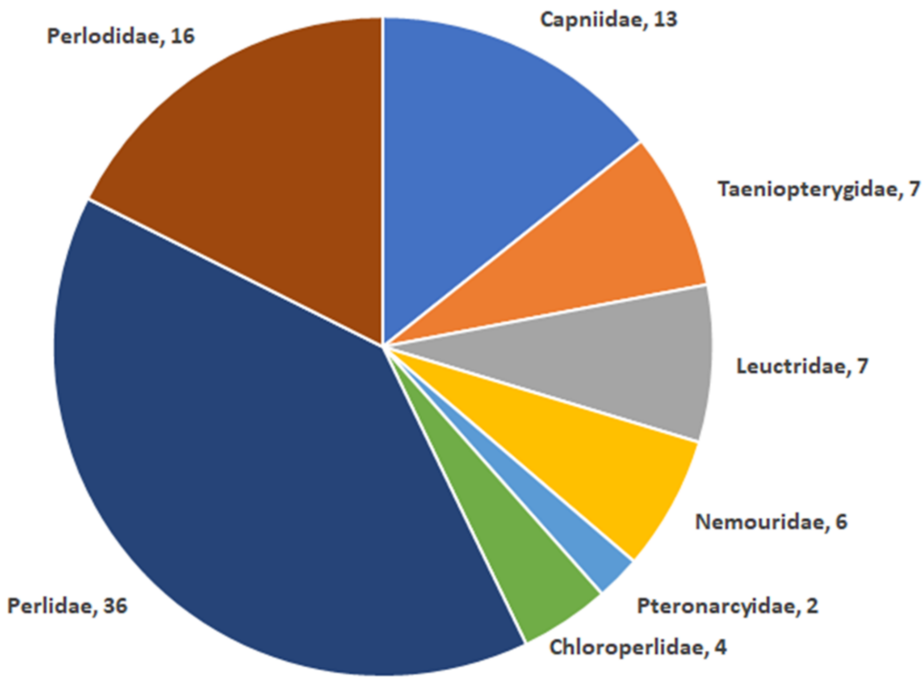

Figure 3. Distribution of stonefly species within families.

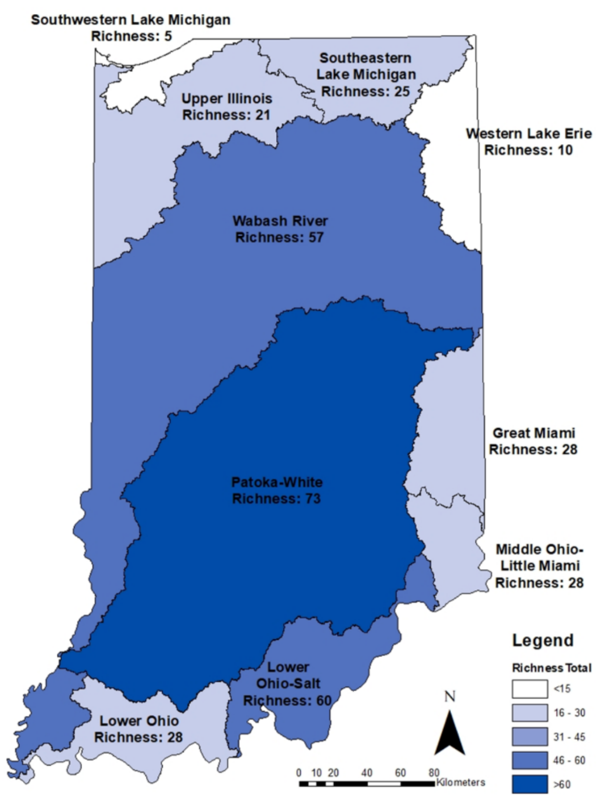

Figure 4. Distribution of stonefly species richness within USGS HUC6 drainages in Indiana.

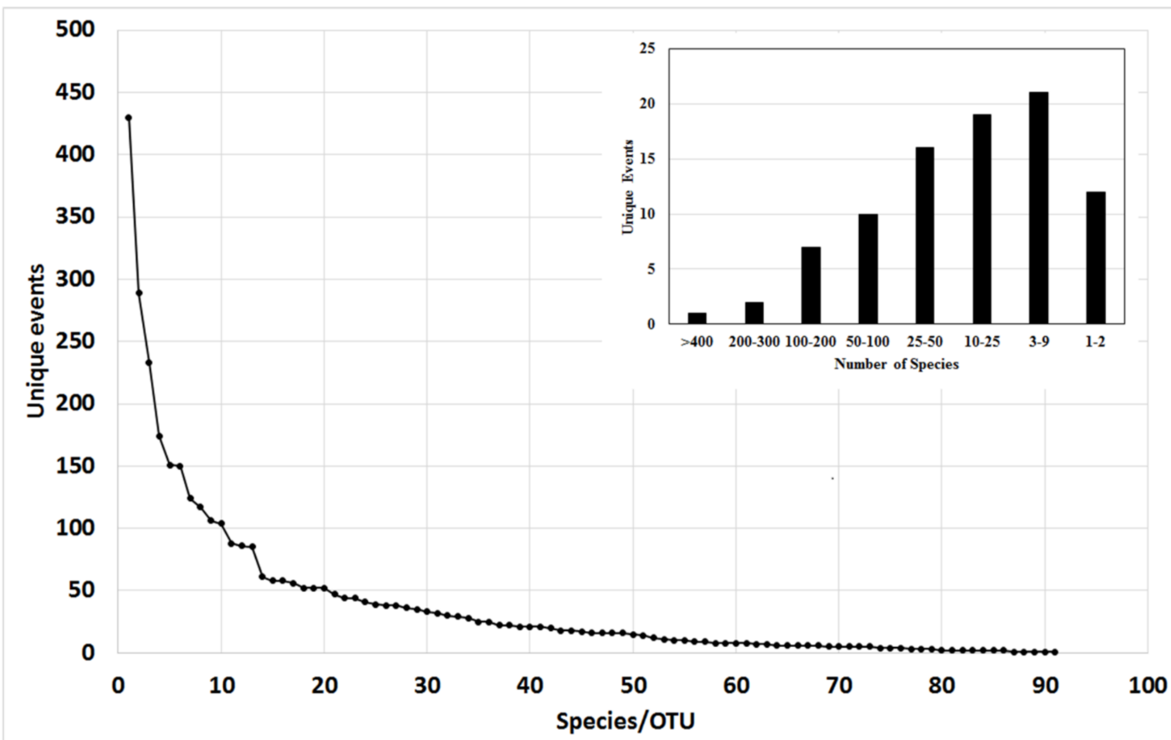

Figure 5. Species prevalence, unique collection events vs. species expressed as Operational Taxonomic Units

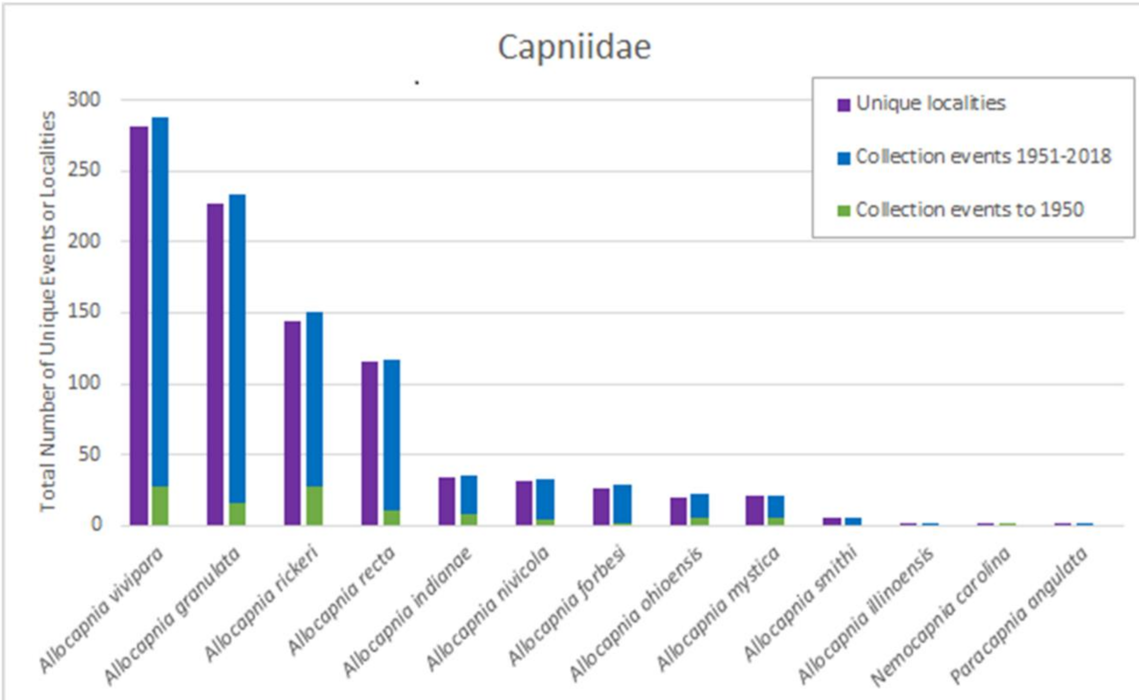

Figure 6. Number of unique localities and collection events by species in the family Capniidae

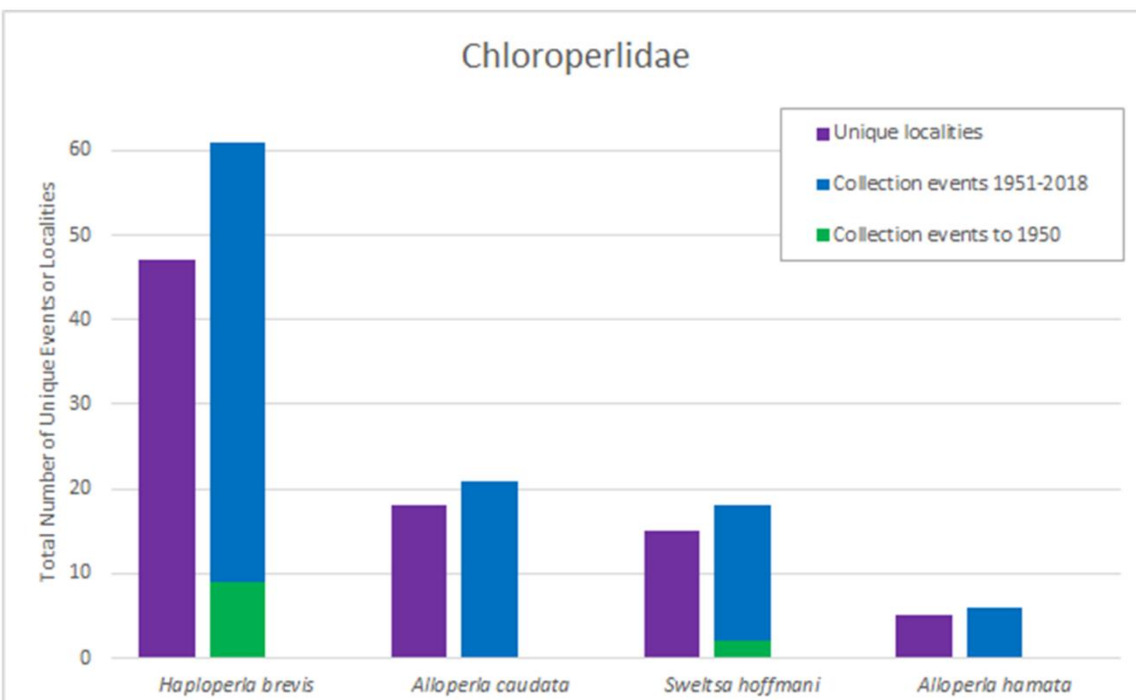

Figure 7. Number of unique localities and collection events by species in the family Chloroperlidae

