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Algal and Macroinvertebrate Assemblages of Selected Ohio Springs

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Abstract. A qualitative study of the algal flora, macroinvertebrate fauna, and water quality of ten Ohio springs was conducted during July-September 1996. The springs were primarily in central and northern Ohio on a variety of surficial geology settings including karst, till, and exposed bedrock. Water quality varied with the ground-water source and local environment (agriculture, woodland). The algal community varied greatly in diversity among sites. One woodland site (Styx River) had only three taxa. In contrast, Cedar Bog (an open alkaline fen) had a great diversity of diatoms (246 taxa) with a total of 258 taxa. At most locations, between 15 and 56 taxa were reported. Like the algal community, the diversity of the macroinvertebrate fauna differed considerably among sites, ranging from 2 to 40 identified taxa. This variation may have been due to the site-specific differences in water chemistry and/or habitat. Computation of Jaccard similarity coefficients for both the algal and macroinvertebrate data resulted in low similarity values among sites. The data collected provide a basis for proposed sampling methods (spring biotic survey protocols) that could be used for the range of spring/seep types found in Ohio.

Introduction

Throughout the United States, including Ohio, springs are of local importance in rural areas as drinking water and agricultural-water supplies. Because springs also represent surface outlets for ground-water, chemical analysis of springs can be employed to help evaluate ground-water quality (Breen and Dumouchelle, 1991). Biological communities, which have been used to evaluate surface-water quality for more than two decades (Patrick, 1973; Davis and Simon, 1995), could potentially provide an additional mechanism for evaluating the quality of ground water exiting at springs with respect to human consumption and agricultural supply. However, little is known about the biota of springs in Ohio or how biotic communities differ in relation to ground-water quality.

Springs are unusual and varied environments. Because the water temperature and chemistry for springs remain relatively constant, springs harbor biotic communities that are unique and, in some cases, include endemic taxa of macroalgae (Sheath and Cole, 1990; Vis and Sheath, 1996), invertebrates (Cole and Watkins, 1977), and diatoms (Czarnecki and Blinn, 1979). Springs also can harbor taxa that are climatic relicts from the glacial epochs of the Pleistocene in North America and Europe (Strayer *et al.*, 1995). Biotic communities of springs have been studied sparingly in Ohio (Hunt, 1983) and elsewhere in the United States (Noel, 1954; Minshall, 1968; Whitford, 1956; Whitford and Schumacher, 1963), compared with the more extensive studies in Europe (Neilsen, 1950; Berg, 1951; Thorup, 1963) and Canada (Biological Survey of Canada, 1990; Williams and Danks, 1991; Williams and Smith, 1990).

As a step toward filling the information gap on spring biota in Ohio, a baseline survey was done to characterize the periphyton and benthic organisms from ten Ohio springs and to create a database. The database could then be used in combination with other surveys (Webb *et al.*, 1995 [Illinois], Whitford, 1956 [Florida], Christensen, 1978, and Sherwood and Sheath, 1999 [Texas]) to provide guidance for future studies in Ohio. A secondary purpose was to develop an approach to sampling spring sites using qualitative collecting methods that could be applied to the range of spring environments found in Ohio.

Methods and Materials

Springs were located by use of the U.S. Geological Survey ground-water database and by consultation with Ohio EPA biologists and others. Ten springs in six counties (Champaign, Fairfield, Madison, Medina, Sandusky, and Summit) were selected to represent a variety of natural hydrogeologic settings in Ohio (Figure 1), specifically karst, till, and exposed bedrock. Springs from quarry walls or acid mine drainage sites, however, were excluded.

The collection of the algal flora, macroinvertebrate fauna, and field measures of water quality from the discharge areas of the ten springs was conducted from July through September 1996, during low-flow conditions undisturbed by precipitation. The sampled areas differed considerably among the springs. General criteria for selecting the sampled area were (1) a position between the point of emergence of water from the ground and any channeled, streamlike flow downgradient from the point of emergence, and (2) sufficient size to be representative of the biota present, as well as could be determined by visual inspection. At some springs, Cedar Bog in particular, multiple areas were sampled because of multiple points of emergence. Field measurements of basic water-quality characteristics (temperature, dissolved oxygen, pH, and specific conductance) were made with a calibrated multiparameter instrument at each spring above and below where the biota were sampled (where possible), and the measurements were then averaged to represent the conditions at the site (Table 1). Each site was visited only once.

The organisms collected, for the most part, represent the epigaean flora and fauna (those living on or near the surface of the water). No attempt was made to collect invertebrates specialized for living in ground-water (stygobionts), which could potentially have been found deeper in the substrate of the spring-discharge area (Strayer *et al.*, 1995).

Qualitative periphyton (algae) samples were collected by scraping, pipetting, or hand-sampling all available substrate surfaces according to the protocols used in the U. S. Geological Survey National Water-Quality Assessment (NAWQA) Program (Porter *et al.*, 1993). Substrates typically included soft substrate, rocks, wood, and macrophyte leaves. The algal material was preserved in 5% buffered glutaraldehyde and sent to the Bowling Green State University Center for Algal Microscopy and Image Digitization for identification of microalgae <http://www.bgsu.edu/Departments/biology/algae/index.html>. Macroalgae were identified at the Department of Environmental and Plant Biology, Ohio University <http://vis-pc.plantbio.ohiou.edu/algaeindex.htm>. Benthic organisms were collected by use of dip-nets, kick-nets, grab samplers, and handpicking. Specimens were preserved in 80% ethanol in the field and subsequently sent to the laboratory for identification. Identifications were made to the lowest taxonomic level possible, which ranged from species for most algae to genus for many macroinvertebrates (such as the Diptera) and higher levels for some groups (such as the Oligochaeta worms).

Once the qualitative samples were collected and identified, Jaccard similarity coefficients were computed on the basis of a presence/absence matrix of taxa recorded from each site (Sneath and Sokal, 1973). Sequential, agglomerative, hierarchical, and nested clustering methods (SAHN) (Sneath and Sokal, 1973) were used to generate tree matrices and cluster diagrams. These cluster diagrams were used as a measure of between-site similarity of the biological communities, where the similarity coefficients range from 0 to 1, with 1 representing the maximum similarity.

Spring Descriptions

Millers Blue Hole near Vickery and Green River Spring at Green Springs (Figures 2-5) are large springs in Sandusky County, north-central Ohio. Because of the high discharge rates and local topography associated with these springs, large spring-fed ponds, whose water chemistry has been influenced by the Silurian and Devonian carbonate bedrock rocks, are found. The carbonate aquifer that supports these springs is the primary source of rural domestic and agricultural water supplies in the area (Breen and Dumouchelle, 1991: pp. 3-9). Both springs are in a karst area (Hull, 1999). Millers Blue Hole is capable of discharging more than 3,000 gal/min (Breen and Dumouchelle, 1991: p. 46; Ohio Division of Water, 1968), and Green River Spring has a discharge of about 5,500 gal/min (Breen and Dumouchelle, 1991: p. 48). The pond of Millers Blue Hole appears milky-blue and is surrounded by a ring of native wetland vegetation, including an algal mat of *Chara* (Figures 2 and 3). Green River Spring (also referred to as “St. Francis Spring S-34-G31,” in Breen and Dumouchelle, 1991: pp. 176-179) is clear with blue-green algal mats extending to form stalagmite shapes along the bottom of the pond (Figures 4 and 5). Dissolution of the calcium sulfate mineral (gypsum) that is present in the Silurian/Devonian aquifer supplying Green River Spring contributes to elevated concentrations of sulfate, which approach 2,000 mg/L. The unusual sulfur-rich water of Green River Springs, which has an odor of hydrogen sulfide, attracted Native Americans, as well as early settlers who built a health institution in 1868 that has persisted since that time (H.K. Williams & Bro., 1882; Works Projects Administration, Writers Program, Ohio, 1940). Currently, the spring is surrounded by mowed lawns, cement walkways, a public park, a hospital, and a large population of Canada Geese.

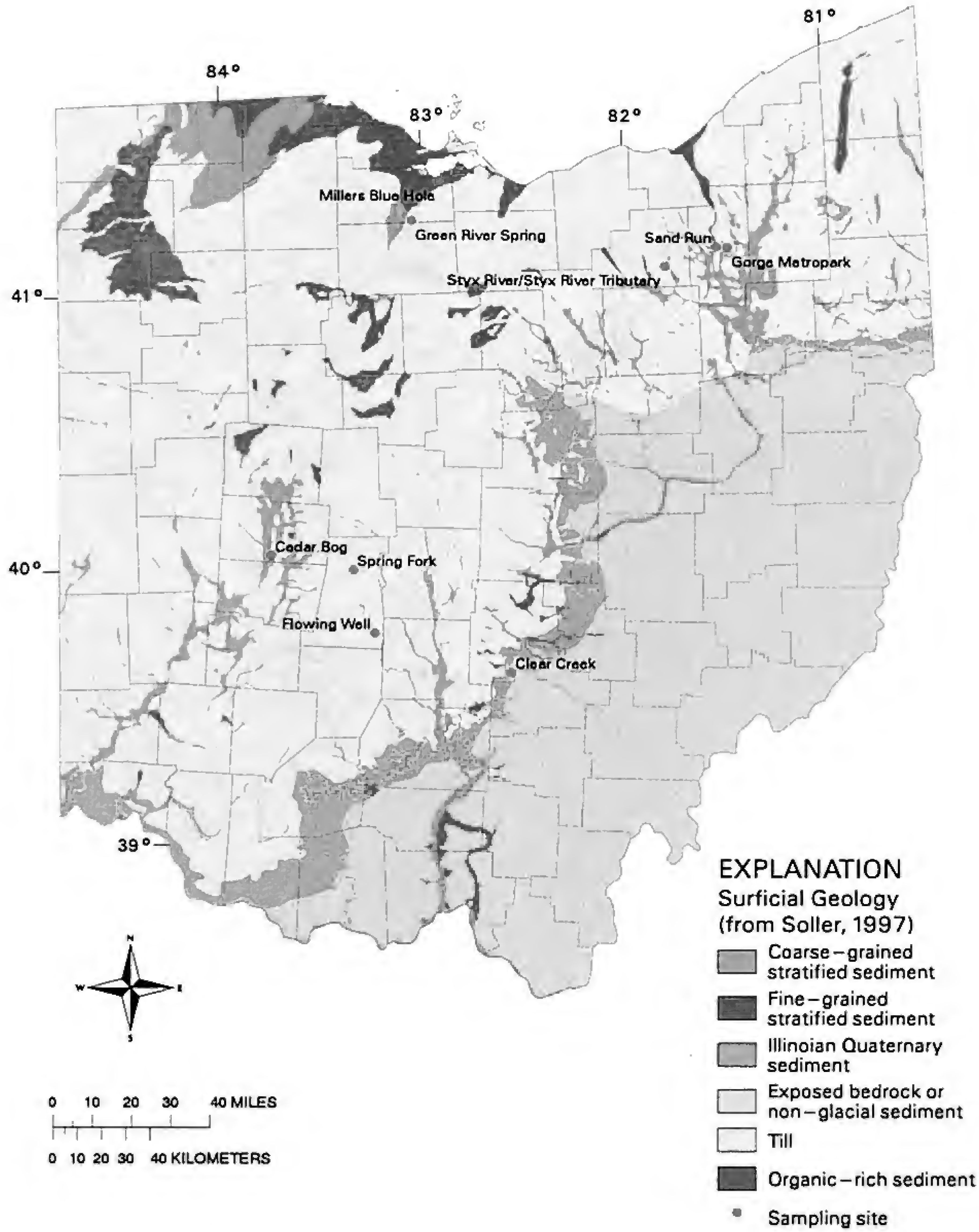

Figure 1. Surficial geology (Soller, 1997) and location of ten spring sites in Ohio.

Figures 2-5: Habitat photographs. **2**- Millers Blue Hole, Ohio Department of Natural Resources, Nature Preserve, Sandusky County, Ohio; **3**- Millers Blue Hole, illustrating mats of *Chara vulgaris* at the edge of the "blue hole;" **4**- Green River Spring, Green Springs, Sandusky County, Ohio; **5**- Green River Spring, detail illustrating growth of benthic stalagmite forms of Cyanophyta blue-green algae.

Figures 6-9: Habitat photographs. **6**- Gorge Metropark wooded area seep, above the trail along the Cuyahoga River dam and past Mary Campbell's Cave, Summit County, Ohio; **7**- Styx River Tributary spring, illustrating orange-red bacterial mat, Medina County, Ohio; **8**- Sand Run spring, a boggy lowland seep in Sand Run State Park, Summit County, Ohio (Julie Hambrook holding a water-quality meter); **9**- Cedar Bog, Ohio Historical Society Preserve, Champaign County, Ohio (Morgan Vis and Wayne Chiasson collecting macroalgal samples).

In contrast to Millers Blue Hole and Green River Spring, the four springs sampled in the Cuyahoga River Valley in northeastern Ohio are low-volume seeps that flow out of bedding planes and fractures in the sandstone and shale bedrock. Three of these springs are in gorges. Two of these springs contribute to the headwaters of the Styx River, whereas the spring in Gorge Metropark (Figure 6) is above the dam of the Cuyahoga River in Cuyahoga Falls. The Styx River tributary spring outlet (Figure 7) was marked by orange-red bacterial mats produced by the oxidation of dissolved ferrous iron in the springwater. The other spring is in a floodplain and contributes to Sand Run in Sand Run State Park (Figure 8).

Cedar Bog in Champaign County, central Ohio, is an alkaline fen (Bolton, 1992) formed by numerous springs that discharge from thick deposits of coarse-grained carbonate-rich glacial outwash (Figure 9). When the ground water, rich in calcium, magnesium, and bicarbonate, recharges the fen, calcareous muds (marl) are precipitated (Bolton, 1992). This marl forms the substrate for the algae and invertebrates collected in this study.

The springs called Spring Fork and Flowing Well in Madison County are in agricultural areas established over glacial till. The discharge from the Flowing Well (known locally as Anderson's Spring) was formerly piped to a pit for watering cattle and horses, and to a roadside fountain for local use by residents and travelers, but the spring was subsequently capped because of high nitrate concentrations after storms, (Niel Babb, Madison County Engineer, oral communication, 1999). These two springs emerge from the till soil and form small wetlands before draining into their respective streams, Spring Fork and Deer Creek.

The Clear Creek spring in Fairfield County flows out of Mississippian shale bedrock and drains into the dam area of Lake Ramona, which, in turn, discharges into Clear Creek. Springwater emerges from the bedrock and flows across the rock, forming small pools with relatively little substrate diversity.

Results of Data Analysis

Values for field-measured water-quality characteristics (Table 1) varied among the springs, indicating diverse ground-water sources (as would be expected given the diverse hydrogeographic and environmental settings of the stream sites). The highest specific conductance values were measured at Millers Blue Hole and Green River Spring. The range of pH was 6.8-8.1, from nearly neutral to slightly alkaline. Dissolved oxygen concentrations were <5 mg/L at four springs (Millers Blue Hole, Green River Spring, Spring Fork, and Styx River tributary), and water temperature was generally warm (12.9-19.3^{o}C) for ground water in Ohio.

In all, 346 algal taxa were identified during this study (Table 2). The flora is made up largely of diatoms (314 taxa or 91%), primarily from the Cedar Bog site (246 diatom taxa). The taxonomic diversity was greatest at the Cedar Bog, where 258 taxa or 75% of those identified in this study were found; of those, 176 or 51% of the total taxa were not found at the other sites. The results of the number of taxa per site and cluster analyses are presented in Figures 10 and 11. Similarity coefficients were low, as reflected in the dendrogram (Figure 11). The greatest similarity was between Clear Creek and the Styx River, with a similarity coefficient of 0.250 out of a maximum of 1; six taxa were in common between the two sites out of 19 and 21 total taxa, respectively. These springs are similar in that they are perennial seeps that emerge from steep slopes in deciduous woods. Millers Blue Hole and the Cedar Bog are larger open areas (Figures 2 and 8) and had the most taxa; despite a low similarity coefficient, they clustered together, separate from the other sites (Figure 11). Three other open sites Green River Spring, Spring Fork, and Flowing Well cluster together with a 0.145 similarity coefficient to the shaded forested areas. The Sand Run and Styx River Tributary sites had the fewest taxa and the least similarity to other sites.

The 95 macroinvertebrate taxa identified during this study are listed in Table 3. The results of the number of taxa and cluster analyses are presented in Figures 12 and 13. Similarity coefficients were lower than for the periphyton data. Millers Blue Hole, with 40 taxa, had the highest macroinvertebrate diversity of any of the springs sampled. Macroinvertebrate diversity was high at the Flowing Well and Cedar Bog sites also, but was very low at the two Styx River sites, the Gorge, Green River Spring, and Sand Run. In the dendrogram (Figure 13), the four most species-rich sites clustered together but shared low coefficient values, indicating a lack of similarity.

To ensure that the disparity in macroinvertebrate species richness between Millers Blue Hole and the other springs did not influence the relations among the other springs as presented in the dendrogram (Figure 13), the analyses were repeated for the nine springs omitting Millers Blue Hole; the results of the alternative cluster analyses indicated that Millers Blue Hole had little influence on the relation of the other sites to each other.