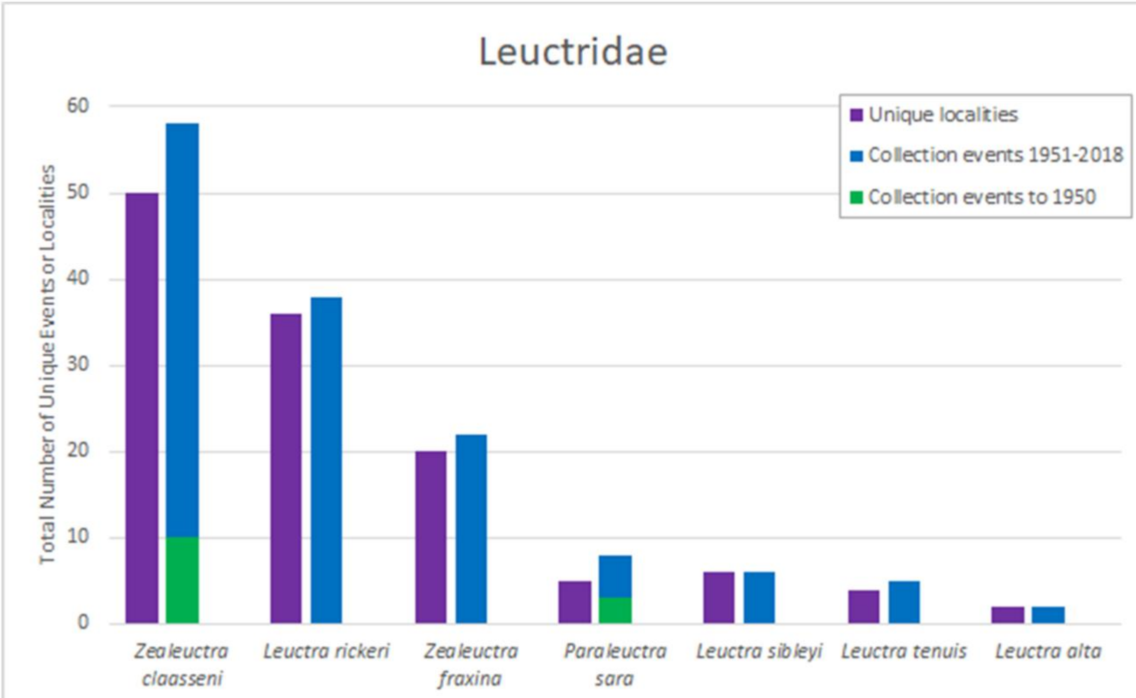

Figure 8. Number of unique localities and collection events by species in the family Leuctridae

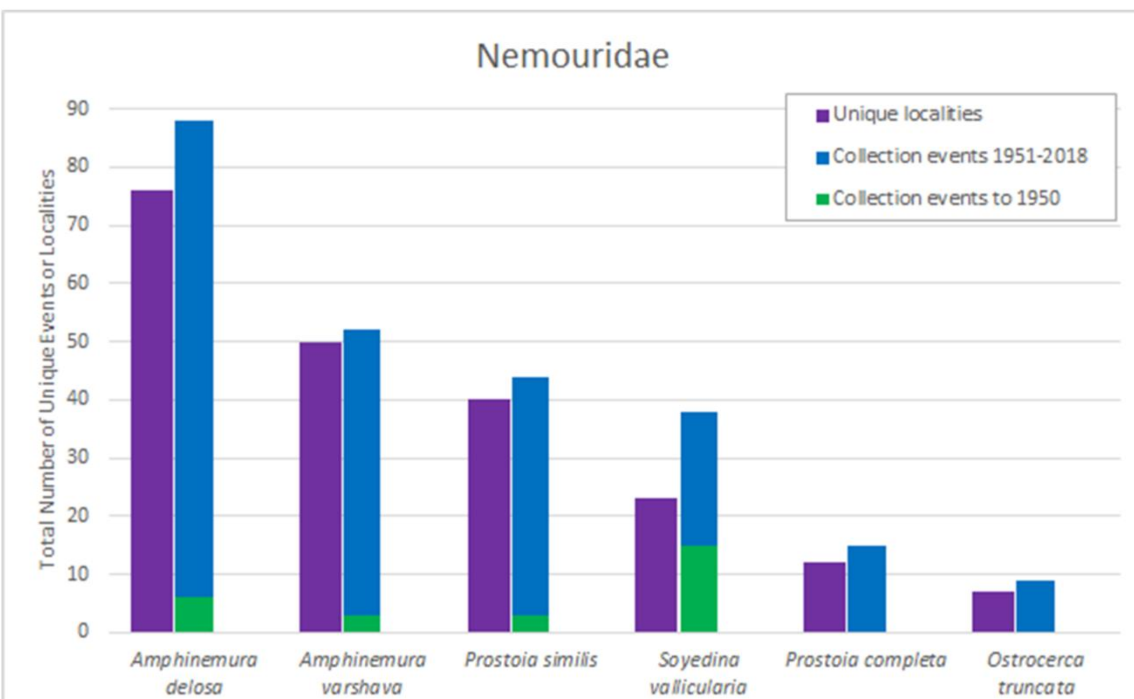

Figure 9. Number of unique localities and collection events by species in the family Nemouridae

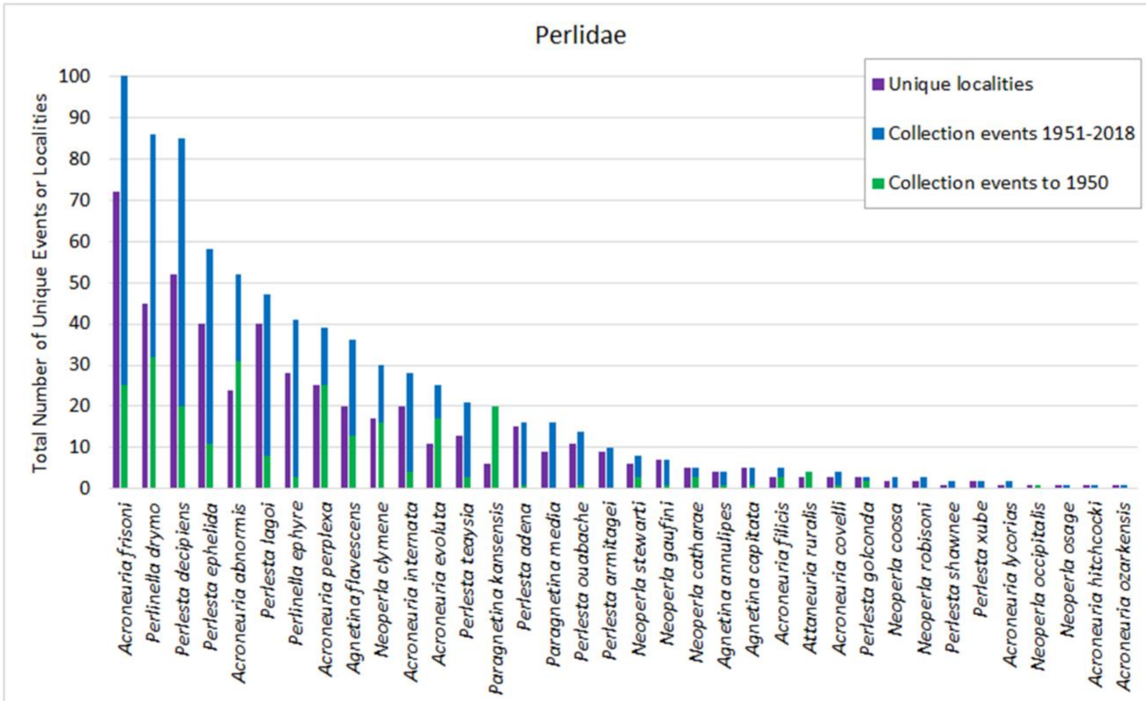

Figure 10. Number of unique localities and collection events by species in the family Perlidae

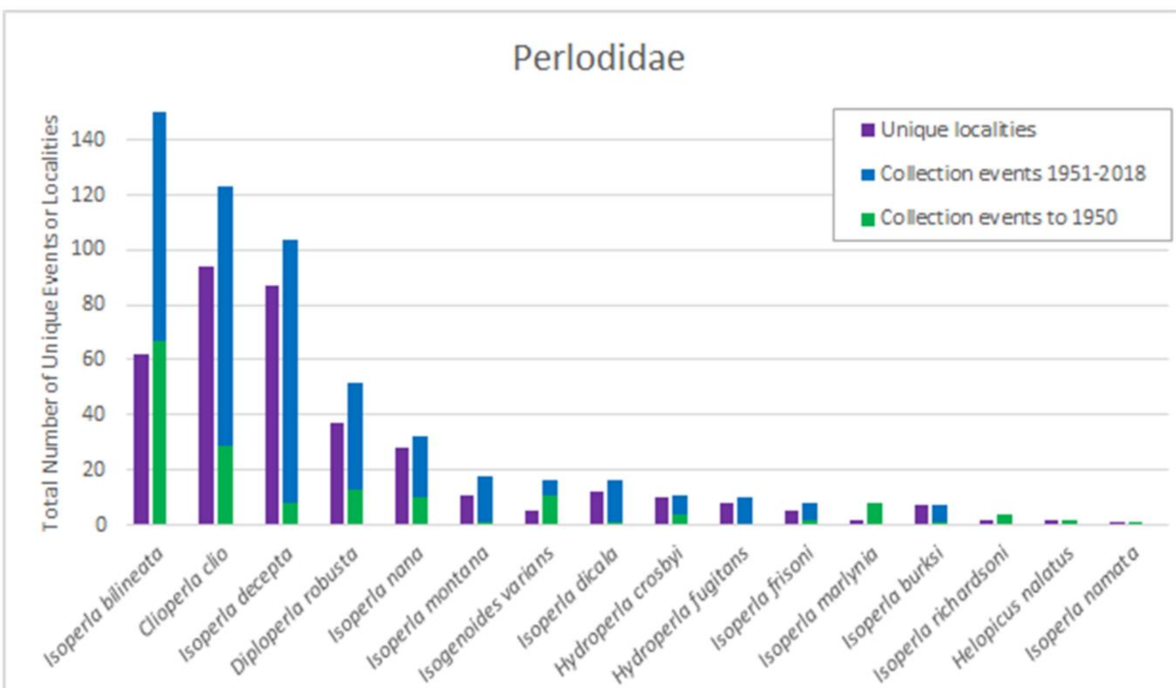

Figure 11. Number of unique localities and collection events by species in the family Perlodidae

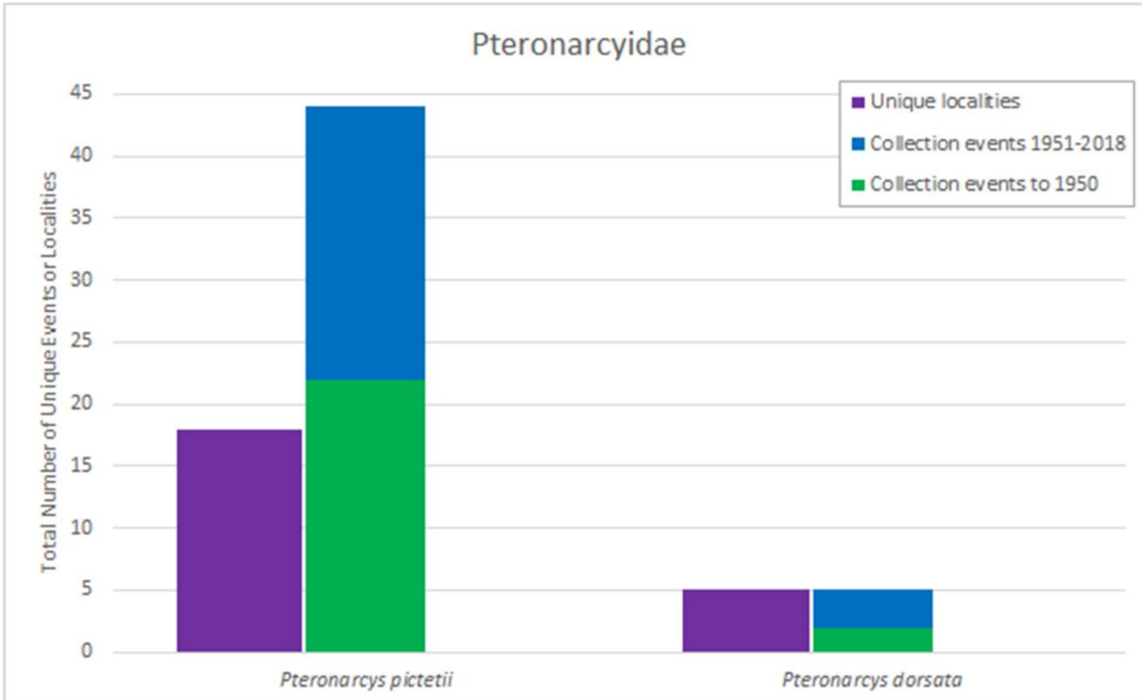

Figure 12. Number of unique localities and collection events by species in the family Pteronarcyidae

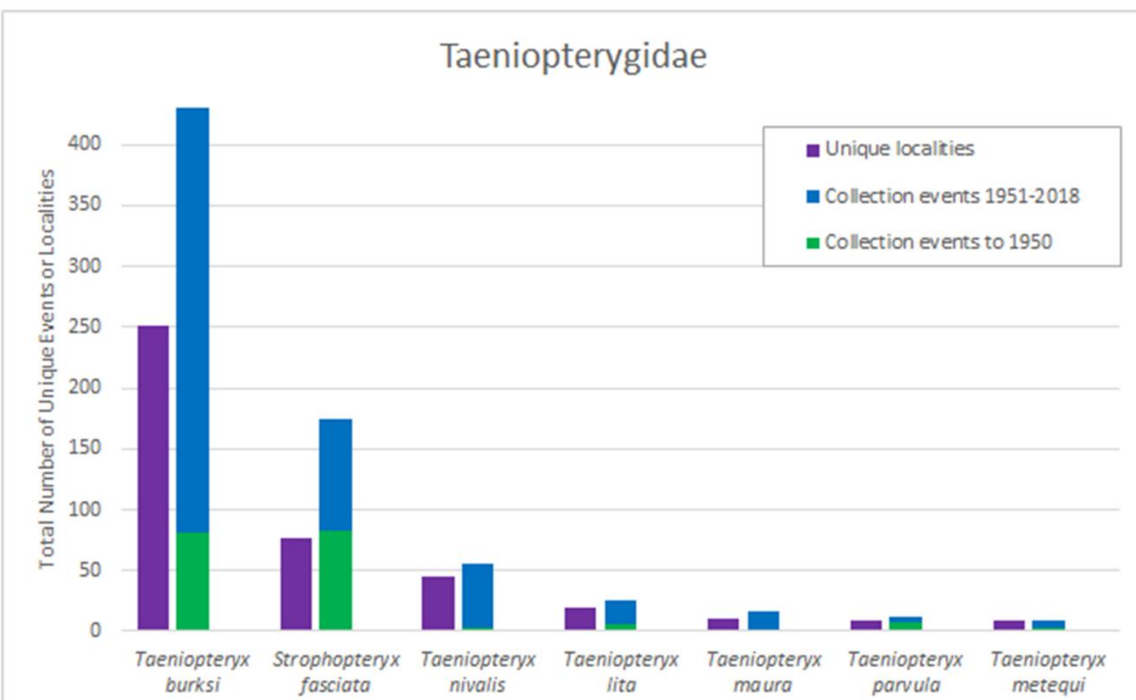

Figure 13. Number of unique localities and collection events by species in the family Taeniopterygidae

Capniidae

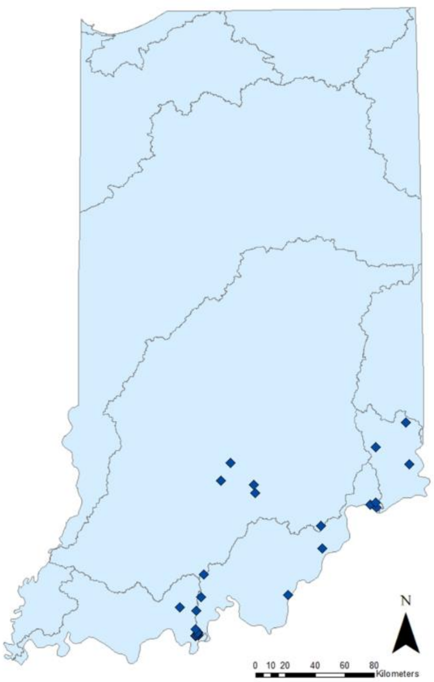

Figure 14. Distribution of *Allocapnia forbesi*

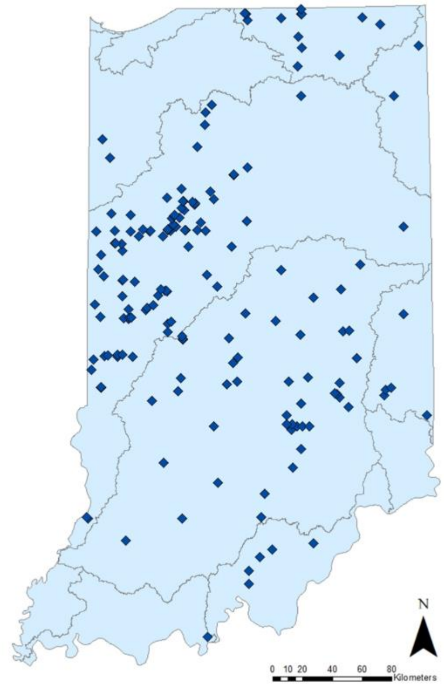

Figure 15. Distribution of *Allocapnia granulata*

Figure 16. Distribution of *Allocapnia illinoensis*

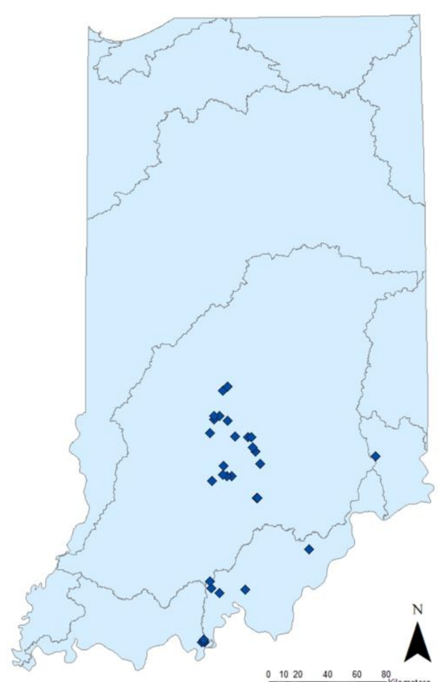

Figure 17. Distribution of *Allocapnia indianae*

Capniidae, cont.

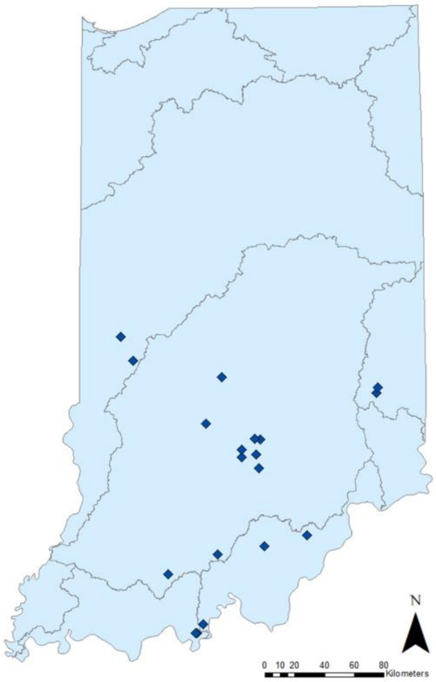

Figure 18. Distribution of *Allocapnia mystica*

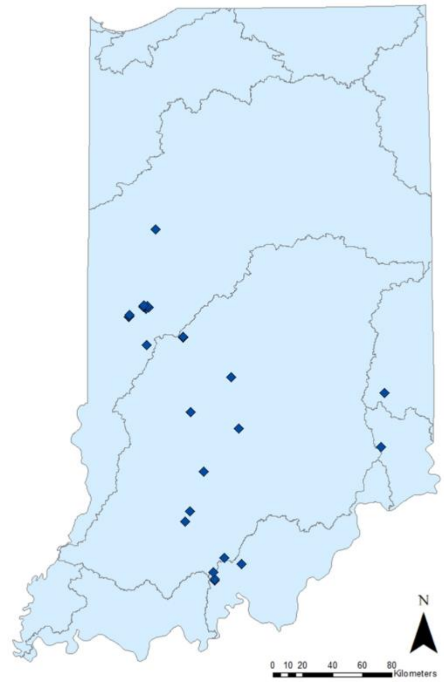

Figure 19. Distribution of *Allocapnia nivicola*

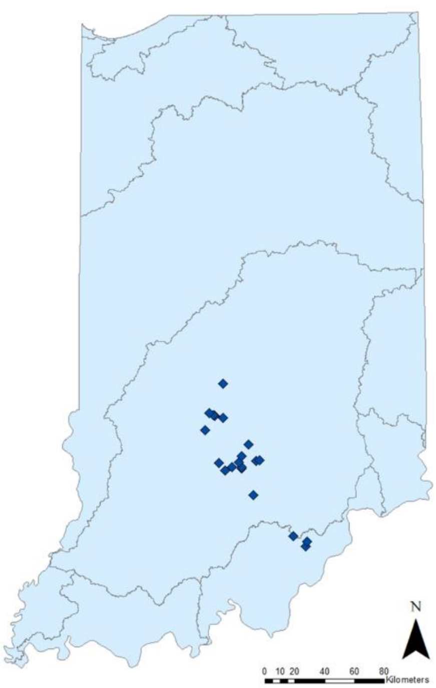

Figure 20. Distribution of *Allocapnia ohioensis*

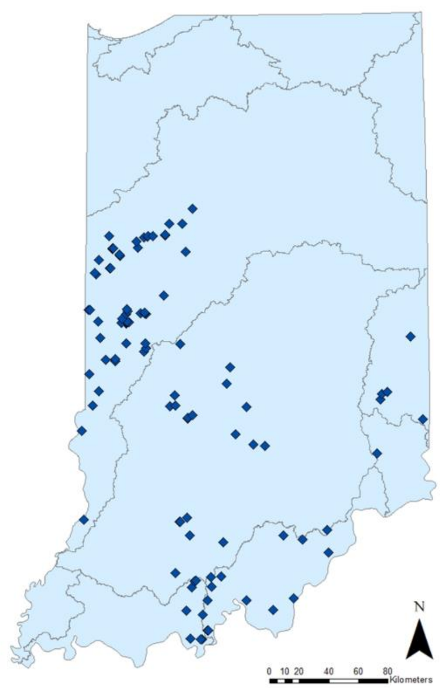

Figure 21. Distribution of *Allocapnia recta*

Capniidae, cont.

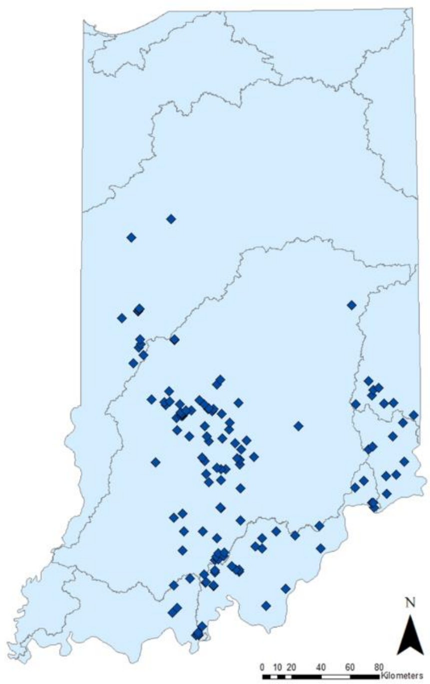

Figure 22. Distribution of *Allocapnia rickeri*

Figure 23. Distribution of *Allocapnia smithi*

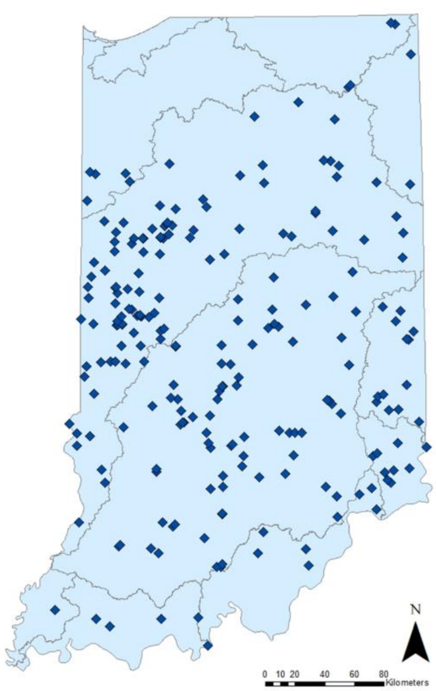

Figure 24. Distribution of *Allocapnia vivipara*

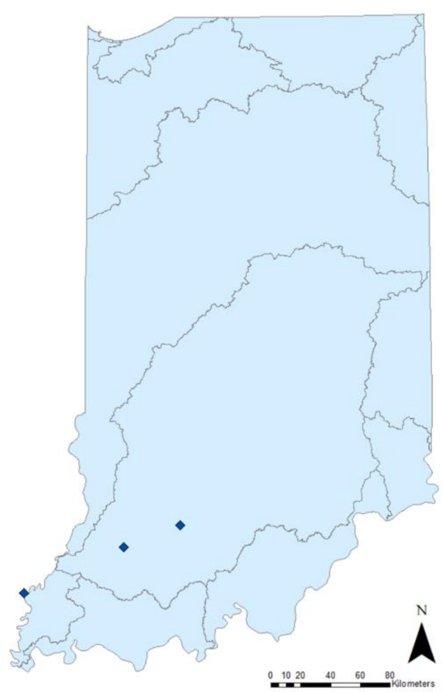

Figure 25. Distribution of *Nemocapnia carolina*

Capniidae, cont.