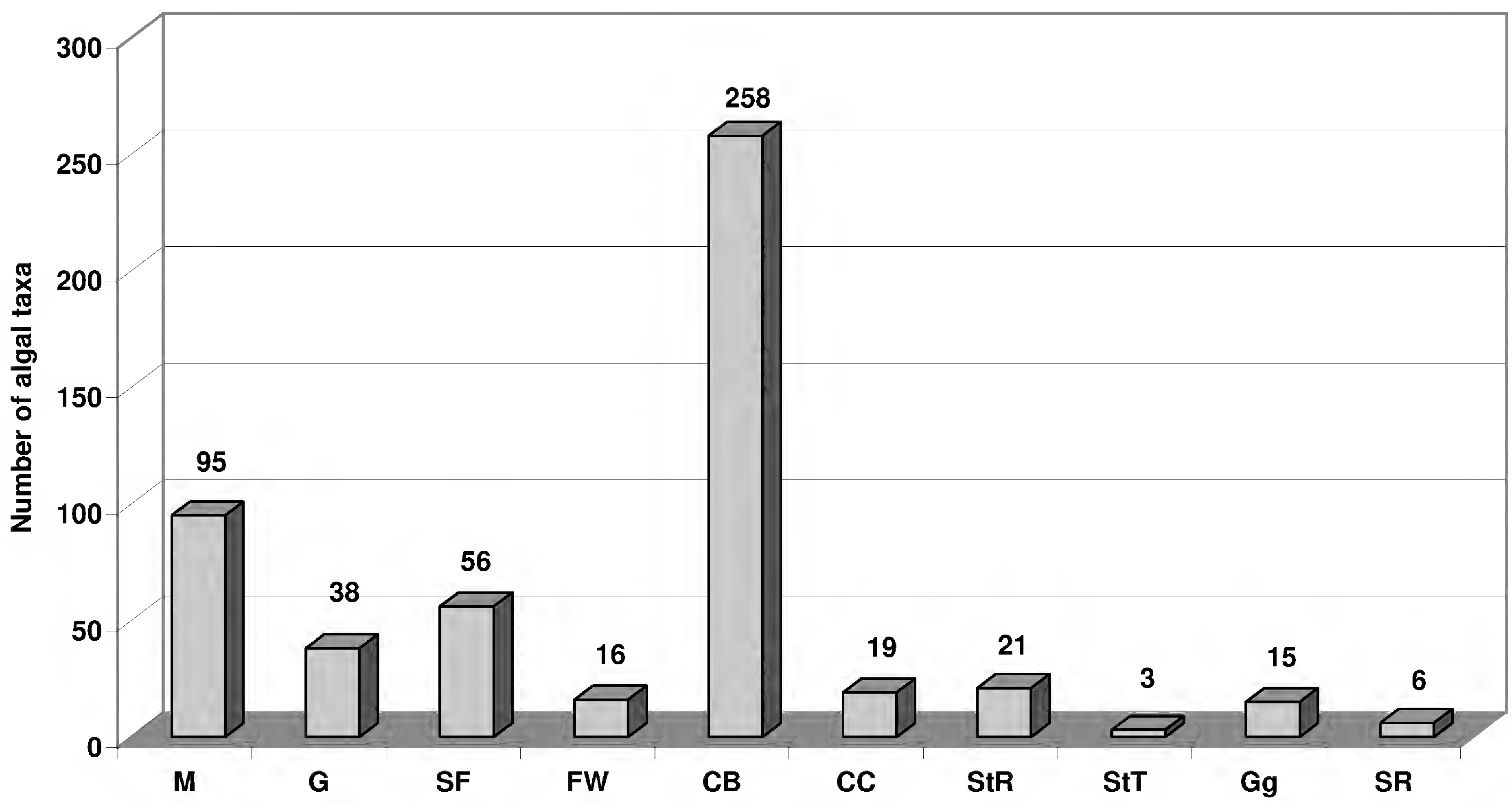

Figure 10. Number of algal taxa found in selected Ohio springs. [M = Millers Blue Hole, G = Green River Spring, SF= Spring Fork, FW = Flowing Well, CB = Cedar Bog, CC = Clear Creek, StR = Styx River, StT = Styx River tributary, Gg = Gorge Run, SR = Sand Run]

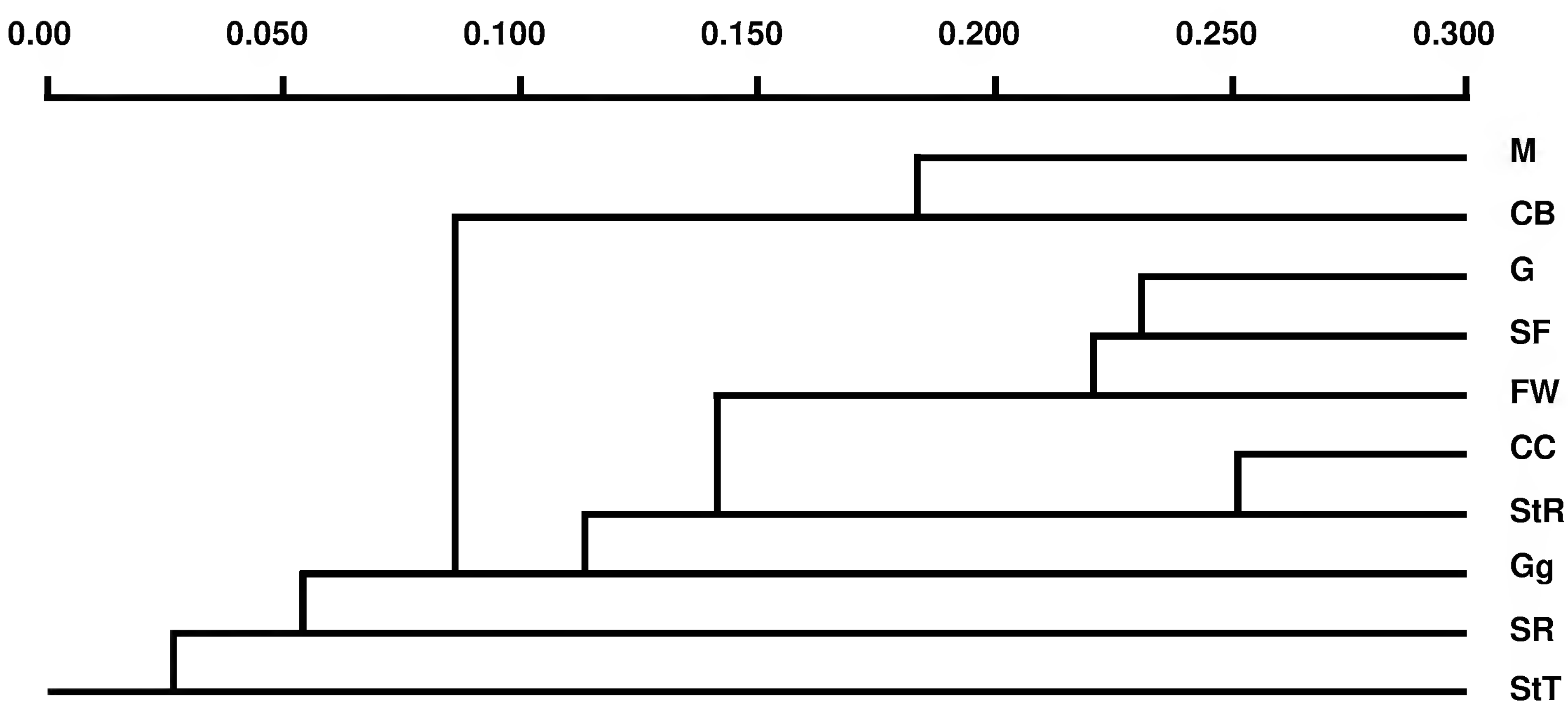

Figure 11. Cluster diagram (dendrogram) of ten Ohio springs based on Jaccard similarity coefficients derived from qualitative algal community composition.

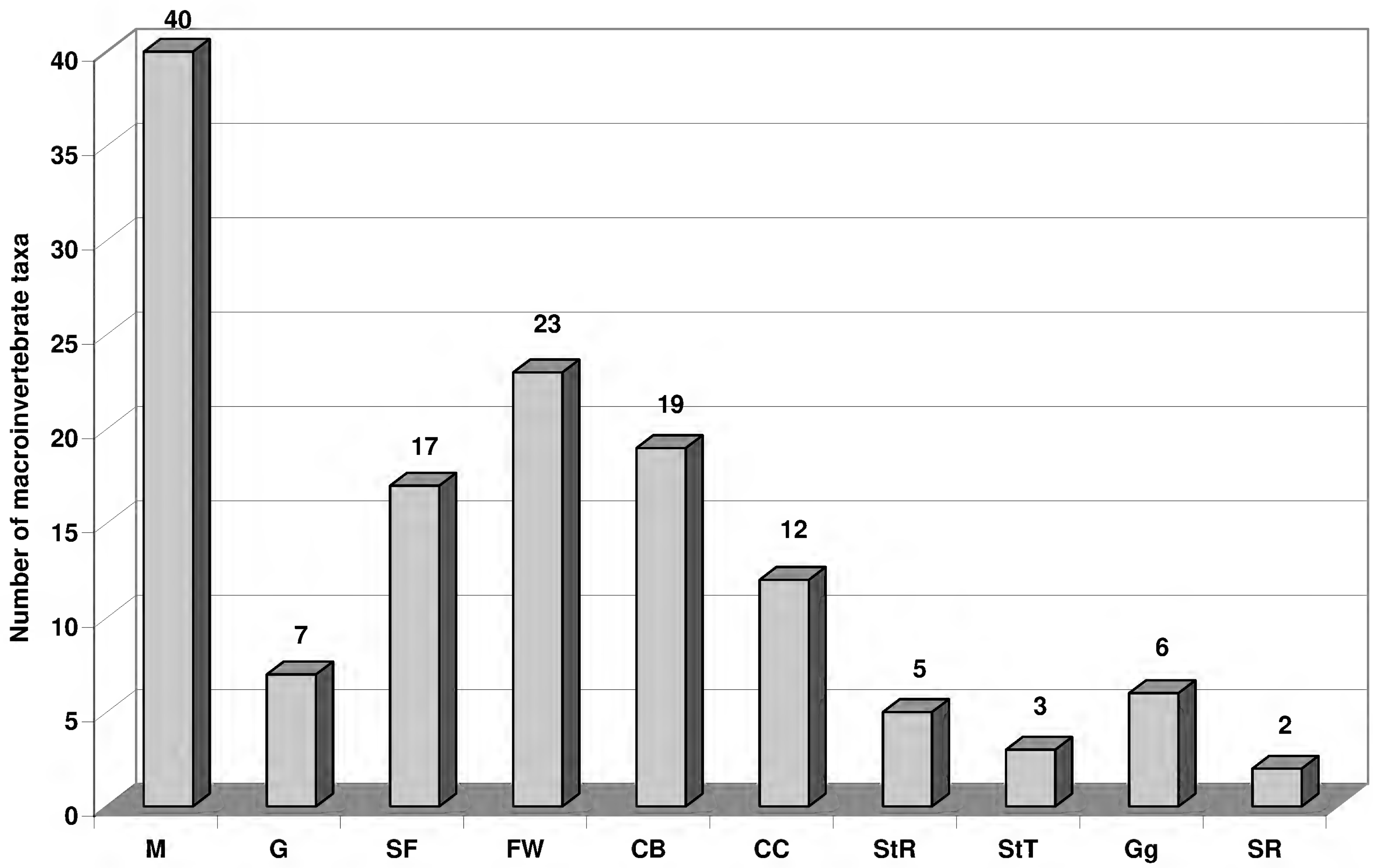

Figure 12. Number of macroinvertebrate taxa found in selected Ohio springs.

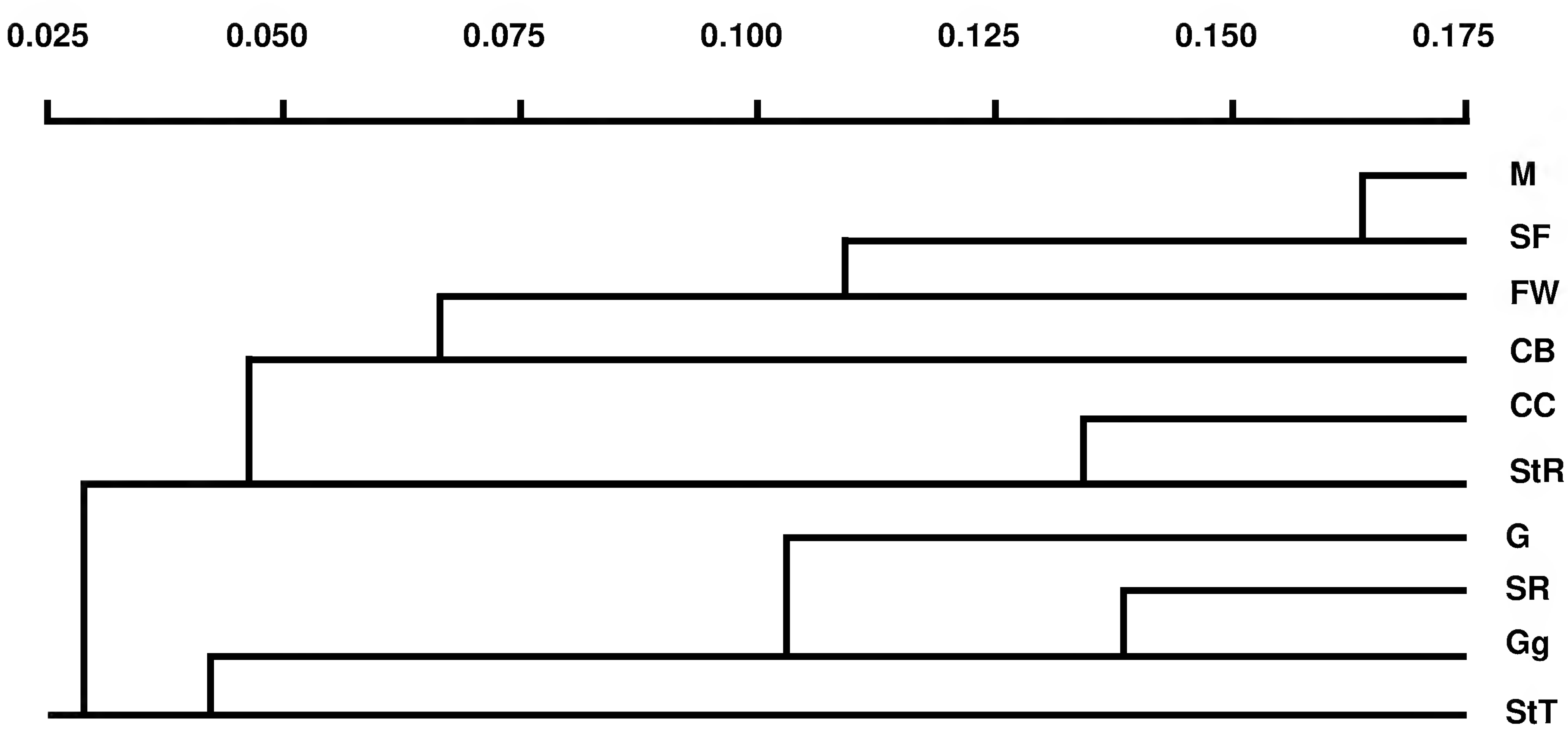

Figure 13. Cluster diagram (dendrogram) of ten Ohio springs based on Jaccard similarity coefficients derived from qualitative macroinvertebrate community composition.

The clustering of the sites based on the macroinvertebrate taxa followed a pattern similar to that for algal communities; *i.e.*, the open field sites were the most similar to each other, and they tended to cluster separately from the wooded spring sites. An exception to this generality is that Green River Spring had relatively low macroinvertebrate diversity and was loosely associated with the woodland spring sites.

Discussion

The springs sampled in this study are in areas of the state that have coarse to fine grained glacial deposits, with the exception of the Clear Creek spring, which emerges from Mississippian bedrock (Figure 1). Water from these springs is neutral to slightly alkaline and varies in specific conductance, reflecting differing ground water sources and interactions with differing bedrock materials. The sites are divided into two types of habitats: open field sites and woodland seeps. The open areas had greater biotic diversity, with the exception of the low taxon richness of the macroinvertebrate community at Green River Spring. Some of the factors that contribute to the high diversity at Cedar Bog include more numerous sampling locations than the other sites where water flows out of the ground, openness (availability of light and potential import of taxa through atmospheric transport/deposition), and the state protection of this area by the Ohio Historical Society. The low dissolved-oxygen concentrations at Green River Spring, Spring Fork, and the Styx River tributary may be limiting the macroinvetebrate diversity at these sites. These low concentrations could be related to the short residence time of water at the sampling sites and the limited exposure of water to the atmosphere after emerging from the ground, such as at Green River Springs, where the flow rate is high (5,500 gal/min). Given the regional proximity, high specific conductances, and substantial flow rates, one might expect Millers Blue Hole and Green River Spring to be more similar, but they clearly have different flora and fauna. Factors that contribute to these differences are the presence of elevated hydrogen sulfide (total sulfide= 2.6 mg/L; Breen and Dumouchelle, 1991) low oxygen concentrations, and organic loading from the numerous Canada Geese frequenting the Green River Spring area. Hydrogen sulfide is a biologically active compound, that can be highly poisonous to aquatic organisms. The U.S. Environmental Protection Area criterion for undissociated H_2S for fish and other aquatic life is 2 ug/L (USEPA, 1986). Hydrogen sulfide was not detected at Millers Blue Hole during the same time period (Breen and Dumouchelle, 1991). Dissolved-oxygen concentrations also differ at these two sites; very little oxygen, only 0.6 mg/L, is available for macroinvertebrates at Green River Spring, whereas the dissolved-oxygen concentration at Millers Blue Hole has reportedly been as high as 5.5 mg/L (Table 1; and Breen and Dumouchelle, 1991).

The low algal diversity at most of the spring sites can be attributed in part to shading, the limited area for colonization and sampling in the woodland seeps, and possibly the time of year that the collections were made. Diatoms that made up 90% of the flora are typically highest in diversity in the spring rather than summer, when these samples were collected. One benefit to sampling during summer low flow was that only perennial springs could be sampled. A perennial spring provides a more constant and suitable habitat for aquatic biota than does a spring with intermittent flows. The woodland springs all flowed over soil, and the influence of the soil substrate was reflected by the presence of several soil-type algae. A comparison with a more complete seasonal analysis of soil algae (41 taxa) from a beech-maple forest in northeastern Ohio (Grondin and Johansen, 1995) revealed only three taxa in common (all diatoms). The majority of soil algae in that study were small green algae in the family Chlorophyceae (29 taxa or 71%), none of which were identified in this study.

In addition to the high species diversity of Cedar Bog, several taxa known to be intolerant of nutrient enrichment/pollution were found, including the freshwater red alga *Batrachospermum gelatinosum* and the diatoms *Fragilaria construens* var. *pumila*, *Fragilaria vaucheria*, and *Nitzschia palea*, indicating good water quality. In contrast, the diatom *Cocconeis placentula* and the blue-green alga *Schizothrix calcicola* that formed the stalagmite growths at Green River Spring are both positively associated with nutrient enrichment (Carrick *et al.*, 1988).

The overall diversity of 95 macroinvertebrate taxa in this study is comparable with the 85 taxa collected from seven springs in southern Illinois (Webb *et al.*, 1995). The differences in diversity between sites were greater in this study (maximum 40 to minimum of 2 taxa). Diptera (30 taxa) were the most diverse group, whereas the oligochaete worms (24 taxa) were the most diverse group in Illinois springs. The maximum diversity for the Illinois springs was 46 taxa, whereas the maximum in this study was 40 taxa, at Millers Blue Hole. The Ohio springs sampled in this study represent a broad range of habitats within agricultural watersheds (unlike the Illinois sites), and were sampled less frequently than the springs in Illinois. The differences in habitat, as well as the amount of flow, are factors influencing biotic diversity recorded from the Ohio spring sites. Millers Blue Hole and Green River Spring, with reported discharges of 3,000 and 5,500 gal/min, respectively (Breen and Dumouchelle, 1991), have formed large pooled areas and a diversity of habitats below their point of emergence. The increased area contributes to the diversity in the protected Millers Blue Hole but not to Green River Spring. The Illinois springs all tended to be low-volume outlets of ground water more closely resembling Ohio's Spring Fork and Flowing Well, except that the Ohio springs were in agricultural pastures.