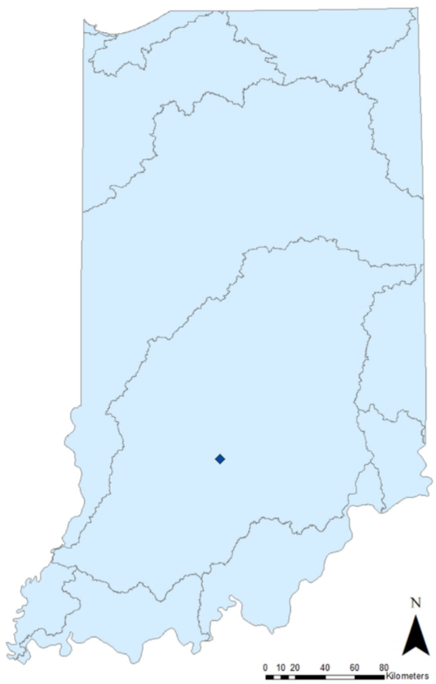

Figure 26. Distribution of *Paracapnia angulata*

Chloroperlidae

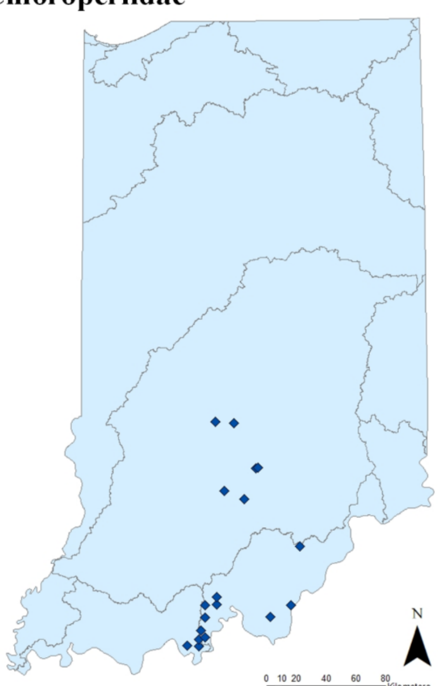

Figure 27. Distribution of *Alloperla caudata*

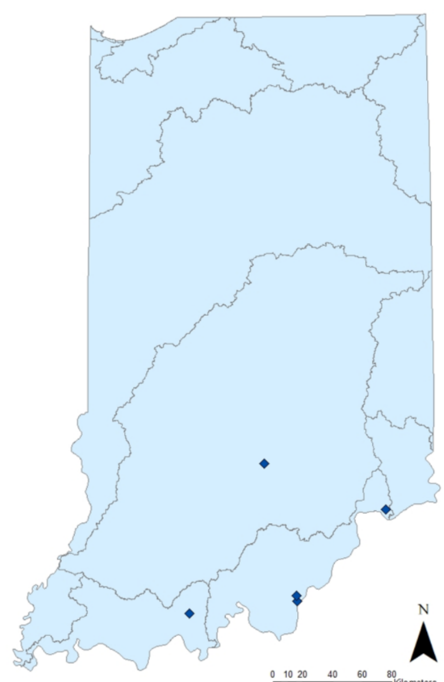

Figure 28. Distribution of *Alloperla hamata*

Chlorperlidae, cont.

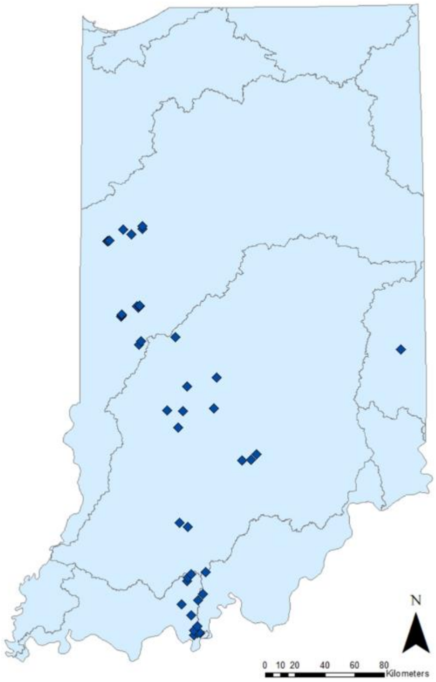

Figure 29. Distribution of *Haploperla brevis*

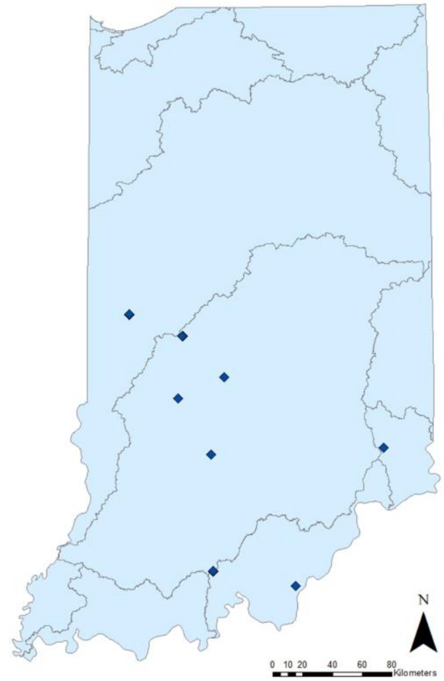

Figure 30. Distribution of *Sweltsa hoffmani*

Leuctridae

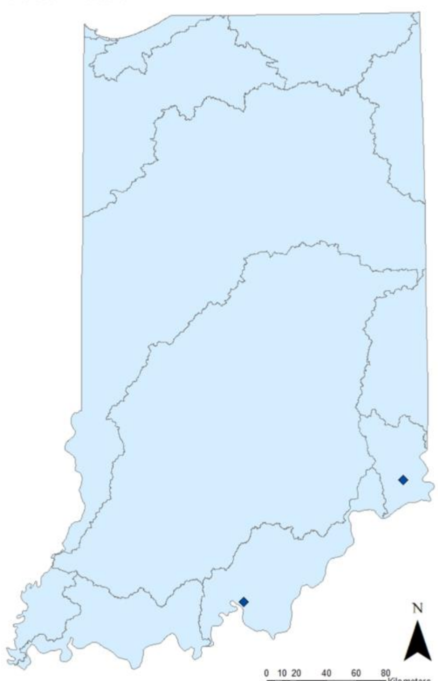

Figure 31. Distribution of *Leuctra alta*

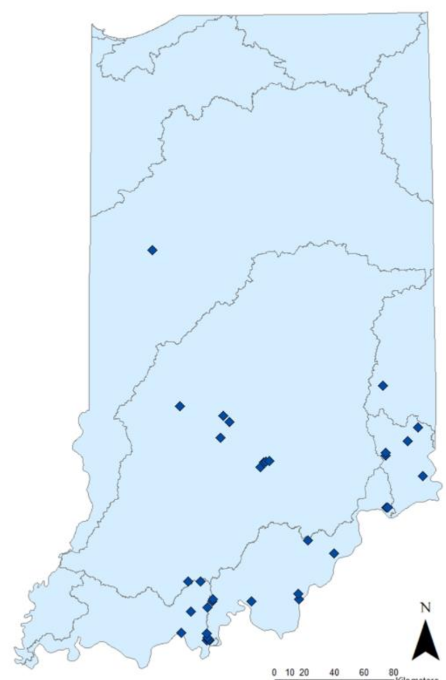

Figure 32. Distribution of *Leuctra rickeri*

Leuctridae

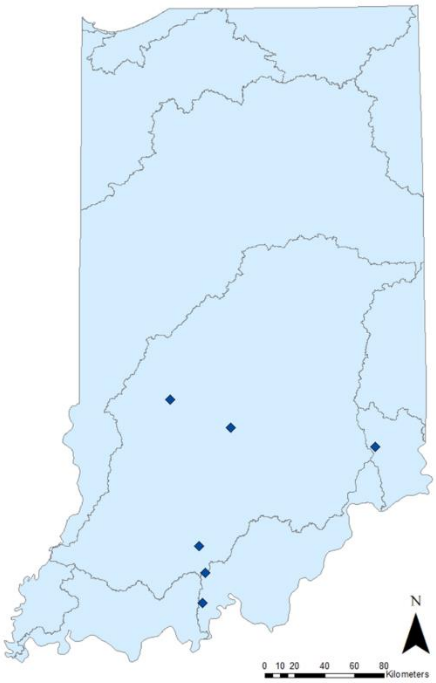

Figure 33. Distribution of *Leuctra sibleyi*

Figure 34. Distribution of *Leuctra tenuis*

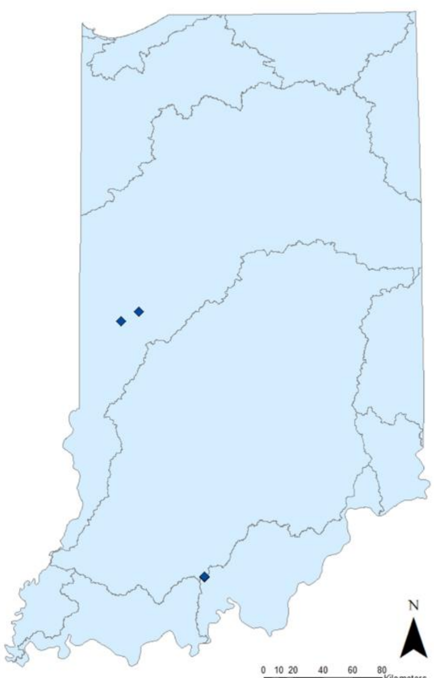

Figure 35. Distribution of *Paraleuctra sara*

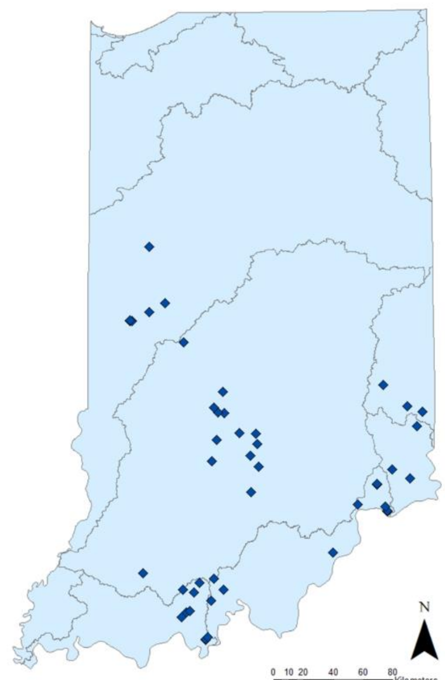

Figure 36. Distribution of *Zealeuctra claaseni*

Leuctridae, cont.