The paucity or absence of snails in the five wooded seep sites that were low in algal diversity is understandable because snails use algae for food. The low algal diversity, however, does not explain the absence of beetle (Coleoptera) taxa at the same sites. Except for the Millers Blue Hole, Flowing Well, and Cedar Bog sites, macroinvertebrate diversity among the springs was low, and a variety of factors could be contributing to reduced diversity. Spring macroinvertebrate diversity would be expected to be lower than that for lotic systems in comparable areas simply because of the uniformity of environmental conditions in the spring-discharge areas and our sampling criteria. The low macroinvertebrate diversity in the 2-15 taxa range may be a result of low dissolved oxygen concentration at the ground/surface-water interface or the presence of other chemicals, such as the hydrogen sulfide in the Green River Spring.

Aquatic insects of the orders Coleoptera (beetles) and Diptera (true flies) were best represented in the list of macroinvertebrates compiled during this study. Whereas most of the springs contributed to the dipteran inventory, Millers Blue Hole contributed all but two of the 18 taxa of coleopterans. Previously published reports for Canadian springs (Biological Survey of Canada, 1990; Roughley and Larson, 1991; Williams and Smith, 1990) also include numerous species of aquatic beetles. Only 2 of 63 Canadian and Alaskan species were found in common among the 18 species of aquatic beetles in this study, possibly because of latitudinal differences. In contrast, the high degree of overlap between Canadian spring chironomids and the ones found in this study can be attributed to the widespread distribution of many species in the genera listed. Seven genera of chironomids in this study are new to the published and unpublished lists of spring chironomids by Bolton (Michael Bolton, Ohio EPA, written communication, 1998), who lists more than 136 taxa. Many of these genera are common and widespread, and not peculiar to spring habitats. Moreover, some of the springs we studied did not fall within the criteria that Bolton established for his springs. The absence of many stonefly, mayfly, and caddisfly taxa in our list was the result of a conscious decision on our part to concentrate on the immediate spring area and not to sample the spring run or brook characteristically included in other studies (*e.g.*, Minshall, 1968; Hunt, 1983).

The qualitative periphyton collection methods resulted in as many as 259 taxa at Cedar Bog and as few as 3 species at the Styx River tributary. The low diversity at some sites is not likely the consequence of collection methods that sampled all available substrates, but rather the small size and diversity of those sites and possible contamination of the ground-water source. Although one of the most striking features of permanent springs is the marked uniformity of algal flora throughout the year (Whitford and Schumacher, 1963), increasing the sampling effort to include other seasons (*i.e.*, without tree canopy, thus increasing light availability) might add to the diversity of flora in the wooded sites. The culturing of small sediment cores (0.5 X 1.0 cm) at the spring seep sites might also reveal additional taxa, particularly those in the family Chlorophyceae, as found by Grondin and Johansen (1995).

Qualitative survey methods used in this study serve as a valuable initial step for documenting the flora and fauna. Quantitative surveys of periphyton on both hard and soft substrates, however, such as those described in Porter *et al.* (1993), would be more useful for measuring differences in the benthic community structure between sites and over time (Stevenson and Pan, 1999; Lowe and Pan, 1996). Other measures (such as nutrients, pesticides, sulfide, chlorophyll and algal ash-free dry weight), as well as sampling seasonally and after storms (when high concentrations of nutrients and pesticides are more likely to run off into springs), would provide a more complete characterization of the spring biota and water quality. Except for dissolved oxygen, the basic water-quality characteristics measured in this study did little to explain the differences in biotic communities among sites. A more focused attempt to relate spring biota to water-nutrients and toxics would be needed if spring biotas are ever to be used as indicators of ground-water quality with respect to domestic and agricultural use of spring water.

The method employed in collecting macroinvertebrates from the ten springs sampled in this study was perhaps not optimal, because the small and shallow springs pools were not easily sampled with kick-nets. Because of the lack of a water column in which to suspend the organisms prior to capture, a more viable technique in such situations would be to include shallow cores where possible to maximize the inclusion of taxa. For future studies, we suggest a multimethod approach to include collecting samples by kick-net, sweep-net, and sediment cores, as well as picking and washing samples from logs, leaf packs, and rocks. Use of these qualitative methods is suggested for initial surveys of occurrence and distribution of the biota found in springs, but quantitative methods could be developed once appropriate target taxa are selected for the range of physical and geochemical spring environments found in Ohio and elsewhere. These latter methods should include emergence traps for quantitative and life history studies of aquatic insects.

Another addition to this type of work that should be considered is a quality-assurance/quality-control (QA/QC) protocol for sample handling and identification. This is particularly important for laboratory identifications because of the potential for many taxa being uncommon, and in some cases endemic, to springs. We suggest that a stratified random sample of postprocessed/identified taxa be done, with emphasis on rare or endemic taxa. These are the species most likely to be misidentified or misassigned, even by experts. A QA/QC verification sample of 15-20% would be appropriate for such specialized habitats.

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Table 1. Location and basic water-quality characteristics for ten Ohio springs.

Sampling Site	**Site ID Figs. 10-13**	**County**	**Latitude**	**Longitude**	**Sampling Date**	**Temp. (oC)**	**DO (mg/L)**	**pH**	Specific **Conductance (uS/cm)**
Millers Blue Hole	M	Sandusky	41º24'17"N	82º54'30"W	10-Jul-96	14.5	3.3	7.1	2310
Green River Spring	G	Sandusky	41º15'51"N	83º03'09"W	10-Jul-96	14.3	0.6	6.8	2520
Spring Fork	SF	Madison	39º59'23"N	83º23'06"W	9-Aug-96	19.0	1.5	7.1	635
Flowing Well	FW	Madison	39º45'29"N	83º17'22"W	9-Aug-96	19.3	5.8	7.4	789
Cedar Bog	CB	Champaign	40º03'00"N	83º47'00"W	6-Sep-96	19.3	6.1	7.5	709
Clear Creek	CC	Fairfield	39º35'58"N	82º38'05"W	17-Sep-96	15.5	6.8	7.7	148
Styx River	StR	Medina	41º03'52"N	81º48'36"W	24-Sep-96	14.0	7.1	8.1	440
Styx River tributary	StT	Medina	41º03'51"N	81º48'37"W	24-Sep-96	12.9	2.5	6.9	1040
Gorge Run	Gg	Summit	41º07'26"N	81º29'54"W	24-Sep-96	14.1	7.4	7.0	1010
Sand Run	SR	Summit	41º07'39"N	81º33'13"W	24-Sep-96	15.6	7.1	7.7	830

Table 2. List of algae identified from ten Ohio spring sites. (The algae reported in this study are arranged in alphabetical order within divisions, which are in phylogenetic order as described by the USGS Biological Unit at URL <http://wwwnwql.cr.usgs.gov/USGS/algae/algae.phylo.info.html>) [M = Millers Blue Hole, G = Green River Spring, SF= Spring Fork, FW = Flowing Well, CB = Cedar Bog, CC = Clear Creek, StR = Styx River, StT = Styx River tributary, Gg = Gorge Run, SR = Sand Run; x = present in the indicated spring].

Taxa **Spring:**	**M**	**G**	**SF**	**FW**	**CB**	**CC**	**StR**	**StT**	**Gg**	**SR**
Cyanophyta										
Chroococcus turgidus (Kuetz.) Naeg.					x					
Chroococcus varius A. Braun in Rabh.					x					
Hapalosiphon intricatus West and West			x							
Merismopedia punctata Meyen					x					
Phormidium autumnale (C.A. Agardh) Gomont		x								
Phormidium retzii (C.A. Agardh) Gomont		x								
Phormidium tenue (Meneghini) Gomont		x								
Schizothrix calcicola (C.A. Agardh) Gomont	x	x	x	x	x	x	x			
Spirulina major Kuetz.		x								
Lyngbya martensiana Meneghini	x									
N = 10. **Subtotal for each site:**	2	5	2	1	4	1	1			
Rhodophyta										
Audouinella hermannii (Roth) Duby									x	
Batrachospermum gelatinosum (L.) DeCandolle					x					
N = 2. **Subtotal for each site:**					1				1	
Cryptophyta										
Cryptomonas erosa Ehr.					x					
N = 1. **Subtotal for each site:**					1					
Euglenophyta										
Trachelomonas hispida (Perty) Stein			x							
Euglena ehrenbergii Klebs			x							
N = 2. **Subtotal for each site:**			2							
Chrysophyta										
Tribonema affine G. S. West	x									
N = 1. **Subtotal for each site:**	1									
Bacillariophyta										
Achnanthes clevei Grun					x					
Achnanthes conspicua v. brevistriata Hust.	x									
Achnanthes deflexa Reim.					x					
Achnanthes exigua Grun.					x					
Achnanthes exigua v. constricta (Grun.) Hust					x					
Achnanthes exigua v. heterovalva Krasske					x					
Achnanthes hauckiana Grun.		x								
Achnanthes hungarica (Grun.) Grun.					x					
Achnanthes lanceolata (Breb. In Kutz.) Grun.	x	x	x	x	x	x	x		x	x
Achnanthes lanceolata v. dubia Grun.				x	x					
Achnanthes lanceolata v. omissa Reim.					x					
Achnanthes lapponica (Hust.) Hust.					x					
Achnanthes lapponica v. ninckei (Guerm and Mang.) Reim.						x				
Achnanthes linearis (W. Sm.) Grun.					x					
Achnanthes linearis f. curta H. L. Sm.					x					

Table 2. List of algae identified from ten Ohio spring sites, continued.

Taxa Spring:	M	G	SF	FW	CB	CC	StR	StT	Gg	SR
Bacillariophyta (continued)										
Achnanthes minutissimum (Kutz.) Czar.	x	x	x	x	x	x	x			
Achnanthes oestrupi (A. Cl.) Hust.					x					
Achnanthes peragalli v. fossilis Temp. and Perag.					x					
Achnanthes subrostrata (Hust.)						x				
Achnanthes wellsiae Reim.					x					
Amphipleura pellucida Kutz.	x				x					
Amphora michiganensis Stoerm. and Yang					x					
Amphora normanii Rabh.				x						
Amphora ovalis (Kutz.) Kutz.					x					
Amphora ovalis v. affinis (Kutz.) V. H. ex DeT.	x		x		x					
Amphora ovalis v. pediculus (Kutz.) V. H. ex DeT.					x					
Amphora perpusilla Grun.	x	x				x	x		x	
Amphora submontana Hust.			x		x					x
Amphora veneta Kutz.	x				x					
Amphora sp.										x
Aulicoseira granulata (Ehr.) Thwaites	x									
Brachysira vitrea (Grun.) Round and Mann					x					
Caloneis alpestris (Grun.) Cl.	x				x					
Caloneis bacillaris v. thermalis (Grun.) A. Cl.	x				x					
Caloneis bacillum (Grun.) Meresch.	x		x	x	x		x			
Caloneis hyalina Hust.			x							
Caloneis limosa (Kutz.) Patr.					x					
Caloneis ventricosa (Ehr.) Meist.					x					
Caloneis ventricosa v. alpina (Cl.) Patr.					x					
Caloneis ventricosa v. minuta (Grun.) Patr.					x					
Caloneis ventricosa v. truncatula (Grun.) Meist					x					
Campylodiscus noricus Hust.					x					
Cavinula pseudoscutiformis Mann and Stickle					x					
Cocconeis diminuta Pant.					x					
Cocconeis disculus (Schum.) Cl.					x					
Cocconeis fluviatilis Wallace					x					
Cocconeis pediculus Ehr.		x			x				x	
Cocconeis placentula Ehr.		x	x		x	x			x	
Cocconeis placentula v. euglypta (Ehr.) Cl.					x				x	
Cocconeis placentula v. intermedia (Herib. and Perag.) Cl.					x					
Cocconeis placentula v. lineata (Ehr.) V. H.	x				x					
Cocconeis thumensis A. Mayer					x					
Craticula cuspidata (Kutz.) Mann	x		x							
Ctenophora pulchella (Ralfs) Williams and Round	x									
Cyclotella comta (Ehr.) Kutz.	x									
Cyclotella kutzingiana Thwaites					x					
Cyclotella kutzingiana v. planetophora Fricke					x					
Cyclotella menenghiniana Kutz.	x		x		x					
Cyclotella operculata Kutz.					x					
Cymatopleura elliptica (Breb.) W. Sm.					x					
Cymatopleura solea (Breb.) W. Sm.					x					
Cymbella aequalis W. Sm. In Grev.					x					
Cymbella aequalis v. subaequalis Grun.					x					
Cymbella affinis Kutz.					x					
Cymbella amphicephala Naeg. Ex. Kutz.					x					
Cymbella angustata (W. Sm.) Cl.					x					

Table 2. List of algae identified from ten Ohio spring sites, continued.

Taxa	Spring:	M	G	SF	FW	CB	CC	StR	StT	Gg	SR
Bacillariophyta (continued)											
Cymbella aspera (Ehr.) H. Perag.						x					
Cymbella cesatii (Rabh.) Grun. Ex. A. S.						x					
Cymbella cistula (Ehr.) Kirchn.		x				x					
Cymbella cymbiformus v. nonpunctata Font.			x								
Cymbella delicatula Kutz.						x					
Cymbella heteropleura (Ehr.) Kutz.						x					
Cymbella incerta (Grun.) Cl.						x					
Cymbella laevis Naeg. Ex Kutz.		x				x					
Cymbella microcephala Grun.		x	x			x					
Cymbella norvegica Grun.		x									
Cymbella obtussa (Greg.) Cl.						x					
Cymbella obtusiuscula (Kutz.) Grun.						x					
Cymbella parva (Hempr.) Kirchn.		x				x					
Cymbella parvula Krasske						x					
Cymbella rupicola Grun.						x					
Cymbella schmidtii Grun.						x					
Cymbella tumida (Breb. Ex Kutz.) V. H.						x					
Denticula elegans Kutz.						x					
Denticula tenuis Kutz.						x					
Denticula thermalis Kutz.						x					
Diadesmus contenta (Grun. Ex Heurck.) Mann		x					x	x			
Diadesmus perpusilla (Grun.) Mann								x			
Diatoma hiemale (Roth) Heib.						x			x		
Diatoma tenue Agardh						x					
Diatoma tenue v. elongatum Lyngb.						x					
Diatoma vulgare Bory				x							
Diatoma vulgare v. linearis Grun.						x					
Diploneis elliptica Kutz.						x		x			
Diploneis oblongella (Naeg.) Cl. - Euler		x		x		x		x			
Diploneis smithii (Breb.) Cl.						x					
Diploneis smithii v. dilata (M. Perag.) Boyer						x					
Encyonema brehmii (Hust.) Mann						x					
Encyonema minuta (Hilse in Rabenhorst) D.G. Mann		x		x		x					
Encyonema turgidum (Greg.) Grun. In A. S.						x					
Epithemia argus v. alpestris Grun.		x									
Epithemia argus v. longicornis (Ehr.) Grun.		x									
Epithemia sorex Kutz.		x									
Epithemia turgida (Ehr.) Kutz.		x				x					
Epithemia zebra v. saxonica (Kutz.) Patr.		x									
Eucocconeis flexella (Kutz.) Hust.						x					
Eucocconeis flexella v. alpestris Brun.						x					
Eunotia arcus Ehr.						x					
Eunotia curvata (Kutz.) Lagerst.				x		x					
Eunotia elegans Ostr.						x					
Eunotia pectinalis (O. F. Mull) Rabh.				x		x					
Eunotia pectinalis v. minor (Kutz). Rabh.						x					
Eunotia valida Hust.		x									
Fragilaria brevistriata v. capitata Herib.			x			x					
Fragilaria brevistriata v. inflatata (Pant.) Hust.		x									
Fragilaria capucina v. lanceolata Grun.						x					
Fragilaria capucina v. mesolepta Rabh.		x				x					
Fragilaria construens v. pumila Grun.						x					

Table 2. List of algae identified from ten Ohio spring sites, continued.

Taxa	Spring:	M	G	SF	FW	CB	CC	StR	StT	Gg	SR
Bacillariophyta (continued)											
Fragilaria construens v. subsalina Hust.						x					
Fragilaria construens v. venter (Ehr.) Grun.						x					
Fragilaria crotonensis Kitton		x									
Fragilaria lapponica Grun.		x									
Fragilaria leptostauron v.dubia (Grun.) Hust.						x					
Fragilaria pinnata v. intercedens (Grun.) Hust.						x					
Fragilaria pinnata v. lancetula (Schum.) Hust.						x					
Fragilaria vaucheriae (Kutz.) Peters				x		x				x	
Fragilaria vaucheriae v. capitellata (Grun.) Patr.						x					
Fragilaria vaucheriae v. continua (C-Eul.) C-Eul.		x									
Fragilariforma virescens (Ralfs) Williams and Round		x				x					
Frustulia vulgaris (Thwaites) DeT.						x					
Gomphonema acuminatum Ehr.				x		x	x				
Gomphonema acuminatum v. brebissonii Kutz.		x				x					
Gomphonema acuminatum v. coronata (Her.) W. Sm.						x					
Gomphonema acuminatum v. pusilla Grun.						x					
Gomphonema acuminatum v. trigonocephala (Ehr.) Grun. In V. H.						x					
Gomphonema angustatum (Kutz.) Rabh.		x		x	x	x	x	x	x		
Gomphonema angustatum v. naviculaformis Mayer						x					
Gomphonema angustatum v. sarcophagus (Greg.) Grun.						x					
Gomphonema gracile Ehr. emend. V. H.			x			x					
Gomphonema gracile v. aurita Braun		x				x					
Gomphonema gracile v. lanceolata (Ehr.) emend. V. H.						x					
Gomphonema insigne Greg.		x	x	x		x					
Gomphonema intricatum Kutz.						x					
Gomphonema intricatum v. dichotomum Kutz.						x					
Gomphonema intricatum v. pumila Grun.		x				x					
Gomphonema intricatum f. pusilla Mayer						x					
Gomphonema lanceolata Ehr.		x				x					
Gomphonema montanum Schum.						x					
Gomphonema montanum v. subclavatum Grun. In V. H.						x					
Gomphonema olivaceum (Lyngb.) Kutz.		x	x	x		x			x		
Gomphonema parvulum Kutz.		x	x	x		x					
Gomphonema sphaerophorum Ehr.				x							
Gomphonema subclavatum (Grun.) Grun.										x	
Gomphonema subtile Ehr.		x				x					
Gomphonema subtile v. sagitta (Schum.) Cl.		x									
Gomphonema tergestinum (Grun.) Fricke			x	x	x						
Gomphonema truncatum Ehr.		x	x			x					
Gyrosigma acuminatum (Kutz.) Rabh.						x					
Gyrosigma attenuatum (Kutz.) Rabh.						x					
Gyrosigma scalproides (Rabh.) Cl.				x							
Gyrosigma spencerii (Quek.) Griff. and Henfr.				x		x					
Gyrosigma spencerii v. curvula (Grun.) Reim.						x					
Hantzschii amphioxys (Ehr.) Grun.		x		x			x				
Luticola heufleriana (Grun.) Mann				x							
Luticola mutica (Kutz.) Mann							x				
Luticola mutica v. tropica		x									

Table 2. List of algae identified from ten Ohio spring sites, continued.