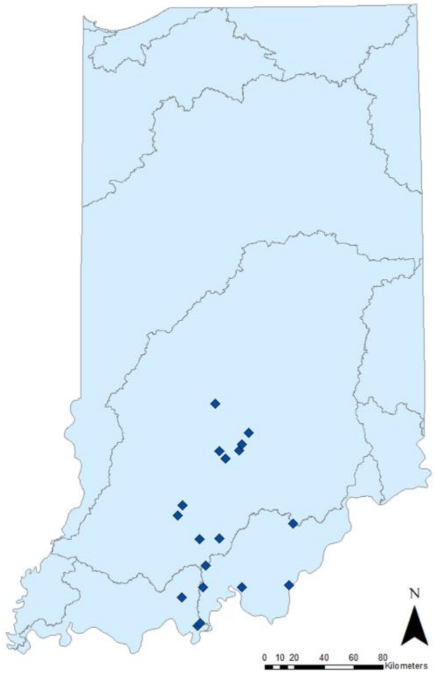

Figure 37. Distribution of *Zealeuctra fraxina*

Nemouridae

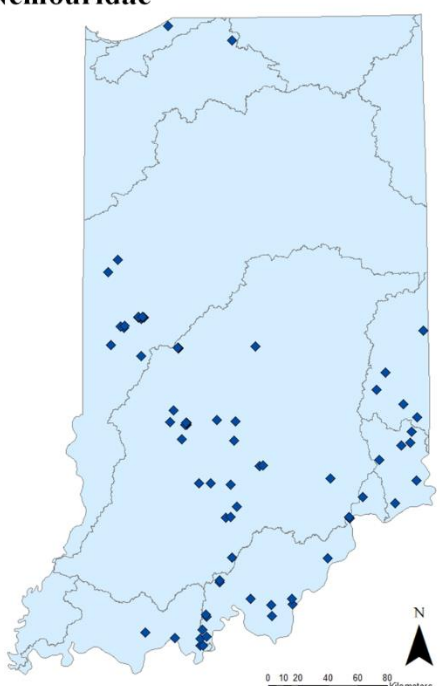

Figure 38. Distribution of *Amphinemura delosa*

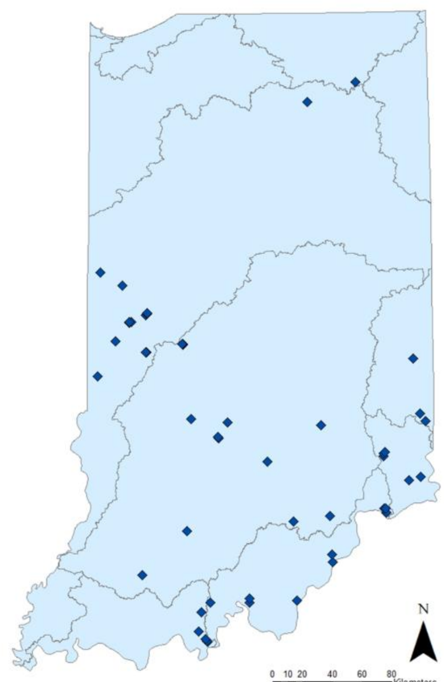

Figure 39. Distribution of *Amphinemura varshava*

Nemouridae

Figure 40. Distribution of *Ostrocerca truncata*

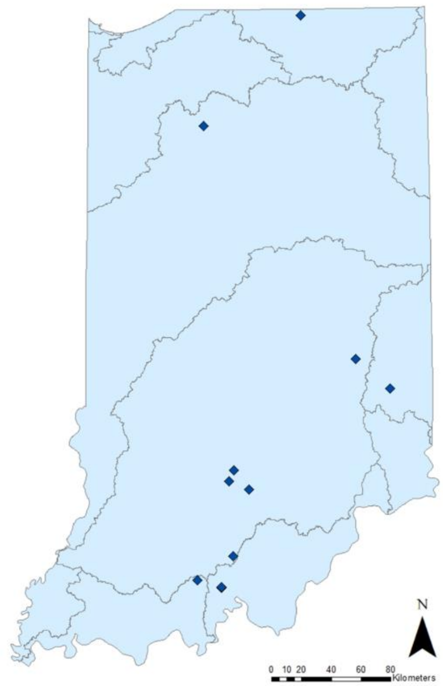

Figure 41. Distribution of *Prostoia completa*

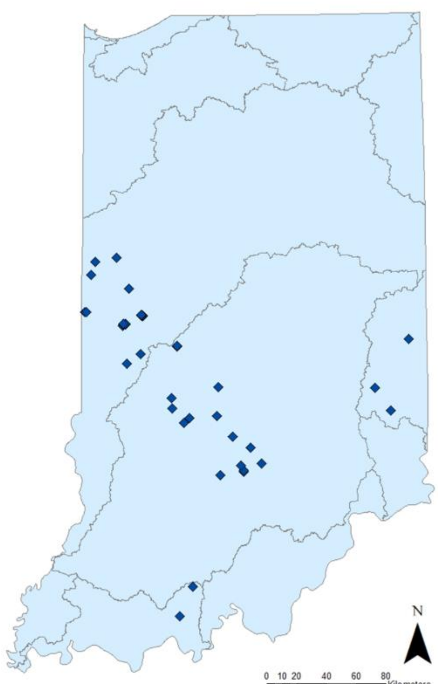

Figure 42. Distribution of *Prostoia similis*

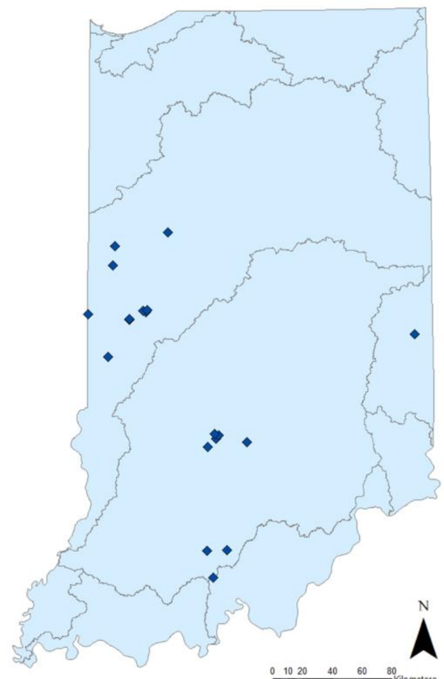

Figure 43. Distribution of *Soyedina vallicularia*

Perlidae

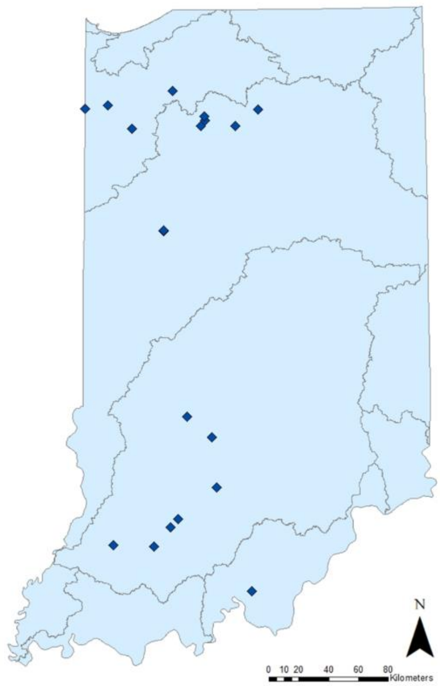

Figure 44. Distribution of *Acroneuria abnormis*

Figure 45. Distribution of *Acroneuria covelli*

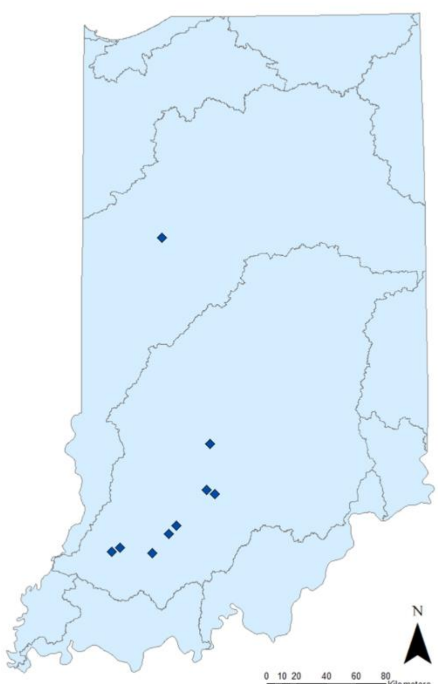

Figure 46. Distribution of *Acroneuria evoluta*

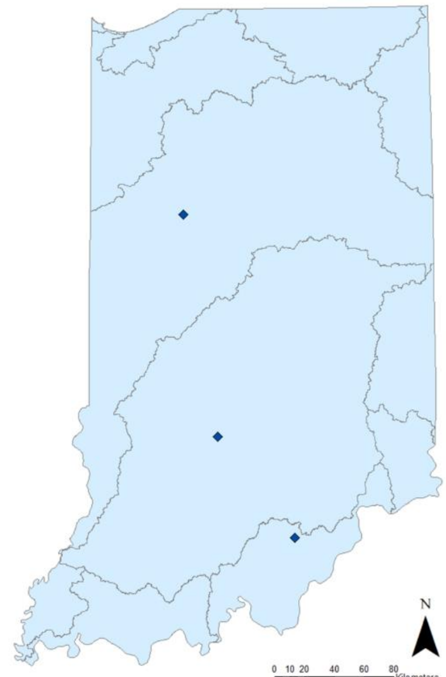

Figure 47. Distribution of *Acroneuria filicis*

Perlidae, cont.

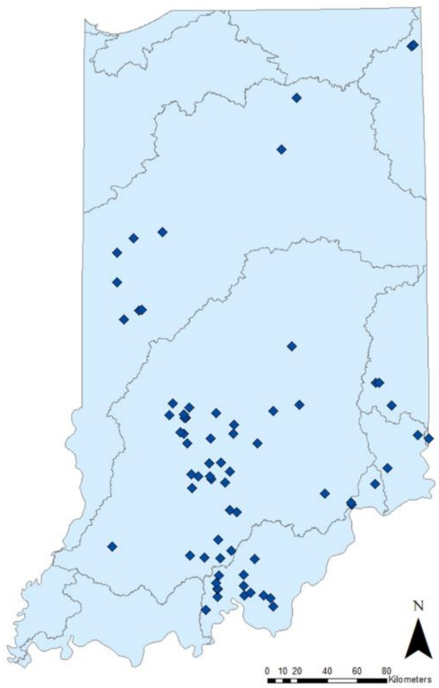

Figure 48. Distribution of *Acroneuria frisoni*

Figure 49. Distribution of *Acroneuria hitchcocki*

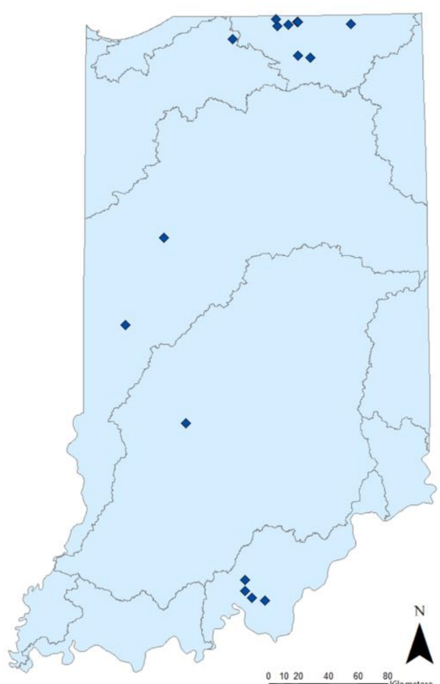

Figure 50. Distribution of *Acroneuria internata*

Figure 51. Distribution of *Acroneuria lycorias*

Perlidae, cont.

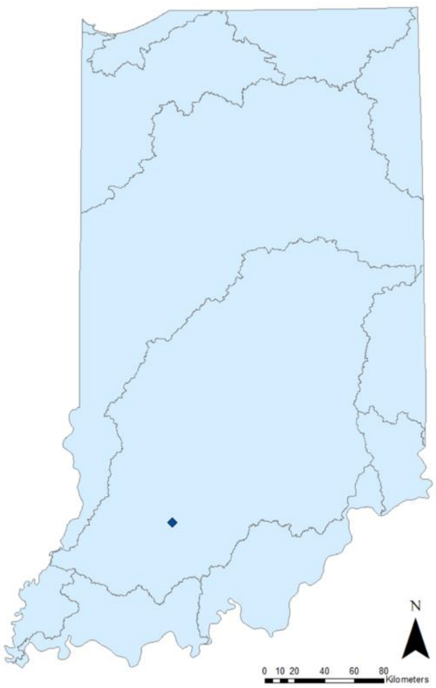

Figure 52. Distribution of *Acroneuria ozarkensis*

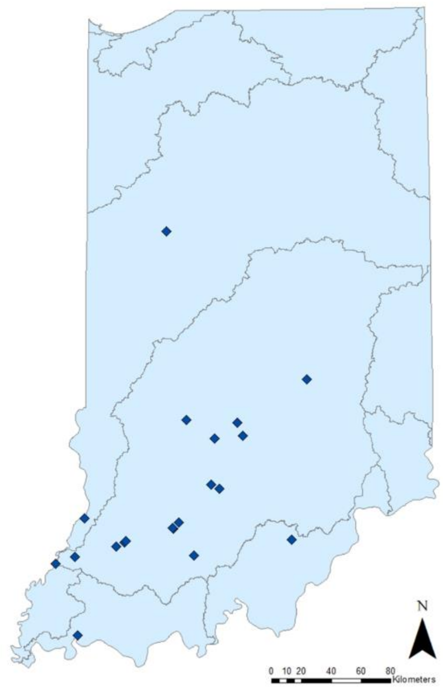

Figure 53. Distribution of *Acroneuria perplexa*

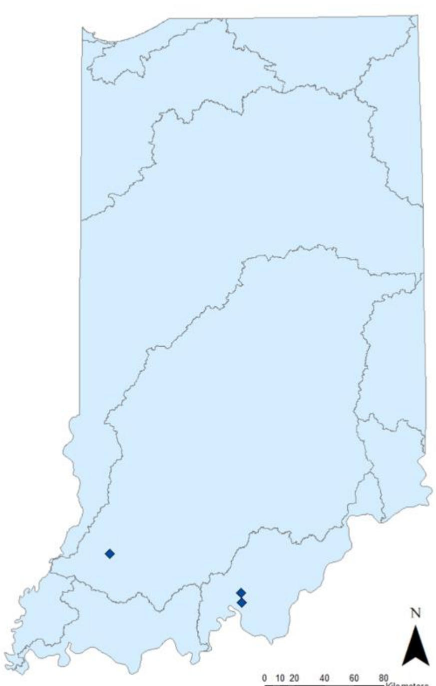

Figure 54. Distribution of *Agnetina annulipes*

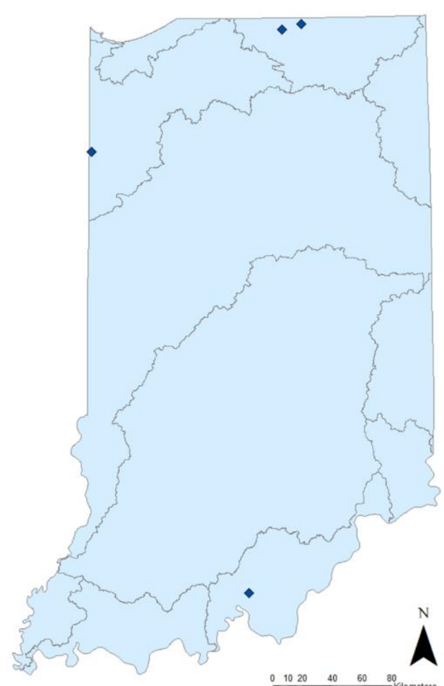

Figure 55. Distribution of *Agnetina capitata*

Perlidae, cont.

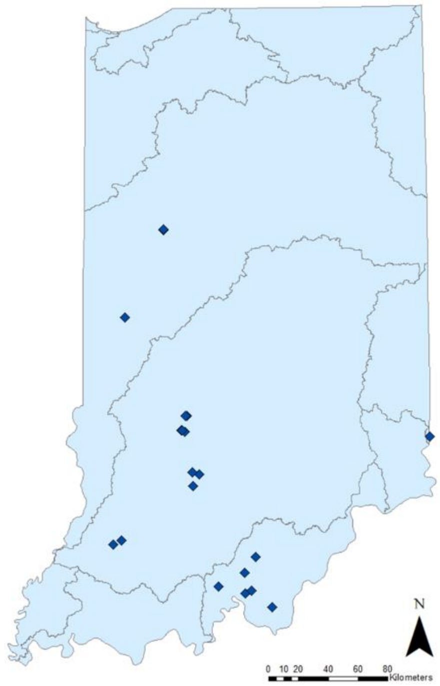

Figure 56. Distribution of *Agnetina flavescens*

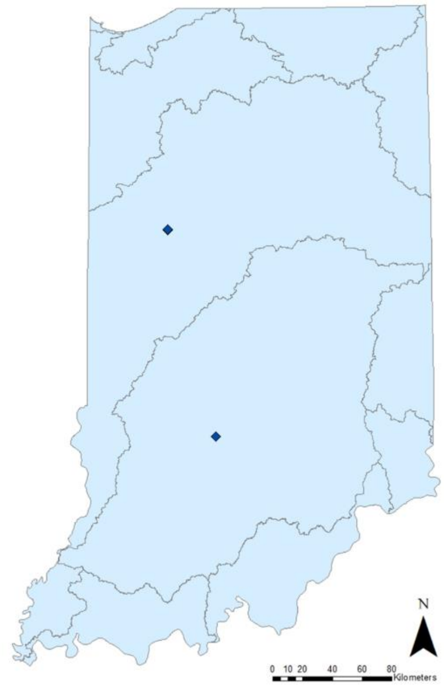

Figure 57. Distribution of *Attaneuria ruralis*

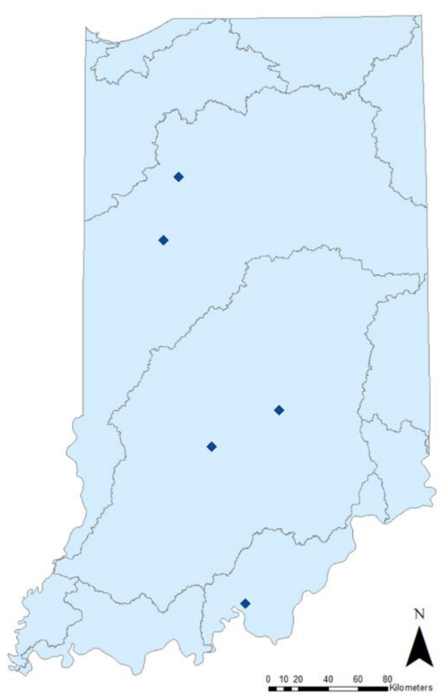

Figure 58. Distribution of *Neoperla catharae*

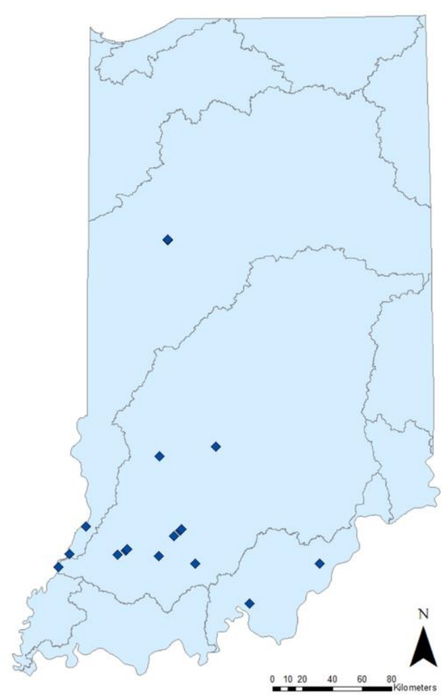

Figure 59. Distribution of *Neoperla clymene*

Perlidae, cont.

Figure 60. Distribution of *Neoperla coosa*

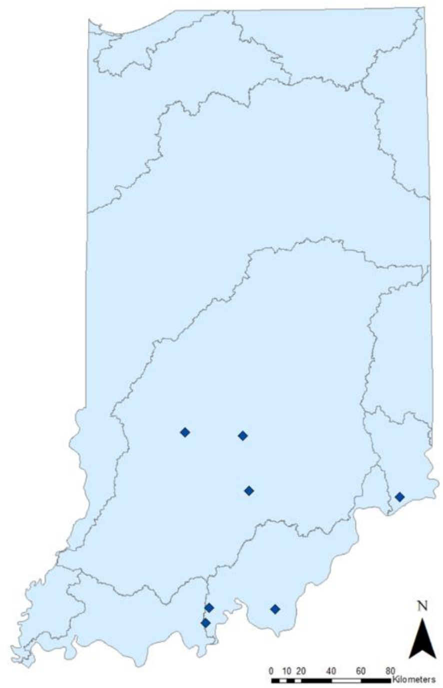

Figure 61. Distribution of *Neoperla gaufini*

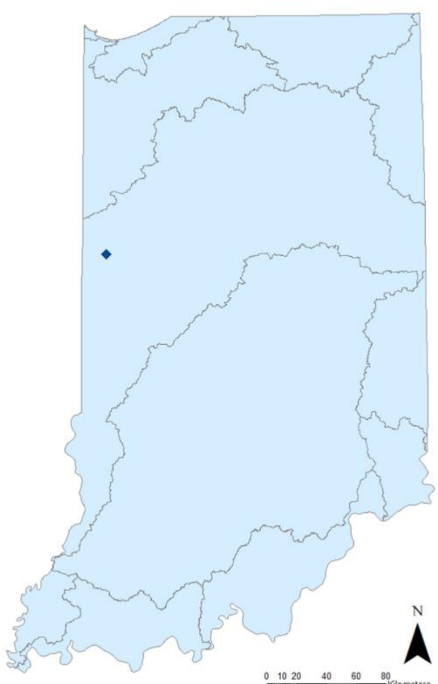

Figure 62. Distribution of *Neoperla occipitalis*

Figure 63. Distribution of *Neoperla osage*

Perlidae, cont.

Figure 76. Distribution of *Perlesta shawnee*

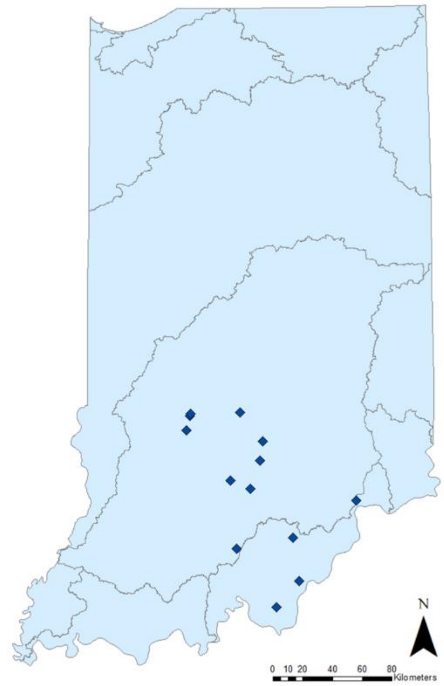

Figure 77. Distribution of *Perlesta teaysia*

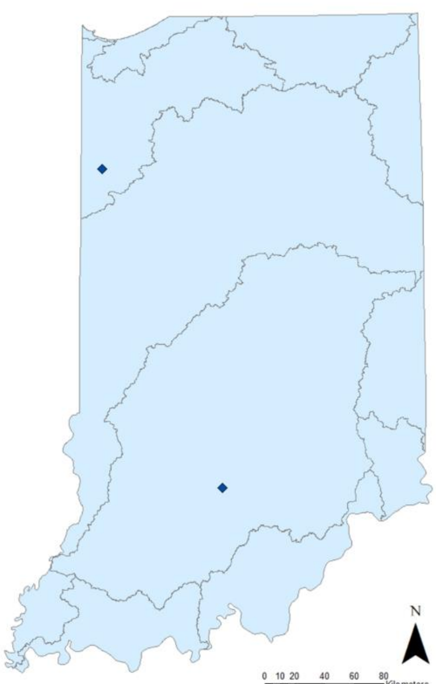

Figure 78. Distribution of *Perlesta xube*

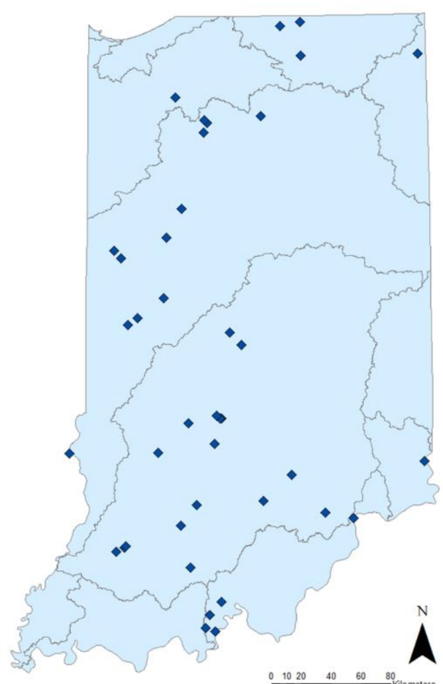

Figure 79. Distribution of *Perlinella drymo*

Perlidae, cont.