Taxa Spring:	M	G	SF	FW	CB	CC	StR	StT	Gg	SR
Bacillariophyta (continued)										
Martyana ansata (as Opephora ansata Horn and Hellerman)					x					
Martyana martyi (Heribaud) Round comb. Nov.					x					
Mastogloia grevillei W. Sm.	x									
Mastogloia smithii v. lacustris Grun.	x				x					
Melosira varians C. A. Ag.		x	x							
Meridion circulare (Grev.) Ag.	x	x	x	x	x					
Meridion circulare v. constricta (Ralfs) V. H.					x					
Meridion lineare D. M. Williams					x					
Navicula abiskoensis Pant.	x		x							x
Navicula atomus (Kutz.) Grun.					x					
Navicula cryptocephala Kutz.			x	x	x					
Navicula cryptocephala v. exilis (Kutz.) Grun.			x							
Navicula cryptocephala v. veneta (Kutz.) Rabh.		x	x		x	x				
Navicula elginensis (Greg.) Ralfs					x					
Navicula elginensis v. rostrata (A. Mayer) Patr.					x					
Navicula falaisiensis v. lanceolata Grun.					x					
Navicula graciloides A. Mayer			x							
Navicula gregaria Donk.									x	
Navicua halophila (Grun.) Cl.		x								
Navicua halophila v. tenuirostris Hust.					x					
Navicula hasta Pant.					x					x
Navicula heufleri Grun.					x		x			
Navicula heustedtii Krasske			x	x						
Navicula lanceolata (Ag.) Kutz.		x	x		x					
Navicula minuscula Schumn.	x									
Navicula minima Grun.					x					
Navicula muralis Grun.					x					
Navicula nigrii De Not.	x									
Navicula nivalis Ehr.	x									
Navicula notha Wallace					x					
Navicula oblonga (Kutz.) Kutz.	x	x			x					
Navicula paludosa v. rhomboidea Reimer					x					
Navicula paucivisitata Patr.					x					
Navicula pelliculosa Hilse.					x					
Navicula potzgeri Reim.					x					
Navicula pupula v. capitata Skv. and Meyer					x					
Navicula pupula v. mutata (Krasske) Hust.					x					
Navicula pupula v. rectangularis (Greg.) Grun.	x				x					
Navicula radiosa Kutz.	x				x					
Navicula radiosa v. tenella (Breb. Ex Kutz.) Grun.	x	x	x		x	x	x			
Navicula rhychocephala Kutz.					x					
Navicula salinarum v. intermedia (Grun.) Cl.					x					
Navicula seminuloides Cl. Et Grun.					x					
Navicula seminulum Grun.	x		x	x	x				x	
Navicula seminulum v. hustedtii Patr.					x				x	
Navicula seminulum v. intermedia Gust.					x					
Navicula simplex Krasske	x									
Navicula simula Patr.					x					
Navicula sohrensis Krasske							x			
Navicula subbacillum Hust.					x					
Navicula subhamulata Grun.					x					

Table 2. List of algae identified from ten Ohio spring sites, continued.

Taxa Spring:	M	G	SF	FW	CB	CC	StR	StT	Gg	SR
Bacillariophyta (continued)										
Navicula symmetrica Patr.					x	x				
Navicula tenelloides Hust.					x					
Navicula tridentula Krasske					x					
Navicula tripunctata (O. F. Mull) Bory			x		x					
Navicula tripunctata v. schizonemoides (V. H.) Patr.					x					
Navicula vanheurckii Patr.					x					
Navicula viridula (Kutz.) Kutz. Emend. V. H.					x					
Navicula viridula v. argunensis Skv.	x									
Navicula viridula v. avenacea (Breb. Ex. Grun.) V. H.					x					
Navicula viridula v. rostellata (Kutz.) Cl.					x					
Neidium binode (Ehr.) Cl.					x	x				
Neidium bisulcatum (Lagerst.) Cl.					x					
Neidium iridis (Ehr.) Cl.					x					
Neidium iridis v. ampliatum (Ehr.) Cl.	x									
Nitzschia acicularis (Kutz.) W. Sm.			x		x					
Nitzschia adapta Hust.					x					
Nitzschia amphibia Grun.	x	x	x	x	x					
Nitzschia angustata (W. Sm.) Grun.					x					
Nitzschia angustata v. acuta Grun.					x					
Nitzschia apiculata (Greg.) Grun.					x					
Nitzschia capitellata Hust.					x					
Nitzschia clausii Hantz.					x					
Nitzschia debilis (Kutz.) Grun.	x						x			
Nitzschia denticula Grun.	x				x					
Nitzschia dissipata (Kutz.) Grun.		x	x		x					
Nitzschia dubia W. Sm.			x							
Nitzschia filiformis (W. Sm.) Hust.					x					
Nitzschia fonticola Grun.					x					
Nitzschia frustulum Kutz.	x				x					
Nitzschia gracilis Hantz.					x					
Nitzschia hantzschiana Rabh.					x					
Nitzschia kutzingiana Hilse					x					
Nitzschia linearis W. Sm.	x		x		x	x	x			x
Nitzschia palea (Kutz.) W. Sm.		x	x	x	x					
Nitzschia parvula W. Sm.				x						
Nitzschia perminuta (Grun.) Perag.		x	x	x					x	
Nitzschia recta Hantz.					x					
Nitzschia romana Grun.					x					
Nitzschia sigmoidea (Nitz.) W. Sm.	x				x					
Nitzschia sinuata v. delognei (Grun.) Lange-Bert.									x	
Nitzschia spectibilis (Ehr.) Ralfs and W. Sm.					x					
Nitzschia stagnorum Rabh.					x					
Nitzschia sublinearis Hust.					x					
Nitzschia subtilis Grun.					x					
Nitzschia tropica Hust.	x				x					
Nitzschia vivax (W. Sm.) Hantz.					x					
Pinnularia abaujensis v. rostrata (Patr.) Patr.					x					
Pinnularia braunii v. amphicephala (A. Mayer) Hust.					x					
Pinnularia brebissonii (Kutz.) Rabh.	x						x			
Pinnularia brebissonii v. diminuta (Grun.) Cl.						x				
Pinnularia brevicostata Cl.					x					
Pinnularia flexuosa Cl.					x					

Table 2. List of algae identified from ten Ohio spring sites, continued.

Taxa Spring:	M	G	SF	FW	CB	CC	StR	StT	Gg	SR
Bacillariophyta (continued)										
Pinnularia gibba Ehr.			x							
Pinnularia kneuckeri Hust.	x									
Pinnularia mesogongyla Ehr.					x					
Pinnularia mesolepta (Ehr.) W. Sm.					x					
Pinnularia rupestris Hantz.					x					
Pinnularia viridis (Nitz.) Ehr.	x				x	x				
Pinnularia viridis v. minor Cl.					x					
Pinnularia viridis v. sedetica (Hilse) Herib.					x					
Reimeria sinuata (Greg.) Kociolek and Stoermer							x			
Rhoicosphenia curvata (Kutz.) Grun. Ex. Rabh.	x	x	x	x	x	x			x	
Rhopalodia gibba (Ehr.) O. F. Mull	x				x					
Rhopalodia gibberula (Ehr.) O. F. Mull	x									
Sellophora laevissima Mann					x					
Sellophora pupula Hust.		x			x					
Stauroneis anceps Ehr.			x		x					
Stauroneis anceps v. americana Reim.			x							
Stauroneis kriegeri Patr.			x							
Stauroneis phoenocentron (Nitz.) Ehr.					x					
Stauroneis phoenocentron v. braunii (M. Perag. and Herib.) Voigt					x					
Stauroneis smithii Grun.					x		x			
Staurosira construens Ehr.					x					
Staurosirella leptostauron (Ehr.) Williams and Round					x					
Staurosirella pinnata (Ehr.) Williams and Round					x					
Stenopterobia delicatissima Breb.					x					
Stephanodiscus hantzschii Grun.	x									
Stephanodiscus invisitatus Hohn and Hellerm.	x									
Surirella angustata Kutz.	x		x		x		x			
Surirella ovata Kutz.			x		x					
Surirella ovata v. pinnata W. Sm.			x							
Surirella robusta Ehr.					x					
Surirella robusta v. spendida Ehr.					x					
Synedra fasciculata (Ag.) Kutz.		x			x					
Synedra fasciculata v. truncata (Grev.) Patr.					x					
Synedra filiformis v. exilis Cl.-Eul.					x					
Synedra minuscula Grun.	x				x					
Synedra parasitica (W. Sm.) Hust.					x					
Synedra parasitica v. subconstricta (Grun.) Hust.					x					
Synedra radians Kutz.	x				x					
Synedra ulna (Nitz.) Ehr.			x		x					
Synedra ulna v. danica (Lutz.) V. H.	x									
Synedra ulna v. longissima (W. Sm.) Brun.					x					
Synedra ulna v. subaequalis (Grun.) V. H.					x					
Thalassiosira pseudonanna Hasle and Heimdal	x									
Tryblionella calida (Grun. and Cl.) Mann			x							
Tryblionella hungarica Grun.	x		x		x					
N = 314. Subtotal for each site:	85	29	56	16	246	18	18	3	14	6

Table 2. List of algae identified from ten Ohio spring sites, continued.

Taxa	Spring:	M	G	SF	FW	CB	CC	StR	StT	Gg	SR
Chlorophyta											
Chaetophora elegans (Roth) C.A. Agardh			x								
Cladophora glomerata (L.) Kuetz.			x							x	
Closterium moniliferum Breb.			x								
Closterium subulatum (Kutz.) Breb.						x					
Cosmarium reniforme (Ralfs) Arch.						x					
Microthamnion strictissimum Rabh.								x			
Mougeotia sp.		x	x		x	x					
Oedogonium sp.		x									
Oocystis submarina Lager.		x									
Pleurotaenium ehrenbergii (Breb.) DeBary						x					
Rhizoclonium crassipellitum West and West				x	x						
Spirogyra sp.		x			x	x					
Tribonema minus (Wille) Hazen		x									
Ulothrix subtilissima Rabh.								x			
Zygnema sp.		x									
N = 15.	**Subtotal for each site:**	6	4	1	3	5		2		1	
Charophyta											
Chara vulgaris L.		x				x					
N = 1.	**Subtotal for each site:**	1				1					
All Algal Divisions											
Total		**M**	**G**	**SF**	**FW**	**CB**	**CC**	**StR**	**StT**	**Gg**	**SR**
N = 346.	**Subtotal for each site:**	95	38	56	16	258	19	21	3	15	6

Note on algal taxonomy:

Most of the *Achnanthes* belong in the genus *Achnanthidium* but authorities were not available at this time. Thus, the varieties of some new genera were listed above under their old generic names.

New Name	=	Old Name with Authority
Pseudostaurosira brevistriata v. capitata	=	Fragilaria brevistriata v. capitata Herib.
Pseudostaurosira brevistriata v. inflata	=	Fragilaria brevistriata v. inflatata (Pant.) Hust.
Sellophora pupula v. capitata	=	Navicula pupula v. capitata Skv. and Meyer
Sellophora pupula v. mutata	=	Navicula pupula v. mutata (Krasske) Hust.
Sellophora pupula v. rectangularis	=	Navicula pupula v. rectangularis (Greg.) Grun.
Staurosira construens v. pumila	=	Fragilaria construens v. pumila Grun.
Staurosira construens v. subsalina	=	Fragilaria construens v. subsalina Hust.
Staurosira construens v. venter	=	Fragilaria construens v. venter (Ehr.) Grun.
Staurosirella leptostauron v. dubia	=	Achnanthes lanceolata v. dubia Grun.
Staurosirella pinnata v. intercedens	=	Fragilaria pinnata v. intercedens (Grun.) Hust.

Table 3. List of macroinvertebrates identified from the ten Ohio spring sites (*x* = present in the indicated spring). [M=Millers Blue Hole; G = Green River Spring; SF = Spring Fork; FW = Flowing Well; CB = Cedar Bog; CC = Clear Creek; StR = Styx River; StT = Styx Tributary; Gg = Gorge; SR = Sand Run].

Taxa	Spring:	M	G	SF	FW	CB	CC	StR	StT	Gg	SR
Annelida											
Oligochaeta		x	x	x	x					x	x
Hirudinea - Erpobdellidae		x		x							
Mollusca											
Gastropoda											
Amnicola limosus						x					
Elimia livescens						x					
Fossaria parva		x			x	x					
Gyraulus parvus		x	x								
Marstonia decepta					x						
Physella gyrina		x		x	x						
Physella integra				x		x					
Planorbella armigera				x	x						
Pomatiopsis lapidaria				x							
Pseudosuccinea columella					x						
Bivalvia											
Pisidium sp.					x	x					
Arthopoda											
Crustacea											
Amphipoda											
Crangonyx sp.		x									
Hyallela azteca		x		x		x					
Synurella dentata					x						
Isopoda											
Caecidotea cf. racovitzai		x		x	x						
Caecidotea cf. intermedius										x	
Lirceus cf. fontinalis					x						
Insecta											
Coleoptera - Haliplidae											
Haliplus immaculicollis		x									
Peltodytes sp.		x									
Coleoptera - Dytiscidae											
Copelatus glyphicus		x									
Dytiscus sp.					x						
Hygrotus nubilis		x									
Hydroporus niger		x									
Coleoptera - Elmidae											
Dubiraphia sp.						x					
Coleoptera - Hydrophilidae											
Anacaena limbata		x									
Berosus striatus		x									
Enochrus cinctus		x									
Enochrus ochraceus		x									
Enochrus sayi		x									
Helophorus lineatus		x									
Helophorus linearis		x									

Table 3. List of macroinvertebrates identified from the ten Ohio spring sites, continued.

Taxa	Spring:	M	G	SF	FW	CB	CC	StR	StT	Gg	SR
Coleoptera - Hydrophilidae, continued.											
Helophorus maginicollis		x									
Hyrdrobius fuscipes		x									
Paracymus subcupreus		x									
Tropisternus lateralis nimb.		x									
Diptera - Ceratopogonidae											
Bezzia sp.		x									
Forcipomyia sp.										x	
Probezzia sp.											x
Diptera - Chironomidae											
Ablabesmyia sp.						x					
Acricotopus sp.		x	x								
Brillia sp.		x					x			x	
Chaetocladius sp.					x						
Chironomus sp.			x								
Conchapelopia sp.					x	x					
Cryptochironomus sp.						x					
Heterotrissocladius sp.					x	x	x				
Krenopelopia sp.					x		x	x			
Larsia sp.		x		x			x				
Micropsectra sp-1.		x			x						
Micropsectra sp-2.							x	x			
Pagastia sp.								x			
Paracladopelma sp.						x	x				
Parakiefferiella sp.			x								
Paralauterborniella sp.						x					
Paraphaenocladius sp-1.		x			x		x			x	
Paraphaenocladius sp-2.					x		x				
Paratendipes sp.					x						
Polypedilum sp.							x				
Procladius sp.						x					
Prodiamesa sp.					x						
Psectrotanypus sp.				x							
Pseudochironomus sp.		x									
Rheocricotopus sp.								x			
Rheotanytarsus sp.						x					
Stempellinella sp.						x					
Symposiocladius lignicola								x			
Thienemannimyia sp.					x						
Zavrelimyia sp.						x	x				
Diptera -Culicidae											
Culex sp.		x		x							
Diptera - Dixidae											
Dixa sp.					x						
Diptera - Muscidae											
Limnophora sp.				x							
Diptera - Ptychopteridae											
Ptychoptera sp.					x						
Diptera - Simulidae											
Simulium sp.		x									

Table 3. List of macroinvertebrates identified from the ten Ohio spring sites, continued.

Taxa	**Spring:**	**M**	**G**	**SF**	**FW**	**CB**	**CC**	**StR**	**StT**	**Gg**	**SR**
Diptera - Stratiomyidae											
Stratiomys sp.						x					
Diptera - Tipulidae											
Hexatoma sp.									x	x	
Pedicia sp.				x							
Prionocera sp.									x		
Ephemeroptera											
Hexagenia sp.				x							
Paraleptophlebia sp.						x					
Hemiptera - Corixidae											
Hesperocorixa obliqua		x									
Sigara alternata		x									
Hemiptera - Gerridae											
Gerris insperatus				x							
Gerris remigus			x								
Megaloptera											
Chauliodes sp.				x							
Nigronia sp.							x		x		
Odonata - Anisoptera											
Anax junius		x		x							
Cordulegaster sp.							x				
Libellula sp.		x									
Pachydiplax longipennis		x									
Odonata - Zygoptera											
Coenagrion/Enallagma sp.			x								
Ischnura verticallis		x									
Lestes rectangularis		x									
Total		**M**	**G**	**SF**	**FW**	**CB**	**CC**	**StR**	**StT**	**Gg**	**SR**
N = 95	**Subtotal for each site:**	40	7	17	23	19	12	5	3	6	2

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Three New State Records of Odonata from Ohio, with Additional County Records

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Abstract. Since 1995 the members of the Ohio Odonata Survey have newly recorded three dragonfly species to the state list: *Lanthus vernalis*, *Neurocordulia molesta*, and *Somatochlora incurvata*. In addition, survey workers have collected a total of 712 new county records. The total Odonata species and subspecies in Ohio now numbers 159.

History and Acknowledgements

The Ohio Odonata Survey was initiated in 1991 and supported in part with funds from the Ohio Department of Natural Resources, Division of Wildlife's income tax check-off funds with additional assistance from the U.S. Fish & Wildlife Service, the Ohio Biological Survey, and the Crane Hollow Foundation. The mostly volunteer members of the survey donated substantial amounts of time and expertise. Many of the volunteers who have found new county records appear in Table 1 along with other individuals whose records were shared. A complete list of survey volunteers will appear in the appendix to a future publication.

Several members of the Ohio Odonata Survey deserve special mention here. Thirteen members helped found the survey and/or later joined the steering committee. These individuals made major contributions in helping to identify potential survey locations, summarizing characteristics of "targeted species" to assist survey volunteers, and identifying specimens collected by non-professional volunteers. These members include: Robert W. Alrutz, John Bater, Eric G. Chapman, Stephen W. Chordas III, Bernie Counts, Susan Heady, David McShaffrey, Dwight L. Moody, Robert A. Restifo, Dan Riggs, Carmen Trisler, Jan Trybula, and the author.