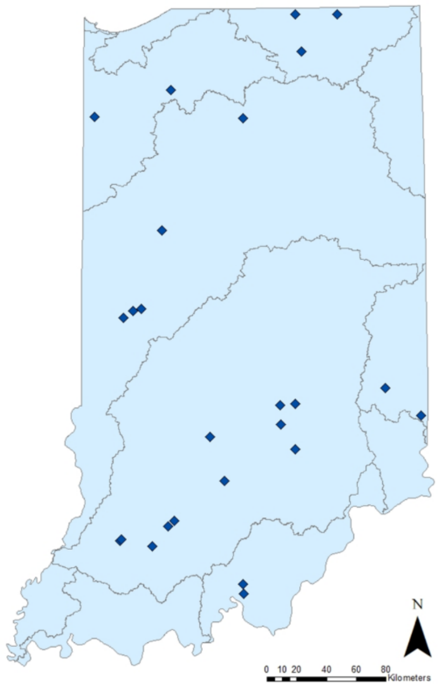

Figure 80. Distribution of *Perlinella ephyre*

Perlodidae

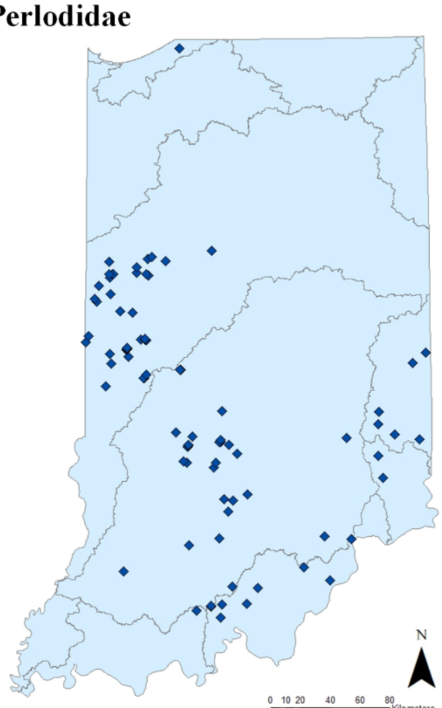

Figure 81. Distribution of *Clioperla clio*

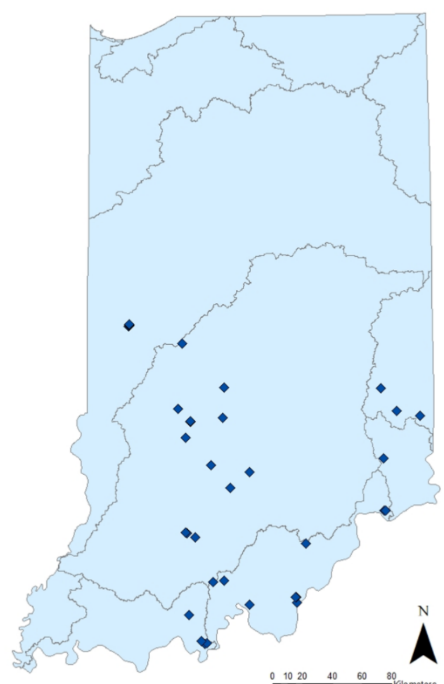

Figure 82. Distribution of *Diploperla robusta*

Perlodidae, cont

Figure 83. Distribution of *Helopicus nalatus*

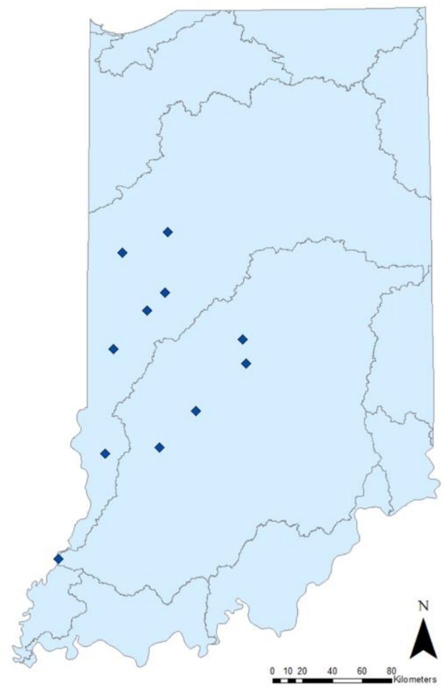

Figure 84. Distribution of *Hydroperla crosbyi*

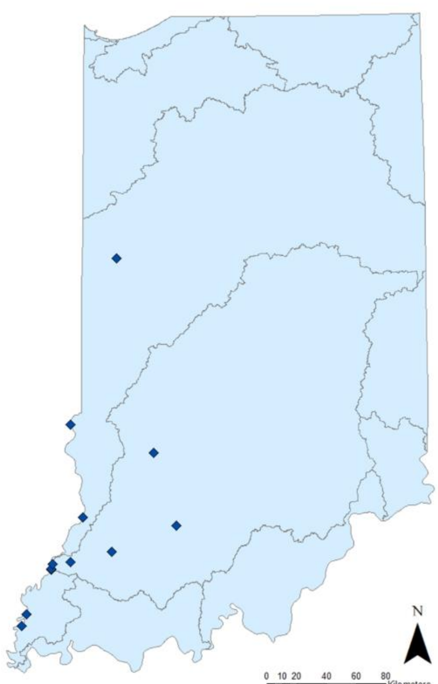

Figure 85. Distribution of *Hydroperla fugitans*

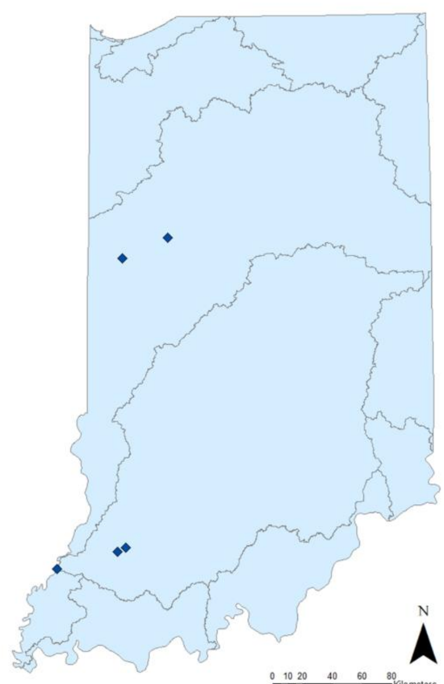

Figure 86. Distribution of *Isogenoides varians*

Perlodidae, cont.

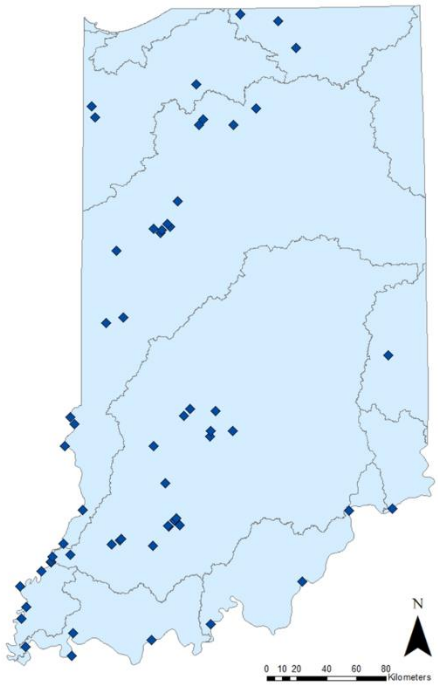

Figure 87. Distribution of *Isoperla bilineata*

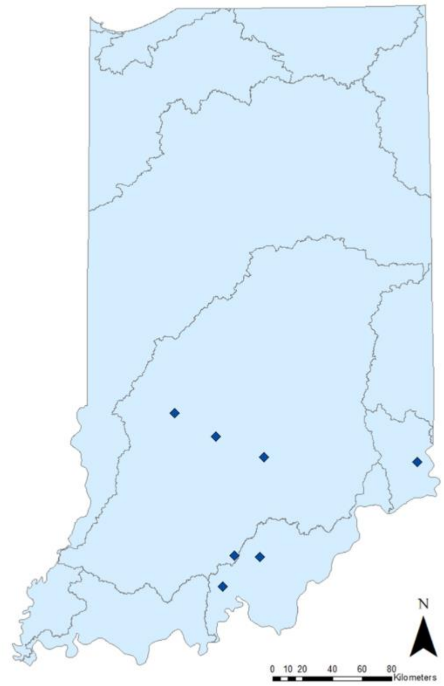

Figure 88. Distribution of *Isoperla burksi*

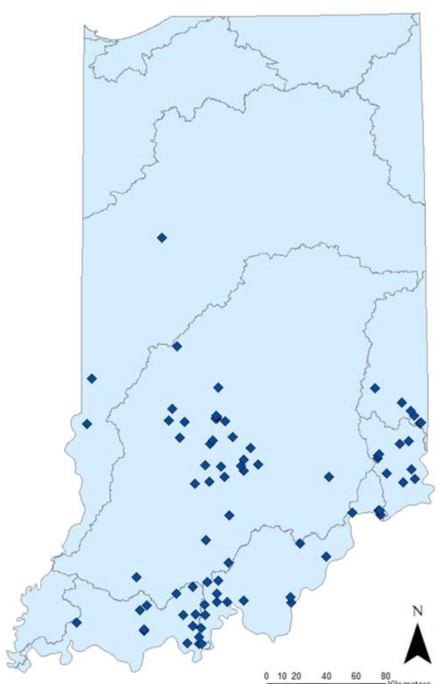

Figure 89. Distribution of *Isoperla decepta*

Figure 90. Distribution of *Isoperla dicala*

Perlodidae, cont.

Figure 91. Distribution of *Isoperla frisoni*

Figure 92. Distribution of *Isoperla marlynia*

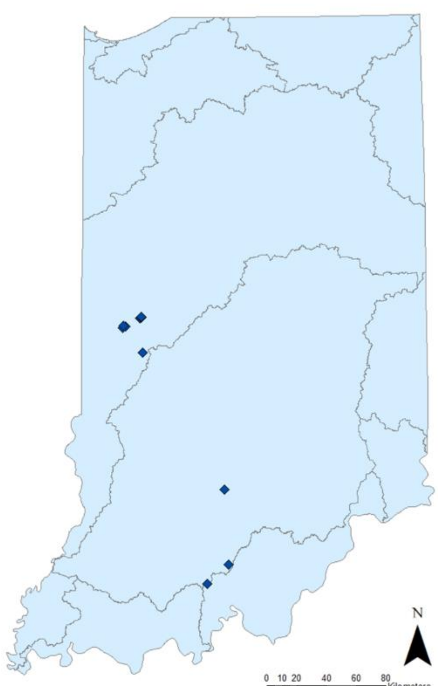

Figure 93. Distribution of *Isoperla montana*

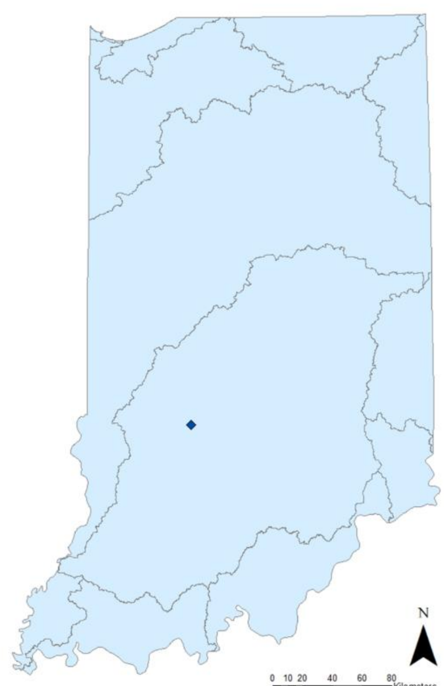

Figure 94. Distribution of *Isoperla namata*

Perlodidae, cont.

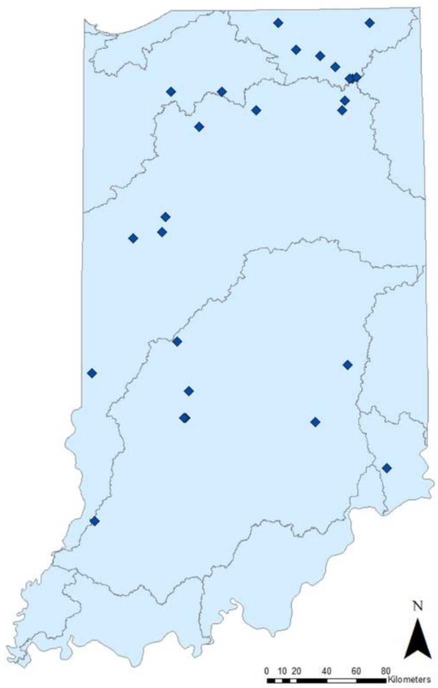

Figure 95. Distribution of *Isoperla nana*

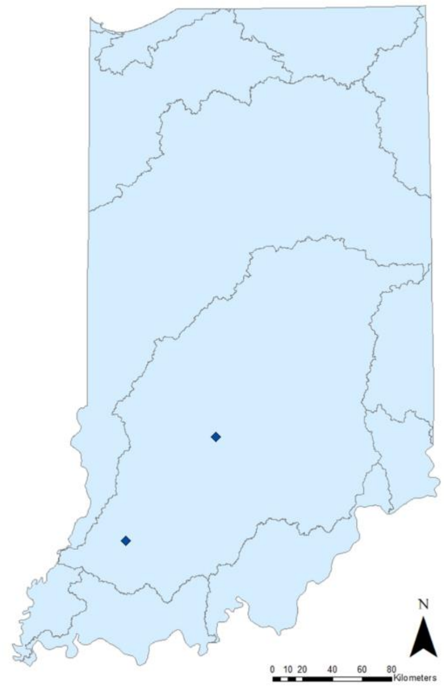

Figure 96. Distribution of *Isoperla richardsoni*

Pteronarcyidae

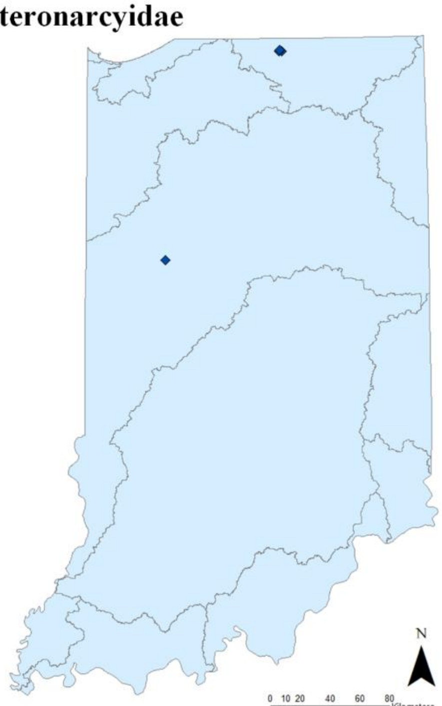

Figure 97. Distribution of *Pteronarcys dorsata*

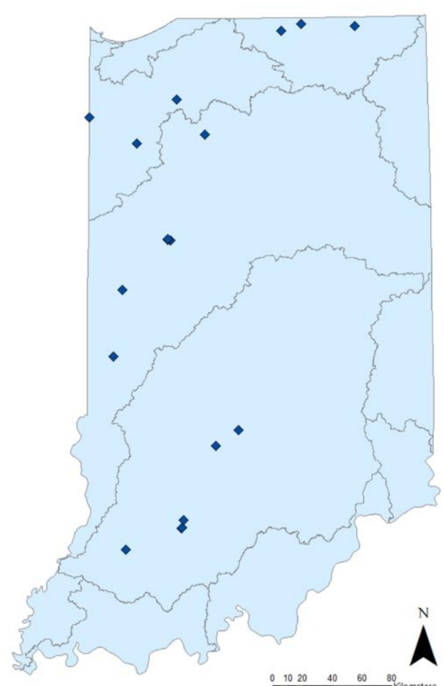

Figure 98. Distribution of *Pteronarcys pictetii*

Taeniopterygidae

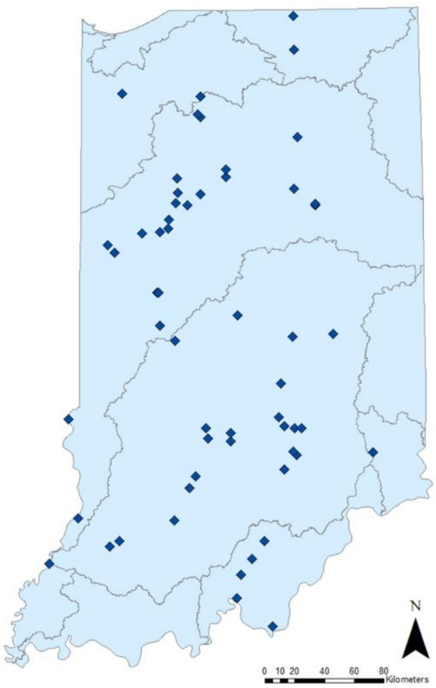

Figure 99. Distribution of *Strophopteryx fasciata*

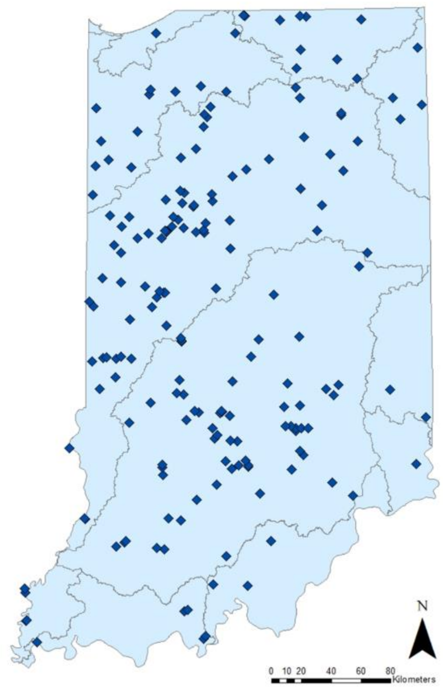

Figure 100. Distribution of *Taeniopteryx burksi*

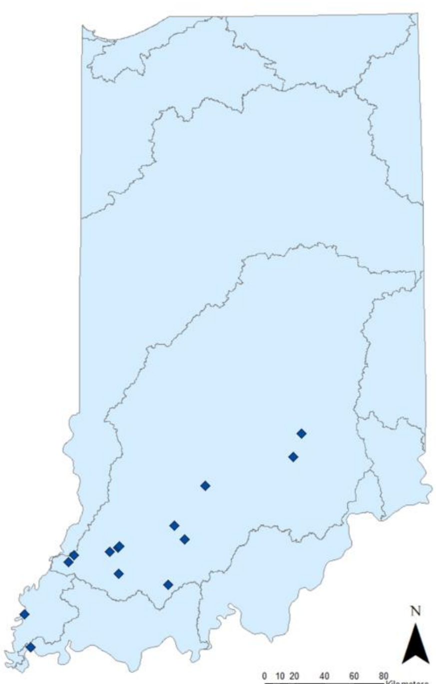

Figure 101. Distribution of *Taeniopteryx lita*

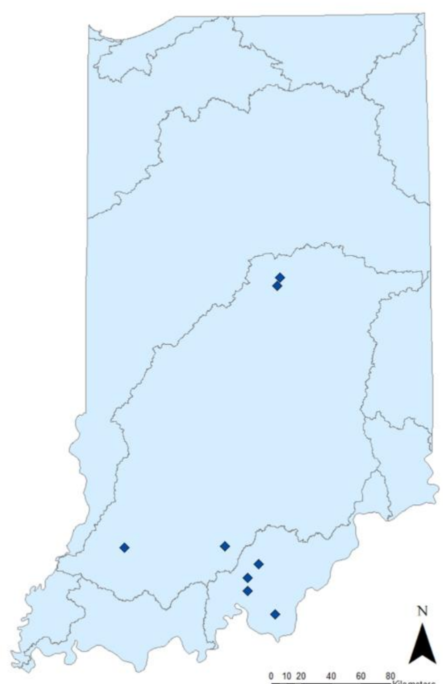

Figure 102. Distribution of *Taeniopteryx maura*

Taeniopterygidae, cont.

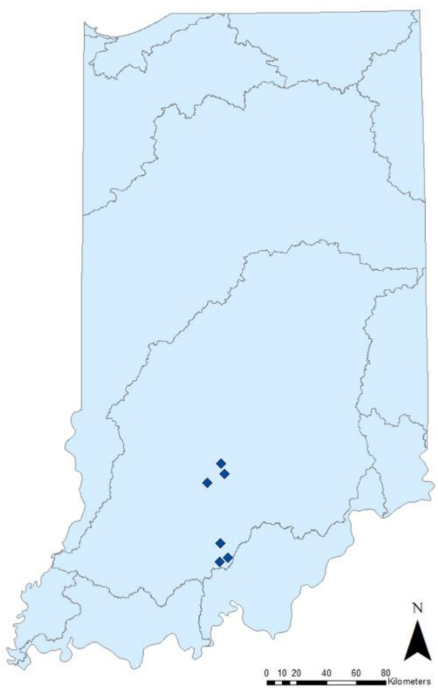

Figure 103. Distribution of *Taeniopteryx metequi*

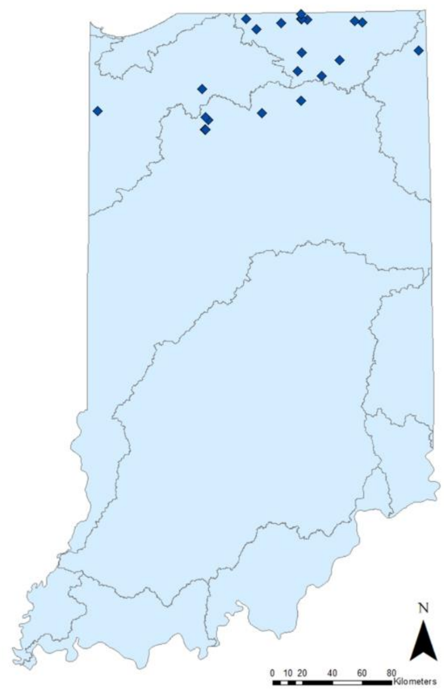

Figure 104. Distribution of *Taeniopteryx nivalis*

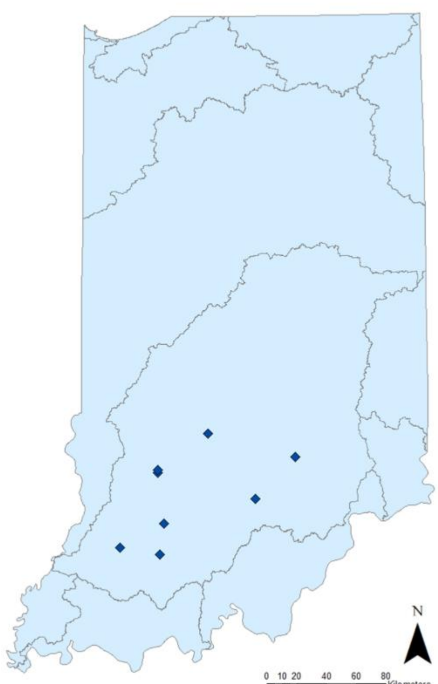

Figure 105. Distribution of *Taeniopteryx parvula*