In 1995, we (Glotzhober *et al.*) newly reported three other species and 611 additional county records for Ohio. The official time period for the survey ended with the 1997 field season. Survey volunteers have since organized as the Ohio Odonata Society and continue both survey and research projects. This paper presents near-final data from the official survey project. Additional reports and publications are in progress. Taxonomy in this report follows the list prepared for the Dragonfly Society of the Americas (1996; 1999).

Discussion

New State Records

Previously, Glotzhober (1995) and Glotzhober *et al*. (1995) reported that *Lanthus vernalis* Carle, 1980 (Gomphidae, Single-striped Clubtail) had been erroneously included in the state list. At that time it was a hypothetical species without actual Ohio records. That species is now correctly re-entered on the state list. Between 31 May and 11 July of 1995 Mark Rzeszotarski collected four males and one female *L. vernalis* at Koelliker Fen in Munson Township, Geauga County while surveying for Lepidoptera. These were later identified by the author and confirmed by Robert Restifo. A local physician, Rzeszotarski volunteers as a Lepidoptera surveyor for the Cleveland Museum of Natural History, which owns the Koelliker Fen preserve. The specimens are in the Cleveland Museum of Natural History collections.

After searches by several field workers at a number of other sites, on 9 June 1997 Chapman collected one male and two female *L. vernalis* at West Branch State Park near Cable Line Road in Portage County. These specimens are in the Ohio Historical Society collections. Current known flight dates in Ohio for *L. vernalis* are 31 May to 11 July, mirroring its species name "of the spring."

The Single-striped Clubtail appears to utilize small, high-quality streams. Koelliker Fen is divided by a very sparkling clear spring-fed stream, which begins a few hundred meters above the fen. Where the stream flows through the fen it is only half a meter wide and very shallow. Carle (1980) described the species' habitat in detail, along with a lengthy discussion of its ecology, life history, and behavior. Bick and Mauffray (1999) reported *L. vernalis* from 15 other states ranging from Maine to Georgia and west to Pennsylvania, West Virginia, and Kentucky.

On 20 June 1991 Kip Will, then a graduate student at The Ohio State University, collected and identified a single male *Neurocordulia molesta* (Walsh, 1863) (Corduliidae, Smokey Shadowfly) at lights on tennis courts near the Shawnee State Park lodge, Scioto County, Ohio. This site is approximately eight air miles (13 km) from the Ohio River, the presumed nearest appropriate larval habitat of this riverine species. Ohio has very few records of any *Neurocordulia* and at that time there were no specimens of *N. molesta* for comparison in any Ohio collection. Therefore, several survey workers, including the author, reviewed the identification, misinterpreted some characters, and overlooked one important character (see below). This resulted in Will's specimen being erroneously listed as *N. yamaskanensis*.

During 1995 data acquired from the Ohio Environmental Protection Agency (OEPA) included larvae of *N. molesta* from nine counties. These were carefully reviewed and confirmed by Bernie Counts. The larvae of *N. molesta* have a conspicuous pyramidal horn on the front of the head that quickly separates them from all other species of *Neurocordulia*. Afterwards Will's specimen was re-evaluated and corrected. Since June of 1996, ten additional adult *N. molesta* have been collected by various workers. Their known Ohio flight period is between 13 June and 17 August, with June having a distinctive peak in these limited records. The Smokey Shadowfly appears to fly only for a brief period beginning at sunset, along slow-moving large rivers. Even with multiple workers at one site (where larvae have been identified), very few adults were taken, as they are very difficult to see and collect. Without the intensive macro-invertebrate sampling of the OEPA, this species may have been overlooked in Ohio. Larvae are in the OEPA Ecological Assessment Section collections and adults are in the Ohio Historical Society collections and the personal collections of Bernie Counts, Robert A. Restifo, and Eric Eaton.

Larvae of *N. molesta* have been found in the following counties and river systems: Athens County, Hocking River; Coshocton County, Wills Creek and Tuscarawas River; Franklin County, Scioto River; Gallia County, Ohio River; Hamilton County, Little Miami River; Muskingum County, Muskingum River; Pickaway County, Scioto River; Pike County, Scioto River; Washington County, Muskingum River. The few adults collected have been near the same locations, excepting records from Lorain, Meigs, and Scioto counties. The last two of these are presumed to be associated with the Ohio River.

Male *N. molesta* in Ohio (four examined) have a distinctive, short, bluntly-toothed internal process of the trochanter of the middle leg as described on pages 351 and 355 of Needham and Westfall (1954). Males are distinctive and readily identified with this character. This character is absent in males found in Florida and other southern areas (Sidney W. Dunkle, pers. comm., 1996), which may require further evaluation of its taxonomic status. Currently this species is listed for states ranging from South Dakota east to Ohio, south to Florida, and west to Texas (Bick and Mauffray, 1999).

During 1997 Dennis Profant, instructor at Hocking College, brought the author several Odonata specimens collected on 4 July 1996 at the Hocking College Land Lab in York Township, Athens County, Ohio, about 2.5 miles (4 km) south of the main campus in Nelsonville. One specimen was a male *Somatochlora incurvata*, Walker, 1918 (Corduliidae, Incurvate Emerald). Identification was confirmed by Restifo, and later by comparison with specimens of this and related species loaned to the author by Mark O'Brien of the Museum of Zoology, University of Michigan. The Athens County specimen is in the Ohio Historical Society collections.

Flight dates of *S. incurvata* range from 19 July to 30 August, with a record from Nova Scotia from October 15 (Needham and Westfall, 1954; Walker and Corbet, 1975). Bick and Mauffrey (1999) listed it for New Brunswick, Nova Scotia, and Ontario in Canada, and in the United States from Maine, Massachusetts, New York, Pennsylvania, Michigan, and Wisconsin. The single Pennsylvania site (Shiffer, 1969), located in the north-central part of the state, represented the southern most record. The Pennsylvania site is at approximately N41 25.4', whereas the new Ohio record is at approximately N39 24.3', making the Ohio record a substantial southern range extension.

Even within its "normal" range, the Incurvate Emerald appears to be quite uncommonly collected. Walker and Corbet (1975) described the habitat as "sphagnum-choked pools in a large bog." Shiffer (1969) described the Pennsylvania site as a tamarack bog, with adults flying beneath thick, low vegetation under the taller conifers and noted that females oviposited in small, nearly dry ponds. The author collected a single male in Mackinac County, Michigan flying in a narrow fen meadow comprised of various sedges, shrubby cinquefoil (*Potentilla fruticosa*), pitcher plant (*Sarracenia purpurea*), scattered pools with sphagnum and scattered northern white cedar (*Thuja occidentalis*). Brunelle (1997; personal communication, 1998) reported that in Maine it was found in both bog ponds and "peatlands which completely lacked standing water except for little puddles in the animal trails, and females were seen laying in these puddles and apparently in areas where there was no standing water at all." The collection site at Hocking College was probably along a wide logging road through an upland oak forest. The site has a number of small ponds and several small creeks, but certainly no bog or other wetlands. A check of the area in July of 1998 was unsuccessful. It appears unlikely that there is a sustained population of *S. incurvata* at the Athens County site and no habitat that fits published descriptions exists anywhere nearby.

Additional County Records

In addition to these three new state records, 712 new county records of Odonata from Ohio are reported. Table 1 lists the abbreviations used for the names of frequent collectors, and Table 2 lists abbreviations used for the collections that house the specimens. Table 3 lists each record grouped by species, showing them as: a.) county name; b.) the collector (or collector abbreviation) and year collected; and, c.) the repository holding the specimen(s). With the addition of these new county records, we now have eight species that have been reported from all 88 counties of Ohio. These are—*Anax junius, Enallagma civile, Erythemis simplicicollis, Ischnura vertialis, Libellula luctuosa, Libellula lydia, Pachydiplax longipennis*, and *Perithemis tenera.*

Despite seven years of effort by a core of workers there are still locations unsampled or sampled inadequately to report all species. Additional new state species and county records are expected.

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Table 1. Abbreviations used for frequent collectors. **(*** indicates Ohio Odonata Survey members**)**

AP	Alice H. Phillips*	HFP	Homer F. Price
BB	Bob Bannister*	HS	Henri C. Siebert*
BC	Bernie Counts*	JF	J. Flenniken
CAT	Charles A. Triplehorn	JH	John H. Hubbard*
CC	Carl Cook	JT	Jan Trybula*
CHK	Clarence H. Kennedy	JW	Jerome Wiedmann*
CJ	C. Janus	KN	K. Noblet
CLC	Cathy L. Corr*	LB	Lynn Barnhart
CP	C. Pfeil	LG	Lou Gardella*
CS	Clark Shiffer	MD	Mark Dillon*
CT	C. Todd	MG	Mike Greene*
DF	Donald Flenniken	MOB	Mark O'Brien
DH	Doug Horvath*	MR	Mark Rzeszotarski
Dilley	Mark A. Dilley*	MS	Mike Silvaggio
DJB	Donald J. Borror	MV	M. Veselica
DKP	David K. Parshall*	NWB	N. W. Britt
DM	Dwight L. Moody*	OEPA	Ohio EPA, Ecological Assessment
DMcS	David McShaffrey*	PDH	Paul D. Harwood
DP	Dennis Profant*	RAR	Robert A. Restifo*
DR	Dan Riggs*	RCG	Robert C. Glotzhober*
DW	Dirk Westfall*	RCO	Raymond C. Osburn
EBW	E. B. Williamson	RKF	R.K. Finley
EC	Eric G. Chapman*	RWA	Robert W. Alrutz*
EDC	Everett D. Cashatt	SAR	Scott A. Roush*
EE	Eric Eaton*	SC	Stephen W. Chordas III *
EMP	Erik M. Pilgrim*	SD	Sidney W. Dunkle
ESM	Eugene S. Morton	TEP	T. Edward Perry
EST	Edward S. Thomas	TS	Tom Schultz*
FJM	Frank J. Moore	TSh	Thomas Shisler*
FP	Foster Purrington	WCS	W.C. Stehr
FWS	F. W. Stehr	?	Collector not listed
GAC	Gary A. Coovert		

Table 2. Abbreviations for repositories of specimens.

Aullwd:	Aullwood Audubon Center, Dayton, Ohio	LAKEPK:	Lake Metroparks, Kirtland, Ohio
ASUMZ:	Arkansas State University, Museum of Zoology, Jonesboro, Arkansas	Miami:	University of Miami, Oxford, Ohio
		OEPA:	Ohio EPA, Columbus, Ohio
EE:	Eric Eaton, personal collection	OHS:	Ohio Historical Society, Columbus, Ohio
BC:	Bernie Counts, personal collection	OSUa:	The Ohio State University, Department of Entomology, Columbus, Ohio
Chap:	Eric Chapman, personal collection		
CinnNH:	Cincinnati (Ohio) Museum of Natural History	OSUmc:	Marietta College (later to OSU)
CMNH:	Cleveland (Ohio) Museum of Natural History	OSUs:	The Ohio State University, Franz Theodore Stone Laboratory, Gibraltar Island, Ohio
CNC:	Cincinnati Nature Center, Milford, Ohio		
DENU:	Denison University, Granville, Ohio	OU:	Ohio University, Athens, Ohio
DMNH:	Dayton Museum of Natural History (now Boonshoft Museum of Discovery, Dayton, Ohio)	RAR:	Robert A. Restifo, personal collection
		RCG:	Robert C. Glotzhober, personal collection
Dunkle:	Sidney W. Dunkle, personal collection	Shiffer:	Clark Shiffer, personal collection
FIND:	University of Findlay, Findlay, Ohio	Summit:	Metro Parks, Serving Summit County
FSCA:	Florida State Collection of Arthropods, Gainesville, Florida	Trybul:	Jan Trybula, personal collection
		TWC:	The Wilderness Center, Wilmot, Ohio
Gardel:	Lou Gardella, personal collection	UMMZ:	University of Michigan, Museum of Zoology Ann Arbor, Michigan
HTC:	Hocking College, Nelsonville, Ohio		
ISM:	Illinois State Museum, Springfield, Illinois	WSU:	Wright State University, Dayton, Ohio

Table 3. New county records of Odonata for Ohio.

Calopteryx maculata: Hancock-KN 91-FIND; Henry-TB 98-FIND; Ottawa-NWB 57-OSUs; Putnam-DM 94-FIND; Wood-DM 96-FIND; Wyandot-? 51-OHS. (Un-recorded Only from Mercer & Scioto).

Hetaerina americana: Guernsey-DMcS 94-OHS; Hamilton-EE 93-EE; Hardin-DM 95-FIND; Ottawa-NWB 56-OSUs and M.W. Boessel 48-OSUs; Stark-EC 90/92- Chap; Trumbull-SC 96-ASUMZ; Van Wert-TB 98-FIND; Washington-DMcS 94-OHS.

Hetaerina titia: Athens-DR 95-OHS; Hocking-DR 95-OHS; Washington-CT 95-OSUmc.

Archilestes grandis: Adams-OEPA 87-OEPA; Greene-OEPA 82-OEPA; Mahoning-SC 96-ASUMZ; Paulding-HFP 62-OSUa; Pickaway-OEPA 93-OEPA; Richland-OEPA 74-OEPA; Stark-OEPA 86-OEPA; Trumbull-CLC 96-OHS; Washington-Barb Peters 94-OHS.

Lestes congener: Greene-K. Harp 74-WSUbio; Miami-B. Guild 73-WSU; Stark-RCG 96-OHS; Trumbull-SC 96-ASUMZ; Wayne-FP 87-OHS; Wood-DM 96-FIND.

Lestes disjunctus australis: Ashtabula-RCO 18-OSUa; Athens-RAR 75-RAR; Champaign-J.L. Williams 64-OSU; Columbiana-EBW 00-UMMZ; Fairfield-DJB 36-OHS; Greene-SAR 97-DMNH; Hamilton-EE 92-OHS; Hardin-DKP 94-OHS; Henry-DKP 94-OHS; Marion-DKP 91-OHS; Mercer-HFP 42-OSU; Ottawa-EST 51-OSUa; Ross-M.E. Crago 36-OSUa; Stark-MG 96-Summit.

Lestes disjunctus disjunctus: Erie-RCO 1899-OSUa & UMMZ; Franklin-RCG 87-OHS; Harrison-EC 97-CMNH; Henry-DKP 96-OHS; Ottawa-David Kellicott 1895-UMMZ; Pickaway-RCG 84-OHS.

Lestes dryas: Medina-RCO 1899-OSUa; Wood- EC 97-CMNH; Wyandot-DM 96-FIND.

Lestes eurinus: Adams-EE 93-EE; Butler-JT 96- Trybul; Clermont-JH 95-CNC; Columbiana-SC 96-ASUMZ; Hamilton-JT 96- Trybul; Hocking-DR 95-OHS; Miami-Chris McKay 94-OHS; Putnam-Nate Closson 94-FIND; Wayne-RCG 97-OHS.

Lestes forcipatus: Carroll-SC 97-ASUMZ; Cuyahoga-LG 97-GARDEL; Delaware-DJB 31-OSUa; Marion-SC 97-ASUMZ; Medina-SC 97-ASUMZ & SD 97-DUNKLE; Summit-RCG 96-OHS; Trumbull-SC 96-ASUMZ; Wayne-FP 87-OHS.

Lestes inaequalis: Carroll-DMcS 95-OHS; Mahoning-SC 96-ASUMZ; Tuscarawas-EC 97-CMNH.

Lestes rectangularis: Adams-MD 94-Aullwd; Carroll-SC 97-ASUMZ; Hamilton-RAR 95-RAR; Seneca-RWA & ESM 60-OSUa. (Un-recorded only from Brown, Monroe, & Scioto).

Lestes unguiculatus: Auglaize-SC 97-ASUMZ; Fayette-SC 96-ASUMZ; Geauga-RAR 72-RAR; Greene-R. Flint 75-WSU; Hamilton-EE 95-EE; Licking-TS 97-DENU.

Lestes vigilax: Ashtabula-EC 97-CMNH; Butler-JT 95-Miami; Clark-DR 96-OHS; Columbiana-SC 96-ASUMZ; Fairfield-TS 98-DENU; Jackson-OEPA 84/86-OEPA; Logan-DR 95-OHS; Medina-SD 97-Dunkle.

Amphiagrion saucium: Gallia-James S. Hine 1900-UMMZ; Highland-RCO 1899-OSUa; Jefferson-JF 65-OSUa; Ottawa-? 68-OSUa; Ross-EST 31-OHS; Stark-MG 95-Summit; Tuscarawas-EC 97-OHS; Vinton-DR 96-OHS.

Argia apicalis: Morrow-SC 97-ASUMZ. (Un-recorded only from Columbiana & Jefferson).

Argia bipunctulata: Greene-EMP 98-OHS, Stark-MG 95-Summit.

Argia fumipennis violacea: Ottawa-D.E. Beilstein 67-OSUa; Wyandot-DM 96-FIND. (Un-recorded only Coshocton, Lucas, Marion, Mercer, Putnam).

Argia moesta: Clark-RCG 94-OHS; Hardin-DM 95-FIND; Hocking-RCG 94-OHS; Madison-PDH 63-FSCA; Trumbull-SC 96-ASUMZ; Washington-DMcS 94-OHS; Wayne-M. Sean Ellis 94-OSUa; Wyandot-DM 96-FIND.

Argia sedula: Henry-DM 98-FIND; Warren-HFP 51-OSUa.

Argia tibialis: Columbiana-EC 97-CMNH; Hamilton-JH 94-CNC; Hocking-RCG 94-OHS; Preble-CS 72-Shiffer; Washington-DMcS 94-OHS.

Argia translata: Licking-Ava Hauck 98-DENU; Portage-RCG 96- OHS; Trumbull-SC 96-ASUMZ.

Chromagrion conditum: Jefferson-JF 65-OSUa. (? Highland EBW 1898-UMMZ = "Danville, OH" could be Highland, Knox, or Meigs Co.).

Enallagma antennatum: Defiance-PDH 46-FSCA & HFP 49-OSUa; Highland-DJB 34-OSUa; Ottawa-? 70-OSUa.

Enallagma aspersum: Hocking-DG 95-OHS; Mercer-DJB 33-OSUa; Scioto-DJB 31-OSUa; Trumbull-SC 96-ASUMZ; Wayne-FP 87-OHS.

Enallagma basidens: Erie-TEP 85-CMNH; Wood-SC 94-ASUMZ. (Un-recorded only from Ashtabula, Henry, Jefferson, Mahoning, and Sandusky counties. Alrutz (1961) considered this an invading species that had become widespread. The first record was by D. J. Borror (1937) in Clermont County.)

Enallagma boreale: Summit-MG 96-Summit.

Enallagma carunculatum: Greene-DJB 34-UMMZ.

Enallagma civile: Jackson-RAR 95-RAR; Seneca-DM 98-FIND; Stark-RWA 59-OSUa. (Recorded from All Counties as of 1998.)

Enallagma cyathigerum: Ottawa-C. Ahrens 70-OSUa.

Enallagma divagans: Highland-DJB 34-OSUa; Lake-JW 96-LAKEPK; Tuscarawas-EC 97-OHS.

Enallagma exsulans: Hardin-DM 95-FIND. (Un-recorded only from Hamilton Co.).

Enallagma geminatum: Wood-DM 96-FIND.

Enallagma hageni: Summit-EC 99-CMNH.

Enallagma signatum: Marion-SC 97-ASUMZ; Richland-SC 97-ASUMZ; Washington-DMcS 94-OHS.

Enallagma traviatum westfalli: Ashland-PDH 49-FSCA; Carroll-PDH 50-FSCA; Clark-RCG 96-OHS; Clermont-CS 72-Shiffer; Cuyahoga-LG 95-GARDEL; Erie-RCO 1897-OSUa; Fairfield-SC 95-ASUMZ; Hocking-PDH 61-FSCA; Lake-RAR 73-RAR; Lucas-RCG 94-OHS; Medina-SD 97-Dunkle; Miami-MD 94-Aullwd; Montgomery-MD 94-Aullwd; Morgan-LB 95-OHS; Richland-PDH 58-FSCA; Ross-RAR 74-RAR; Seneca-DM 96-FIND; Wayne-PDH 59-FSCA..

Enallagma vesperum: Clermont-CS 72-Shiffer; Scioto-RCG 97-OHS.

Ischnura hastata: Greene-D.J. Grumbarger 96-DMNH; Ross-DJB 42-OSUa; Stark-RWA 59-OSUa; Washington-DMcS 94-OHS.

Ischnura posita: Athens-RAR 74-RAR; Henry-DM 96-FIND; Ottawa-CAT 50-OHS. (Un-recorded only from Hamilton, Harrison, and Wyandot counties.)

Nehalennia gracilis: Athens-DP 95-HTC; Portage-MG 94-Summit.

Nehalennia irene: Delaware-DJB 30-OSUa; Highland-RCO 1899-OSUa.

Tachopteryx thorey: Gallia-CC 94-FSCA; Geauga-MR 95-CMNH; Highland-RCG 94-OHS; Jefferson-DF 65-OSUa; Ross-W.B. Shively 95-OHS.

Aeshna canadensis: Lucas-MOB 97-UMMZ; Ross-? 1897-CinnNH.

Aeshna constricta: Ashtabula-EC 93- Chap; Athens-HS 79-OU; Greene-SAR 97-DMNH; Huron-PDH 60-FSCA; Lucas-MOB 97-UMMZ; Mahoning-SC 96-ASUMZ; Montgomery-E.J. Koestner 56-DMNH; Ross-? 1897-CinnNH; Stark-R.M. Ritter ?-TWC.

Aeshna mutata: Geauga-RCG 95-OHS, RAR 95-RAR, & MD 95-Summit.

Aeshna tuberculifera: Athens-Chris Tahyi 94-OHS; Carroll-OEPA 92-OEPA; Harrison-EC 97-CMNH; Hocking-EC 93?- Chap & DR 96-OHS; Licking-S. Peters 96-DENU; Pike-Lyons & Hauk 68-DMNH; Summit-MG 95-Summit.

Aeshna umbrosa: Athens-FWS 48-OU; Delaware-OEPA 85-OEPA; Greene-MV 75-WSU; Hocking-Mike Flynn 94-OHS; Jefferson-DF 64-OSUa; Montgomery-G.R. Pilate 1900-DMNH; Muskingum-SC 96-ASUMZ; Perry-DR 93-OHS; Putnam-NC 94-FIND; Sandusky-OPEA 86-OEPA; Union-OEPA 85-OEPA; Washington-DMcS 94-OHS; Wayne-PDH 70-FSCA.

Aeshna verticalis: Ashtabula-JW 97-LAKEPK; Carroll-SC 97-ASUMZ; Portage-LG 98-Gardel; Ross-? 1898-CinnNH; Washington-CT 94-OHS; Wayne-Mike Wright 39-UMMZ.

Anax junius: Columbiana-EBW 1901-UMMZ. (Now recorded from all 88 counties.)

Anax longipes: Athens-HS 87-OU; Meigs-EC 97-CMNH; Ross-EC 97-ASUMZ; Sandusky-Russ Philpot 13-OSUa; Wayne-FP 87-OHS; Williams-EDC 96-ISM. (Note: Previous sight records for Wayne-DJB-37 and Williams-HFP-58 are now confirmed.)

Basiaeshna janata: Adams-MD 94-Aullwd; Athens-WCS 32-OU; Carroll-OEPA 84-OEPA; Champaign-OEPA 87-OEPA; Clermont-OEPA 90-OEPA; Crawford- OEPA 79-OEPA; Cuyahoga-OEPA 92-OEPA; Gallia-OEPA-90-OEPA; Guernsey-OEPA 92-OEPA; Hardin-OEPA 93-OEPA; Harrison-OEPA 92-OEPA; Holmes-OEPA 93-OEPA; Huron-OEPA 87-OEPA; Jackson-OEPA 84-OEPA; Knox-OEPA 87-OEPA; Lawrence-OEPA 90-OEPA; Logan-OEPA 96-OEPA; Mahoning-OEPA 85-OEPA; Medina-OEPA 92-OEPA; Miami-OEPA 82-OEPA & MD 94-Aullwd; Montgomery-MD 94-Aullwd; Pike-OEPA 92-OEPA; Preble-OEPA 86-OEPA; Ross-OEPA 92-OEPA; Stark-OEPA 93-OEPA; Warren-OEPA 93-OEPA. (Note: Most of these records are from larva only. The adults fly early and are missed by many collectors, despite their widespread abundance.)

Boyeria vinosa: Allen-OEPA 74-OEPA; Athens-WCS 53-OU; Brown-OEPA 83-OEPA; Clark-OEPA 79-OEPA: Columbiana-OEPA 85-OEPA; Cuyahoga-OEPA 91-OEPA; Fayette-OEPA 89-OEPA; Guernsey-OEPA 87-OEPA; Hamilton-OEPA 91-OEPA; Hancock-OEPA 83-OEPA: Harden-OEPA 84-OEPA; Harrison-OEPA 82-OEPA; Henry-OEPA 86-OEPA: Jefferson-OEPA 83-OEPA; Lorain-OEPA 82-OEPA; Lucas-OEPA 93-OEPA; Medina-OEPA 81-OEPA; Meigs-OEPA 89-OEPA: Mercer-OEPA 84-OEPA; Monroe-OEPA 92-OEPA; Montgomery-U. Khot 80-DMNH; Morgan-OEPA 89-OEPA; Morrow-OEPA 84-OEPA; Muskingum-OEPA 88-OEPA; Noble-OEPA 87-OEPA; Pickaway-OEPA 82-OEPA; Pike-OEPA 93-OEPA: Richland-OEPA 84-OEPA; Ross-OEPA 81-OEPA; Sandusky-OEPA 81-OEPA; Scioto-OEPA 90-OEPA; Shelby-OEPA 82-OEPA; Summit-MG 94-Summit; Union-OEPA 78-OEPA; Van Wert-OEPA 88-OEPA: Warren-OEPA 89-OEPA; Washington-DMcS 94-OHS; Wood-OEPA 88-OEPA; Wayne-OEPA 93-OEPA; Wyandot-OEPA 79-OEPA. (Un-recorded only from Clermont, Fulton, and Ottawa.)

Boyeria grafiana: Hocking-DR 96-OHS; Ross-Denis Case 97-OHS; Summit-MG 94-Summit.

Epiaeschna heros: Ashtabula-SC 96-ASUMZ; Clark-J.C. Roseberry 86-DMNH; Cuyahoga-CP 85-CMNH; Gallia-OEPA 93-OEPA; Medina-SC 96-ASUMZ; Montgomery-P. Johnson 69-DMNH; Trumbull-SC 96-ASUMZ.

Nasiaeshna pentacantha: Auglaize-OEPA 91-OEPA; Delaware-OEPA 85-OEPA; Franklin-OEPA 92-OEPA; Madison-OEPA 86-OEPA; Marion-OEPA 87-OEPA; Miami-MD 94- Aullwd; Montgomery-MD 94- Aullwd; Union-OEPA 85-OEPA; Van Wert-OEPA 84-OEPA..

Arigomphus furcifer: Geauga-MG 94-Summit; Summit-OEPA 88-OEPA..

Arigomphus villosipes: Ashtabula-SC 96-ASUMZ; Carroll-DMcS 95-OSUmc; Champaign-RCG 85-RCG; Clark-RCG & DR 96-OHS; Defiance-CC 94-FSCA; Greene-SAR 97-DMNH; Henry-DM 94-FIND; Medina-SD 94-Dunkle; Morrow-SC 97-ASUMZ; Stark-EC 97-CMNH; Washington-DMcS 94-OHS.

Dromogomphus spinosus: Athens-DR 95-OHS; Defiance-CC 94-FSCA; Fairfield-DR 96-OHS; Gallia-OEPA 93-OEPA; Greene-SAR 97-DMNH; Hamilton-B.M. Branson 97-CNC; Hocking-EC 92-Chap; Huron-OEPA 87-OEPA; Meigs-OEPA 93-OEPA; Monroe-DMcS 95-OSUmc; Noble-EC 97-OHS; Ottawa-CHK 34-FSCA; Pickaway-DR 96-OHS; Union-OEPA 90-OEPA; Van Wert-OEPA 84-OEPA; Washington-DMcS 94-OHS; Williams-OEPA 84-OEPA..

Dromogomphus spoliatus: Athens-FWS 53-OU.

Gomphus viridifrons: Adams-MD 94-Aullwd; Franklin-? 1903-OSUa; Monroe-CC 94-FSCA;.

Gomphus fraternus: Adams-MD 94-Aullwd; Ashtabula-CLC 96-OHS; Athens-HS 88-OU; Cuyahoga-LG 95-Gardel; Fayette-SC 95-ASUMZ; Greene-MD 94-Aullwd; Medina-SD 97-Dunkle; Montgomery-MD 94 & DH 94-Aullwd; Pickaway-RCG 96-OHS; Sandusky-RCO 1899-OSUa; Warren-MD 94-Aullwd; Washington-DMcS 95-OSUmc; Wyandot-DM 96-FIND.

Gomphus externus: Darke-OEPA 90-OEPA; Erie-OEPA 84-OEPA; Montgomery-OEPA 92-OEPA; Pickaway-RCG & Nick Donnelly 96-OHS; Ross-OEPA 87-OEPA; Seneca-OEPA 90-OEPA; Tuscarawas-OEPA 88-OEPA: Williams-OEPA 92-OEPA: Wyandot-OEPA 90-OEPA..

Gomphus crassus: Madison-CHK 20-UMMZ; Miami-MD 94-Aullwd; Montgomery-GAC 69-DMNH.

Gomphus vastus: Licking-OEPA 93-OEPA: Meigs-DR 95-OHS; Muskingum-OEPA 88-OEPA; Stark-OEPA 88-OEPA; Tuscarawas-OEPA 88-OEPA; Washington-DMcS 95-OHS.

Gomphus ventricosus: Montgomery-DH 94-Aullwd.

Gomphus lividus: Carroll-OEPA 91-OEPA: Champaign-MD 94-Aullwd; Clark-RCG & DR 96-OHS; Clinton-OEPA 93-OEPA; Coshocton-DJB 34-UMMZ; Crawford-OEPA 92-OEPA; Cuyahoga-LG 95-Gardel; Jefferson-OEPA 83-OEPA; Lake-JW 97-LAKEPK; Miami-MD 94-Aullwd; Montgomery-MD 94-Aullwd; Preble-OEPA 83-OEPA; Scioto-RCG 97-OHS; Washington-DMcS 95-OSUmc.

Gomphus graslinellus: Adams-RCG 97-OHS; Butler-JT 96-Miami; Clermont-JH 95-CNC; Hancock-OEPA 83-OEPA; Madison-? 1897-UMMZ; Miami-MD 94-Aullwd; Seneca-DM 91-FIND.

Gomphus exilis: Lawrence-EC 97-CMNH; Licking-RWA 91-OSUa; Medina-SD 94-Dunkle.

Gomphus spicatus: Geauga-MG 94-Summit; Morrow-SC 94-ASUMZ.

Gomphus quadricolor: Knox-OEPA 87-OEPA; Miami-MD 94-Aullwd; Montgomery-MD&DH 94-Aullwd; Shelby-OEPA 82-OEPA; Washington-DMcS 95-OSUmc.

Hagenius brevistylus: Delaware-Mike Wright 39-UMMZ; Fairfield-DR 96-OHS; Gallia-OEPA 93-OEPA; Geauga-MG 95-Summit; Hocking-DR 94-OHS; Lake-T. Hagestrom 94-LAKEPK; Meigs-OEPA 93-OEPA; Monroe-CC 94-FSCA; Pike-BC 93-Counts; Scioto-BC 94-Counts; Tuscarawas-OEPA 83-OEPA; Washington-DMcS 97-OHS: Warren-MD 94-Aullwd.

Lanthus parvulus: Adams-OEPA 87-OEPA; Ashtabula-MS 95-OHS; Athens-HS 88-OU; Columbiana-OEPA 83-OEPA; Cuyahoga-CJ 73-RAR; Coshocton-OEPA 93-OEPA; Geauga-MG 95-Summit; Jefferson-OEPA 83-OEPA; Licking-OEPA 86-OEPA; Scioto-OEPA 84-OEPA.

Lanthus vernalis: New State Record. Geauga-MR 95-CMNH; Portage-EC 97-OHS.

Ophiogomphus rupinsulensis: Ashland-CHK 39-UMMZ; Belmont-Tony Minamyer 91-OEPA; Columbiana-SC 96-ASUMZ; Madison-Div. Natural Areas & Preserves 93-OHS; Pickaway-Mark Dilley 90-OHS.

Ophiogomphus carolus: Columbiana-SC 96-ASUMZ; Jefferson-JF 65-OSUa; Lake-JW 97-LAKEPK.

Progomphus obscurus: Fairfield-DR 96-OHS; Meigs-WCS 38-OU; Ross-OEPA 92-OEPA.

Stylurus notatus: Adams-MD 95-Aullwd; Coshocton-OEPA 88-OEPA; Gallia-OEPA 90-OEPA; Hamilton-EE 92-Eaton; Meigs-DR 95-OHS; Pike-OEPA 85-OEPA; Tuscarawas-OEPA 88-OEPA; Washington-DW 94-OHS.

Stylurus plagiatus: Adams-BB 96-DMNH; Putnam-DM 95-FIND.

Stylurus spiniceps: Athens-WCS 43-OU; Clark-CC 49-FSCA; Coshocton-OEPA 88-OEPA; Cuyahoga-OEPA 88-OEPA; Greene-MD 95-Aullwd; Holmes-OEPA 88-OEPA; Jefferson-OEPA 83-OEPA; Licking-TS 98-DENU; Pickaway-OEPA 88-OEPA; Portage-LG 98-Gardel; Stark-OEPA 89-OEPA; Tuscarawas-OEPA 92-OEPA; Washington-CT 95-OSUmc; Wayne-OEPA 93-OEPA.

Stylurus laurae: Fairfield-TSh 96-OHS; Gallia-DR 93-OHS.

Stylogomphus albistylus: Adams-OEPA 87-OEPA; Belmont-OEPA 91-OEPA; Cuyahoga-OEPA 88-OEPA; Hocking-DR 96-OHS; Holmes-OEPA 93-OEPA; Knox-OEPA 89-OEPA; Medina-OEPA 92-OEPA; Monroe-OEPA 92-OEPA; Richland-OEPA 93-OEPA; Summit-OEPA 88-OEPA & MG 96-Summit; Washington-OEPA 84-OEPA.

Cordulegaster bilineata: Licking-"MDN" 31-OHS; Montgomery-R.K. Finley 69-DMNH; Ross-EST 31-OHS

Cordulegaster diastatops: Summit-AP 94-Summit.

Cordulegaster erronea: Ross-DC 96-OHS.

Cordulegaster maculata: Licking-TS 98-DENU; Warren-MD 94-Aullwd; Washington-DW 94-OHS.

Cordulegaster obliqua: Athens-DR & RCG 98-OHS; Franklin-J.B. Parker 1899-OSUa; Mahoning-SC 96-ASUMZ; Meigs-BC 97-OEPA; Pike-BC 97-OEPA.

Didymops transversa: Butler-"MWB" 65-Miami; Gallia-OEPA 93-OEPA; Meigs-OEPA 93-OEPA; Pike-OEPA 92-OEPA.

Macromia alleghaniensis: Fairfield-DR 96-OHS; Hocking-DR 96-OHS; Vinton-DR 95-OHS.

Macromia i. illinoiensis: Belmont-OEPA 91-OEPA; Butler-JT 96-Trybul; Clermont-"N. Col." 1897-CinnNH; Coshocton-Mike Hoggarth 96-OSUa; Darke-OEPA 82-OEPA; Delaware-OEPA 85-OEPA; Gallia-OEPA 93-OEPA; Hamilton-EE 93-Eaton; Madison-OEPA 79-OEPA; Meigs-DR 94-OHS; Muskingum-OEPA 88-OEPA; Warren-GAC 88-DMNH; Washington-DMcS 94-OSUmc.

Macromia i. georgina: Adams-MD 94-Aullwd.

Macromia pacifica: Auglaize-HFP 61-OSUa; Defiance-DR 95-OHS; Morgan-DR 95-OHS.

Macromia sp. indet.: Miami-MD 94-Aullwd; Paulding-HFP 61-OSUa.

Macromia taeniolata: Athens-FWS 53-OU; Auglaize-HFP 61-OSUa; Hardin-DM 95-FIND; Meigs-DR 94-OHS; Montgomery-R. Newman 90-DMNH; Morgan-DR 95-OHS; Portage-Alice Phillips 95-OHS; Putnam-DM 95-FIND; Scioto-MD 96-DMNH; Stark-EC 97-CMNH; Wyandot-DM 96-FIND.

Macromia wabashensis: Logan-DR 95-OHS; Montgomery-GAC 87-DMNH; Putnam-CC 93-FSCA.

Cordulia shurtleffi: Portage-MG 94-OHS & RCG 94-OHS.

Epitheca canis: Cuyahoga-LG 95-Gardel; Trumbull-SC 96-ASUMZ.

Epitheca cynosura: Ashtabula-TEP 75-CMNH; Clark-DR 96-OHS; Columbiana-SC 96-ASUMZ; Cuyahoga-LG 94-Gardel; Gallia-OEPA 93-OEPA; Lawrence-EC 97-CMNH; Miami-MD 94-Aullwd; Montgomery-DH & MD 94-Aullwd; Trumbull-SC 96-ASUMZ.

Epitheca princeps: Fulton-MD 94-FIND; Greene-SAR 97-DMNH; Henry-RCO 1898-OSUa; Mahoning-EC 97-CMNH; Mercer-EC 97-CMNH; Trumbull-EC 97-CMNH.

Helocordulia uhleri: Adams-MD 94-OHS; Ross-R.A. Champlain 54-OSUa. NOTE: Champlain & Whiting (1955) reported this species from Tar Hollow State Forest as Hocking County. They did not give a precise location in the forest, and the forest today includes portions of Hocking, Ross, and Vinton Counties. Two males in the OSU collections (from the 3 males & 1 female reported) are labeled Ross county, apparently "corrected" by someone without an explanation. The addition of Ross County should be accepted with some question.

Neurocordulia molesta: New State Record. Athens-OEPA 90-OEPA; Coshocton-OEPA 87-OEPA; Franklin-OEPA 91-OEPA; Gallia-OEPA 90-OEPA & DR 95-OHS; Hamilton-OEPA 93-OEPA & EE 94-Eaton; Lorain-DMcS 96-OHS; Meigs-DR 95-OHS; Muskingum-OEPA 88-OEPA; Pickaway-OEPA 88-OEPA; Pike-OEPA 85-OEPA; Scioto-Kip Will 91-OHS; Washington-OEPA 88-OEPA & CT 95-OHS.

Neurocordulia obsoleta: Columbiana-OEPA 87-OEPA; Morgan-OEPA 85-OEPA; Scioto-OEPA 83-OEPA; Washington-OEPA 88-OEPA.

Neurocordulia yamaskanensis: Adams-OEPA 87-OEPA; Knox-OEPA 87-OEPA; Meigs-DR 95-OHS; Morgan-OEPA 89-OEPA; Ross-BC 97-OEPA; Washington-DMcS 96-OSUa. Note: The Scioto County record previously reported (Glotzhober *et. al.*, 1995) should be deleted as it represents a misidentification of *N. molesta*).

Somatochlora ensigera: Van Wert-HFP 61-OUSa.

Somatochlora linearis: Butler-? 69-Miami; Delaware-OEPA 92-OEPA; Fairfield-OEPA 88-OEPA; Hocking-EST 40-OHS; Jackson-RAR 95-RAR; Lake-JW 96-LAKEPK; Lucas-EDC 96-ISM; Mahoning-EC 96-Chap; Meigs-OEPA 89-OEPA; Stark-OEPA 85-OEPA; Vinton-OEPA 80-OEPA & DR 96-OHS; Warren-FJM 60-OSUa; Wyandot-DKP 93-OHS.

Somatochlora incurvata: New State Record. Athens-DP 97-OHS.

Somatochlora tenebrosa: Fairfield-TSh 96-OHS; Jefferson-OEPA 83-OEPA; Lucas-HFP 58-OSUa; Pike-TS 98-DENU.

Celithemis eponina: Butler-Dobies & Wessells 92-Miami; Crawford-DJB & CHK 37-OSUa; Greene-J.A. Gessaman 57-DMNH; Monroe-DMcS 95-OSUa; Ottawa-HFP 41-OSUa; Union-SC 94-ASUMZ.

Celithemis elisa: Allen-EC 97-CMNH; Columbiana-SC 96-ASUMZ; Geauga-MG 94-Summit; Greene-SAR 97-DMNH; Medina-SD 97-Dunkle; Sandusky-E. Easton 1900-OSUa; Trumbull-SC 96-ASUMZ.

Celithemis fasciata: Defiance-CC 94-FSCA; Scioto-BB 96-DMNH.

Leucorrhinia frigida: Portage-MG 94-Summit.

Leucorrhinia intacta: Carroll-SC 97-ASUMZ; Mahoning-SC 96-ASUMZ.
Libellula cyanea: Carroll-DMcS 95-OHS; Lawrence-DKP 96-OHS.
Libellula deplanata: Butler-JT 95-Miami; Vinton-RCG 95-OHS.
Libellula incesta: Fairfield-DR 96-OHS; Lawrence-DKP 93-OHS; Pike-TS 98-DENU.
Libellula lydia: Adams-MD 94-Aullwd; Lawrence-DKP 96-OHS. Reported in all counties.
Libellula pulchella: Clark-DR 96-OHS. (Recorded in all counties, but only by sight record in Fayette, DJB,1937).
Libellula quadrimaculata: Stark-MG 96-Summit.
Libellula semifasciata: Clermont-JH 95-CNC; Meigs-EC 97-CMNH.
Libellula vibrans: Clark-EC 99-Chap; Hocking-Borror & Jenkins 37-OSUa; Lucas-HFP 59-OSUa; Portage-RCO 1900-OSUa; Wayne- Borror & Jenkins 37-OSUa.
Pantala flavescens: Adams-EC 97-CMNH; Champaign-HFP 58-OSUa; Clinton-FJM 56-OSUa; Greene-B. Stiles 68-WSU; Hardin-DR 95-OHS; Jackson-RAR 95-RAR; Lucas-HFP 58-OSUa; Putnam-HFP 61-OSUa; Stark-EC 92-Chap; Summit-MG 95-Summit; Warren-J.J. Falke 68-DMNH; Washington-CT 95-OSUmc.
Pantala hymenaea: Coshocton-OEPA 83-OEPA; Cuyahoga-LG 94-Gardel; Geauga-MG 94-Summit; Hocking-DR 94-OHS; Meigs-DR 94-OHS; Miami-OEPA 82-OEPA; Montgomery-DH & MD 94-Aullwd; Pickaway-RCG 96-OHS; Stark-OEPA 85-OEPA; Warren-OEPA 83-OEPA; Washington-DMcS 94-OHS; Wyandot-DKP 94-OHS.
Sympetrum ambiguum: Crawford-CHK 37-OSUa; Hocking-J.S. Thomas 36-OHS; Jackson-RAR 95-RAR; Montgomery-T.D.Center 68-DMNH; Warren-Finley et al. 68-DMNH.
Sympetrum corruptum: Logan-? 1896-UMMZ; Lucas-HFP 58-OSUa; Mercer-RCO 1896-OSUa.
Sympetrum obtrusum: Champaign-J.N. Knull 43-OSUa; Darke-Alrutz/Morton 60-OSUa; Fulton-HFP 56-OSUa; Geauga-TEP 72-CMNH & RAR 72-RAR; Greene-Koestner & Riegel 56-DMNH; Preble-C.S. Fox 80-Miami.
Sympetrum rubicundulum: Clark-GAC 73-DMNH; Clinton-FJM 60-OSUa; Guernsey-BC 95-OEPA; Jefferson-JF 65-OSUa; Morgan-LB 95-OHS.
Sympetrum semicinctum: Ashtabula-EST 35-OHS; Columbiana-SC 96-ASUMZ; Darke-Bob Roth 59-DMNH; Hocking-DR 95-OHS; Mahoning-SC 96-ASUMZ; Morgan-LB 95-OHS; Ottawa-LG 94-Gardel; Sandusky-EBW 1903-UMMZ; Stark-CAT 50-OSUa; Vinton-J.J. Jenkinson 58-OHS; Warren-Center & Finley 68-DMNH.
Sympetrum vicinum: Crawford-RWA 58-OSUa; Fulton-DM 98-FIND; Hocking-DR 96-OHS; Lawrence-DKP 93-OHS; Madison-SC 94-ASUMZ; Ross-DJB 42-OSUa.
Tramea carolina: Adams-MD 95-Aullwd; Allen-OEPA 88-OEPA; Clinton-FJM 62-OSUa; Cuyahoga-LG 98-Gardel; Defiance-CC 94-FSCA; Lucas-HFP 58-OSUa.
Tramea lacerata: Allen-EC 97-CMNH; Fulton-DM 94-FIND; Trumbull-SC 96-ASUMZ; Washington-DMcS 95-OHS; Wayne-FP 87-OHS; Wood-DM 96-FIND.
Tramea onusta: Adams-EC 97-CMNH; Butler-K.F. Horn 74-Miami; Stark-EC 92-Chap; Trumbull-SC 96-ASUMZ; Union-EC 97-CMNH.

Ohio Biological Survey Notes 2: 35-37, 1999.

Rediscovery of the Water Boatman *Sigara signata* (Hemiptera: Corixidae) in Ohio, with Brief Notes on Habitat and Distribution

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Introduction

Water boatmen (Hemiptera: Corixidae) are common and widespread aquatic insects found throughout North America. Of the 17 genera known from the United States and Canada (Polhemus *et al.*, 1988), the transcontinental genus *Sigara* Fabricius, 1775, consisting mainly of small insects (range 2 to 9 mm), is the most diverse with 50 species. In Ohio only one *Sigara* species, *Sigara alternata* (Say, 1825), exceeds 6 mm in length. Very small *Sigara* specimens can be easily overlooked in the field by general collectors and are also taxonomically challenging.

The Corixidae of Ohio, as well as several other aquatic insect groups, are relatively poorly known. However, several ongoing projects are addressing this deficiency and have thus far resulted in many interesting discoveries. In 1998 alone, 80 aquatic insect species were reported as new records for Ohio [45 aquatic Coleoptera by Chapman (1998); five Corixidae by Chordas and Armitage (1998); 30 Ephemeroptera by Randolph and McCafferty (1998)]. Although we do not report a new state record, this note addresses the interesting find of a small *Sigara* species [*Sigara signata* (Fieber, 1851)] that apparently has not been collected in Ohio for over 80 years.

Methods

We collected *Sigara signata* specimens in dip-net samples and in illuminated underwater bottle traps. Identification was made using the key to North American *Sigara* by Hungerford (1948). Specimens were preserved in 75% ethanol. All voucher specimens have been retained by the first author and deposited in his personal collection (SWAC Collection) at The Ohio State University. The prominent Ohio museum collections of the Cincinnati Museum of Natural History, Cleveland Museum of Natural History, Boonshoft (Dayton) Museum of Discovery, the Ohio Biological Survey, The Ohio State University, and Youngstown State University were searched for additional *Sigara signata* records.

Results and Discussion

We collected *Sigara signata* in July of 1996 and October of 1997 from a marsh area located in Berlin Lake Wildlife Area, Portage County (41° 00.9' N : 81° 05.3' W). This habitat covered approximately 1.5 hectares, was less than 2 meters deep with clear water, and contained a mixture of cattails, grasses, sedges, and reeds along with edge-line filamentous algae and a scant covering of duckweed. In October of 1997 we collected *Sigara signata* from a pond on the Lake County YMCA property (41° 44.16' N : 81° 07.9' W). This habitat was less than 0.1 hectare in size, less than 1 meter deep with clear water, and contained filamentous algae along with scant cattail and grass stands. Initially we thought that this species was a new state record for Ohio, because in their most recent synopsis, Polhemus *et al.* (1988) did not list *Sigara signata* for Ohio. However, further research found that Hungerford (1948) did list it from Summit County, Ohio (from an unknown number of specimens, possibly only one) with a collection date of August, 1916. Its omission from the Ohio fauna by Polhemus *et al.* (1988) was either a typographical error or simply an oversight by the authors (personal communication, John T. Polhemus, Colorado State Museum, Englewood). No *Sigara signata* specimens were found in any of the museum collections examined. It was also absent from several hundred black light samples, obtained over five years, in the Ohio Biological Survey Collection. However, this is not too surprising as we know of no report of it being taken in black light samples. Thus, our specimens appear to be the first *Sigara signata* specimens collected in Ohio since 1916.

The dearth of corixid specimens in nearly all of Ohio's insect collections may be due to the lack of collecting effort. However, we have made well over 300 dip-net and bottle-trap collections from 1995 through 1998, mainly targeting aquatic Hemiptera and Coleoptera, from many aquatic habitats throughout Ohio. Of these, only three collections contained *Sigara signata* specimens (with no more than four specimens of this species from any collection). Excluding the single literature report, which does not provide specific data (*e.g.* number of specimens, sex, habitat information, *etc.*), this species is known from only eight specimens taken at two sites located in two northeastern Ohio counties (Lake and Portage) (Figure 1). Thus, in Ohio, *Sigara signata* has been taken only during July, August, and October, and seems to prefer well vegetated, permanent, shallow ponds or marsh areas.

Although its range in Ohio is apparently restricted to the northeastern corner, *Sigara signata* is widespread in North America north of Mexico, occurring mainly east of the Mississippi and Assiniboine rivers (Figure 2). Bobb (1974) reported this species as a new state record for Virginia and found adults every month of the year except January, noting that it occurred in largest abundance in ponds. Wilson (1958) listed it as possibly occurring in Mississippi. It has been taken in pool areas of streams (Bobb, 1974; Hilsenhoff, 1984) which are generally believed to be the overwintering sites for many corixids in the northern portion of North America.

Of the 50 species known for the United States and Canada, there are currently only eight *Sigara* species reported from Ohio. Further, two of these eight were recently reported by Chordas and Armitage (1998). Comparatively, there are 23 *Sigara* species known from both Michigan (Stephen W. Chordas III, unpublished data) and Wisconsin (Hilsenhoff, 1984), and 14 from Virginia (Bobb, 1974). Many more *Sigara* species could yet be reported for Ohio.

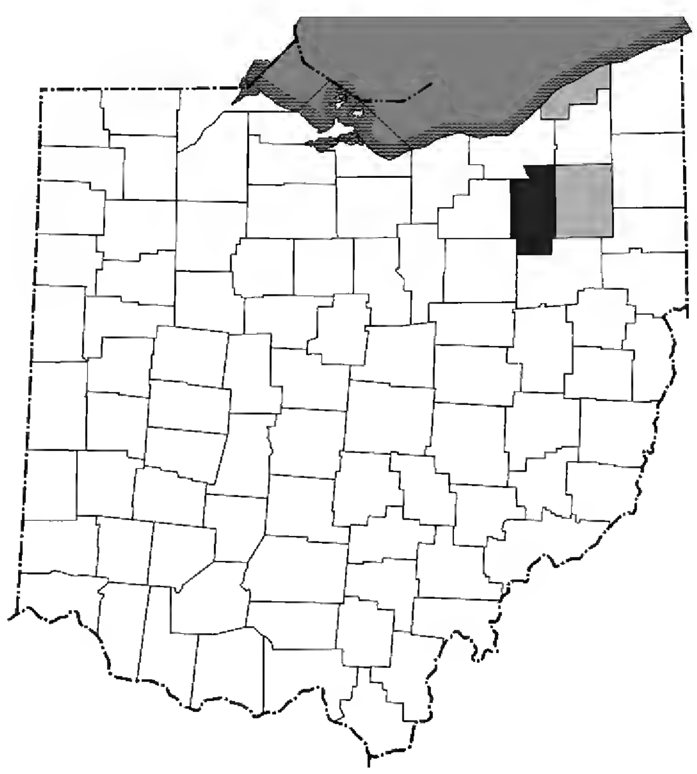

Figure 1. Distribution of *Sigara signata* in Ohio. Light-shaded fill represents new county records. Dark-shaded fill represents literature record (see text).

Figure 2. Distribution of *Sigara signata* in the United States and Canada.

Acknowledgments

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Ohio Biological Survey Notes 2: 39-42, 1999.

Hesperocorixa semilucida (Hemiptera: Corixidae) New to Ohio, with Notes on Distribution, Habitat, and Color Dimorphism

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Introduction

Overall, the aquatic Hemiptera fauna of Ohio is generally poorly known. For instance water boatmen (Corixidae) are the most specious group of aquatic Hemiptera in North America, yet only about 25 species representing six genera are recorded from Ohio. By comparison, 49 species representing nine genera are reported from Wisconsin (Hilsenhoff, 1984). In Ohio, the genus *Hesperocorixa* Kirkaldy, 1908 contains about half the species reported for the state.

The genus *Hesperocorixa* is Holarctic in distribution and encompasses 34 species, 19 of which occur in the United States and Canada (Dunn, 1979; Polhemus *et al.,* 1988). Of these, eight have previously been reported from Ohio; Polhemus *et al.* (1988) listed seven *Hesperocorixa* species, and while Williams *et al.* (1996) unknowingly reported an additional state record. This paper reports the occurrence and distribution of an additional *Hesperocorixa* species from Ohio together with notes on habitat, biology, and color dimorphism.

Materials and Methods

All specimens were collected in dip-net samples and preserved in 70% ethanol. Specimens were identified using the key to North American *Hesperocorixa* by Hungerford (1948). Taxonomic verification was done by William L. Hilsenhoff (University of Wisconsin-Madison). Voucher specimens have been deposited into the University of Wisconsin-Madison collection and the John T. Polhemus collection at the University of Colorado Museum. Remaining specimens have been retained by the author and deposited into his personal collection (SWAC collection).

New Records and Distribution of *Hesperocorixa semilucida*

Hesperocorixa semilucida (Walley, 1930) is a rare to uncommon species known only from the Midwestern and eastern United States and southeastern Canada (see Hungerford, 1948; Polhemus *et al.,*1988). Even though Ohio lies within this range, this species was absent from Ohio museum collections and not reported for the state in the scientific literature. It has heretofore been reported from only one state (Michigan) bordering Ohio (Polhemus *et al.,* 1988). It was recently collected from seven localities in five adjoining counties (Geauga, Lake, Portage, Summit, and Trumbull) in the northeastern corner of the state (Figure 1). It was captured in single sites in Geauga, Lake and Summit counties and from two sites in Portage and Trumbull counties.

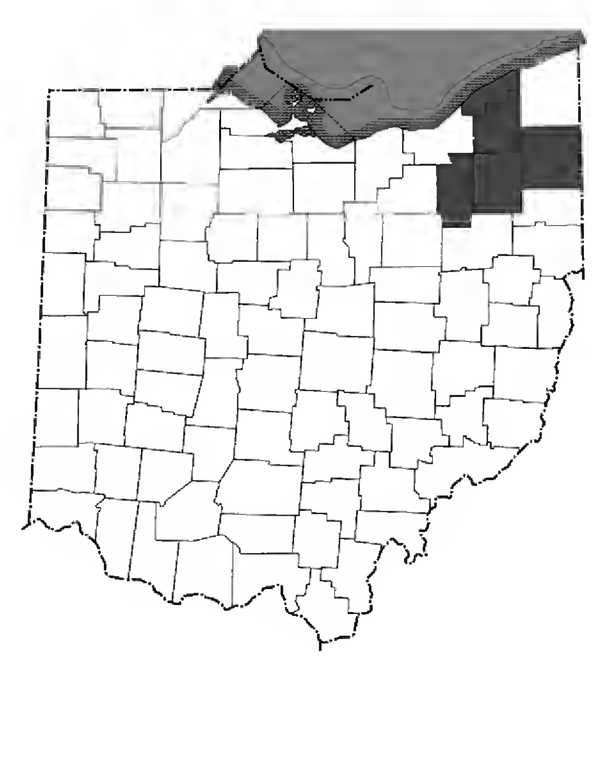

Figure 1. Distribution of *Hesperocorixa semilucida* in Ohio.

Figure 2. Distribution of *Hesperocorixa semilucida* in the United States and Canada.

Hesperocorixa semilucida has now been reported from the following 12 states: Delaware, Florida, Illinois, Louisiana, Massachusetts, Michigan, New Jersey, New York, North Carolina, Ohio, Tennessee, and Wisconsin. Outside of the United States it is known from only one province, Ontario, in Canada (Figure 2). Bobb (1974), Froeschner (1962), and Wilson (1958) listed this species, based on its distribution, as probable for Virginia, Missouri, and Mississippi, respectively, but none had specimens from their state. Additional surveys within its range should add records.

Habitats and biology of *Hesperocorixa semilucida*

There is little information available concerning the habitat ecology, and life cycle of *H. semilucida*. In the original description Walley (1930) stated only that the type series was "dredged from among *Typha* debris in a large marsh bordered pond." The best account of ecological information to date is that of Hilsenhoff (1984) for Wisconsin specimens who found it from ponds in spring, and from pool areas of large rivers in late fall. He recorded no collections from the summer and suspected that it overwinters in the river sites. The overwintering habits of this species in Ohio is unknown. Thus far *H. semilucida* has been taken only during the spring and late fall from lentic habitats in Ohio. The complete life cycle is unknown.

In Ohio this species has been found in bogs and fishless marshy habitats. The bogs are classified as kettle-hole bogs, which are rare undisturbed aquatic habitats in Ohio (Andreas and Bryan, 1990). *H. semilucida* was typically found at the bog margin in shallow water (40 cm deep) among sprouting or standing vegetation with a firm substrate and absent from the unconsolidated bottoms of the bogs open water areas. In all bogs *H. kennicotti* was found concomitantly with *H. semilucida.* In most marsh habitats *H. semilucida* was found sparsely throughout the sites and was typically the only *Hesperocorixa* species encountered. However, a small marsh in Trumbull County contained a very large population along with five other *Hesperocorixa* species. The marsh habitats were nearly replete with vegetation, both submersed aquatic and flooded riparian, and had scant stands of *Typha.* One of the marshes was most likely an ephemeral habitat as it contained *Eubranchipus* sp. (Anostraca: Chirocephalidae) individuals. Thus, in Ohio, *H. semilucida* prefers shallow vegetated kettle-hole bogs as well as shallow, vegetated, fishless marsh habitats containing submerged aquatic vegetation (all marshes contained water milfoil, *Myriophyllum* sp.) and containing at least some *Typha.*

Color dimorphism notes for Ohio *Hesperocorixa semilucida* specimens

H. semilucida individuals apparently go through distinctive color changes throughout their lifetime. Color characteristics of individuals seem to be linked to the season of collection. All specimens taken during the spring possessed a striking bright red background color, whereas all specimens taken during the late fall lacked red color and instead had a smokey to golden-brown background color. Antti Jansson (University of Helsinki, Finland) noted this same pattern for this species (personal communication). Two yellowish, apparently teneral individuals, were collected in late June. Because the life history and overwintering habits of this species in Ohio are currently unknown, it is not possible to infer a connection between specific color characteristics and factors which may determine them (*e.g.* age, environmental conditions, *etc.*). Further, the limited number of specimens known from the state and the current lack of intergrades does not allow a surmisable chromatic progression to be put forth at this time. All specimens obtained in Ohio thus far definitively possess one of these color characteristics.

Discussion

With the addition of *H. semilucida*, there are now nine *Hesperocorixa* species reported from Ohio (Table 1) which seems to be a nearly comprehensive representation of this genus for the state. There are four species, *H. harrisii* (Uhler, 1878), *H. lobata* (Hungerford, 1925), *H. michiganensis* (Hungerford, 1926), and *H. scabricula* (Walley, 1936), that are known from states bordering Ohio and there is a possibility that any of these extralimital species may be discovered in Ohio. Except for these four, based on distributions by Hungerford (1948) and Polhemus *et al.* (1988), it seems unlikely that additional *Hesperocorixa* species will occur in Ohio.

Table 1. List of the *Hesperocorixa* species reported from Ohio.

H. atopodonta (Hungerford, 1927)	*H. interrupta* (Say, 1825)
H. kennicotti (Uhler, 1897)	*H. laevigata* (Uhler, 1893)
H. lucida (Abbott, 1916)	*H. nitida* (Fieber, 1851)
H. obliqua (Hungerford, 1925)	*H. semilucida* (Walley, 1930) = New state record.
H. vulgaris (Hungerford, 1925)	

Hungerford (1948) tabulated individuals he examined and recorded no more than 20 individuals from any state; most collections contained less than five specimens. Although he made no statement about its scarceness, these records suggest, along with the opinion of Hilsenhoff (1984) for Wisconsin and this author for Ohio, that this species is uncommon or rare. Based on specimens at hand, published records, and museum holdings, it appears that this species is currently known from about only 200 individuals. With this relatively small number of specimens, it is clear why little information is available about the ecology and biology of this species. Additionally, this relatively small number supports the contention this species is uncommon to rare throughout its range.

Acknowledgments

Special thanks to William L. Hilsenhoff (University of Wisconsin-Madison) for the time and effort spent on taxonomic verification, and for providing additional information about *H. semilucida*. Thanks must also be extended to Eric G. Chapman (Kent State University; Kent, Ohio) for his exemplary collection efforts which greatly contributed to this paper. I would also like thank Alan D. Christian (Miami University; Oxford, Ohio) and Eric G. Chapman (Kent State University; Kent, Ohio) for kindly offering to review early drafts of this manuscript.

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Ohio Biological Survey Notes 2: 43-47, 1999.

The 1999 Emergence of the Periodical Cicadas in Ohio (Homoptera: Cicadidae: *Magicicada* spp. Brood V)

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Abstract. The periodical cicadas belonging to Brood V emerged in 1999 over most of eastern Ohio. The emergence was widespread and heavy in the southeastern portion of the state and in Summit, Medina, and southern Cuyahoga counties. The brood is experiencing a recession along its western boundary, which is as much as 10 miles eastward from its 1914 western boundary. The brood is also declining in parts of Wayne, Holmes, Stark, and Tuscarawas counties.

Introduction

The periodical cicada Brood V emerged over much of eastern Ohio in 1999. This brood was recorded in 1812 by S. P. Hildreth (1826) who described the emergence in Marietta and documented its appearance in that city in 1795. It was carefully mapped by Webster (1897) in 1897, by Gossard (1916) in 1914, by Parks (1948) in 1931, and by Forsythe (1976) in 1965. These maps, when combined with the 1999 emergence, provide a century-long history of this brood in Ohio.

Materials and Methods

The 1999 distribution of the periodical cicada was mapped with the help of hundreds of contributors. A website was established to encourage people to e-mail the first author when the periodical cicada emerged in their areas. They were requested to provide the county, city, and zip code for each emergence site. Phone calls were made to the state parks and wildlife areas in the emergence area to determine if the insects had appeared in those localities. Finally, surveys were conducted to determine the distribution limits of the periodical cicada's emergence. These surveys involved driving through the suspected emergence area and looking for nymphal skins and adults, listening for cicada singing, and/or looking for oviposition damage.

Results

The first author received 430 e-mails detailing information about when and where the cicadas had emerged in eastern Ohio. The e-mails, phone calls, and surveys documented that the periodical cicadas emerged in 42 counties. The counties and localities are listed in Table 1 and the distribution is shown in Figure 1. Following the practice of cicada reports for the past century, the emergence map (Figure 1) was produced with large circles for counties where the emergence was heavy and widespread, and small circles for light, scattered emergences. All three species, *Magicicada septendecim*, *M. cassini*, and *M. septendecula*, emerged.

Discussion

The 1999 emergence of Brood V in Ohio further documented the decline of this brood as first described by Forsythe (1976). The extent of this decline can be seen by comparing the 1999 emergence (Figure 1) with the 1914 emergence (Figure 2). The 1914 map was reconstructed using Gossard's (1916) record of the 1914 Brood V emergence. Large circles represent counties where Gossard recorded at least two "swarms" and at least five additional emergence reports. Small circles represent counties where Gossard had reported scattered emergences and at most only one swarm. The recession in the emergence area is occurring throughout the margins of the brood's historical range. The periodical cicadas are now gone from Erie County, and they have disappeared from northern Huron County and from most of Seneca County. The scattered emergences from Trumbull, Mahoning, and Columbiana counties which occurred in 1914 were not reported in 1999.

The brood is also disappearing along its western limits. Forsythe (1976) noted this recession in the 1965 emergence. Surveys in western Licking and western Knox counties documented that the periodical cicada has disappeared from these regions. Gossard (1916) had several localities from these counties when they emerged 85 years ago. Even more dramatic is the reduction along the southwestern boundary of the brood. The periodical cicadas did not emerge in Pickaway, western Ross, western Pike, and western Scioto counties. Indeed, the 1999 emergence western boundary was at least 10 miles eastward of the 1914 boundary in Pike, Ross, and Scioto counties.

The brood is also declining in eastern Wayne, western Stark, northeastern Holmes, and western Tuscarawas counties. Gossard's (1916) map from the 1914 emergence shows that periodical cicadas emerged throughout this area. The reasons for this decline are unknown. However, similar declines have been observed in Indiana for Brood X where the brood has disappeared throughout the north-central part of the state (Kritsky, 1988a).

We did receive an e-mail report of approximately 25 individuals in Columbus in Franklin County. This would be the first report of Brood V periodical cicadas in Franklin County in this century and, if true, would suggest that they have not entirely disappeared from the county, but that small isolated numbers are still surviving. The fact that they were noticed was likely due to the intense media coverage in the Columbus area. How long periodical cicadas can survive in extremely low numbers has not been determined, but other studies indicate that they could survive for centuries (Kritsky, 1999). Our survey of the Columbus area did not confirm any emergence in the county. Therefore, Figure 1 does not represent a Franklin County emergence.

The periodical cicada was confirmed in western Ashtabula County. It was reported as occurring there in 1863 and 1880 by Webster (1897), and again by Forsythe (1976) in 1965.

The emergence was heaviest in the southeastern part of the state where there are more woodlands, and in Summit, Medina, and southern Cuyahoga counties in more urban areas. This increase in urban areas is not surprising because periodical cicadas prefer to oviposit in trees in full sunlight surrounded by low vegetation (Lloyd, 1984). This increase in periodical cicadas in cities has been observed in other broods, especially Brood X in Cincinnati (Kritsky, 1988b).

Summary

The periodical cicada Brood V is the most widespread brood in Ohio occurring over the eastern half of the state, but this brood is declining in parts of its range. Surveys of the 1999 emergence documented that the brood's western limits have moved as much as 10 miles eastward since 1914 in some areas. Moreover, the brood is also declining in parts of Wayne, Holmes, Stark, and Tuscarawas counties. These declines are likely due the clearing of woodlands for agricultural activities. The brood is still strong in the southeastern portion of the state. In Summit, Medina, and southern Cuyahoga counties the brood may be increasing, continuing a trend of population expansion in urban areas.

Acknowledgements

We thank Lester Daniels, Kathleen Bradley, Kit Whitaker, and hundreds of citizens for information on where the cicadas emerged. Support for the website was provided by the College of Mount St. Joseph and the Ohio Biological Survey. We also thank Dr. Brian J. Armitage for his support of this project and the three anonymous reviewers for their many helpful comments.

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Table 1. Counties and locations of the 1999 emergence of the periodical cicadas.

County	City	County	City
Ashland	Mifflin Twp.	Guernsey	Cambridge
Ashland	Mohican State Park	Guernsey	Quaker City
Ashtabula	Rock Creek	Guernsey	Salt Fork State Park
Athens	Athens	Guernsey	Senecaville
Athens	Glouster	Harrison	Cadiz
Athens	Lodi Twp.	Harrison	Scioto
Athens	Millfield	Hocking	Haydenville
Athens	Nelsonville	Hocking	Logan
Athens	Southern part of county	Hocking	Rockbridge
Athens	Stewart	Hocking	Tar Hollow State Park
Athens	Strouds Run State Park	Holmes	Millersburg
Belmont	Barkcamp State Park	Holmes	Southwestern part of county
Belmont	Bellaire	Huron	Boughtonville
Belmont	Martins Ferry	Huron	New Haven
Belmont	Powhatan Point	Huron	North Fairfield
Belmont	Shadyside	Jackson	Jackson
Carroll	Dellroy	Jackson	Jackson Lake State Park
Carroll	Kensington	Jefferson	Fairfield
Carroll	Minerva	Jefferson	Mingo Junction
Coshocton	Woodbury Wildlife Area	Jefferson	Richmond
Cuyahoga	Bedford	Jefferson	Steubenville
Cuyahoga	Berea	Jefferson	Toronto
Cuyahoga	Brecksville	Jefferson	Winterville
Cuyahoga	Brecksville Res.	Knox	Bladensburg
Cuyahoga	Garfield Heights	Knox	Gambier
Cuyahoga	North Royalton	Lake	Colburn Rd
Cuyahoga	Olmstead Falls	Lake	Concord Twp.
Cuyahoga	Parma	Lake	Holden Arboretum
Cuyahoga	Peninsula	Lake	Kirtland Hills
Cuyahoga	Solon	Lake	Perry
Cuyahoga	Strongsville	Lawrence	Decatur Twp.
Cuyahoga	Strongsville Wildlife Refuge	Licking	Fallsburg
Fairfield	Lancaster	Licking	Granville
Fairfield	Wahkeena Nature Preserve	Licking	Jacksontown
Franklin	Columbus?	Lorain	Columbia Twp.
Gallia	Cheshire	Lorain	Findlay State Park
Gallia	Gallipolis	Lorain	Grafton
Gallia	Huntington Twp.	Lorain	Lagrange
Geauga	Chardon	Lorain	Wellington

Table 1. Counties and locations of the 1999 emergence of the periodical cicadas, continued.

County	City
Medina	Chatham Twp.
Medina	Hinckley
Medina	Mallet Creek
Medina	Medina
Medina	Medina Twp.
Medina	Spencer
Medina	Valley City
Medina	Westfield Center
Meigs	Columbia Twp.
Meigs	Darwin
Meigs	Pomeroy
Monroe	Woodsfield
Morgan	Chesterhill
Morgan	Glouster
Morgan	Pennsville
Morgan	Stockport
Morrow	Mount Giliad State Park
Morrow	Northeast county
Muskinghum	Blue Rock State Park
Muskinghum	Dresden
Muskinghum	Nashport
Muskinghum	New Concord
Muskinghum	Norton
Muskinghum	Roseville
Muskinghum	Zanesville
Noble	Buffalo Twp.
Noble	The Plains
Noble	Wolf Run State Park
Perry	Crooksville
Perry	Hopewell Twp.
Perry	New Lexington
Perry	Somerset
Pike	Jackson Lake
Pike	Waverly
Portage	Aurora
Portage	Edinburg
Richland	Butler
Richland	Malabar Farm State Park
Richland	Mansfield
Richland	Mifflin Twp.
Ross	Adelphi
Ross	Chillicothe
Ross	Massieville
Ross	Scioto Trail State Park
Scioto	Clarktown
Scioto	Lucasville
Scioto	Minford
Scioto	Sciotoville
Seneca	Attica
Seneca	Bloomville
Seneca	Frank
Seneca	Scipio Siding
Seneca	West Lodi
Stark	Canton
Summit	Akron
Summit	Bath Twp.
Summit	Cuyahoga
Summit	Hudson
Summit	Macedonia
Summit	Northfield
Summit	Northfield Center
Summit	Richfield
Summit	Stow
Summit	Stow
Summit	Twinsburg
Summit	West Branch State Park
Tuscarawas	Midvale
Vinton	Allensville
Vinton	Knox Twp.
Vinton	Lake Hope
Vinton	Tar Hollow State Forest
Vinton	Zaleski State Forest
Washington	Belpre
Washington	Marietta
Washington	Vincent
Wayne	Shreve Lake Wildlife Area
Wayne	West Salem

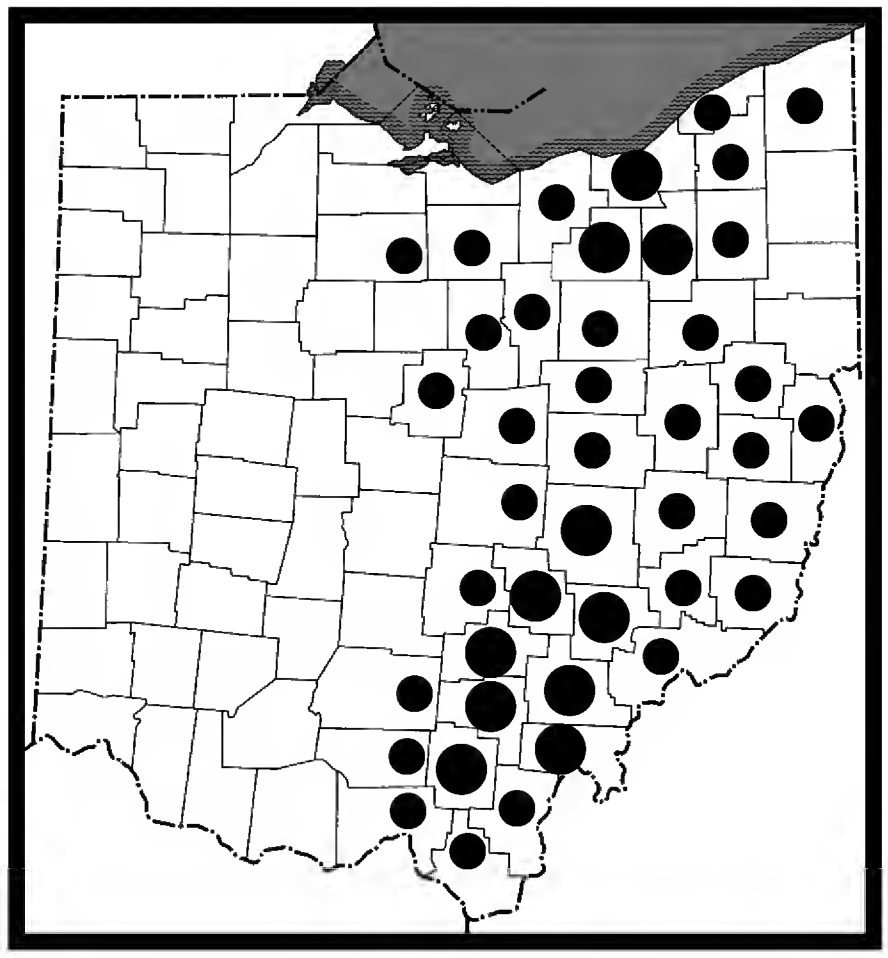

Figure 1. The 1999 distribution of the periodical cicada in Ohio. Large circles represent heavy emergences and small circles represent light and scattered emergences.

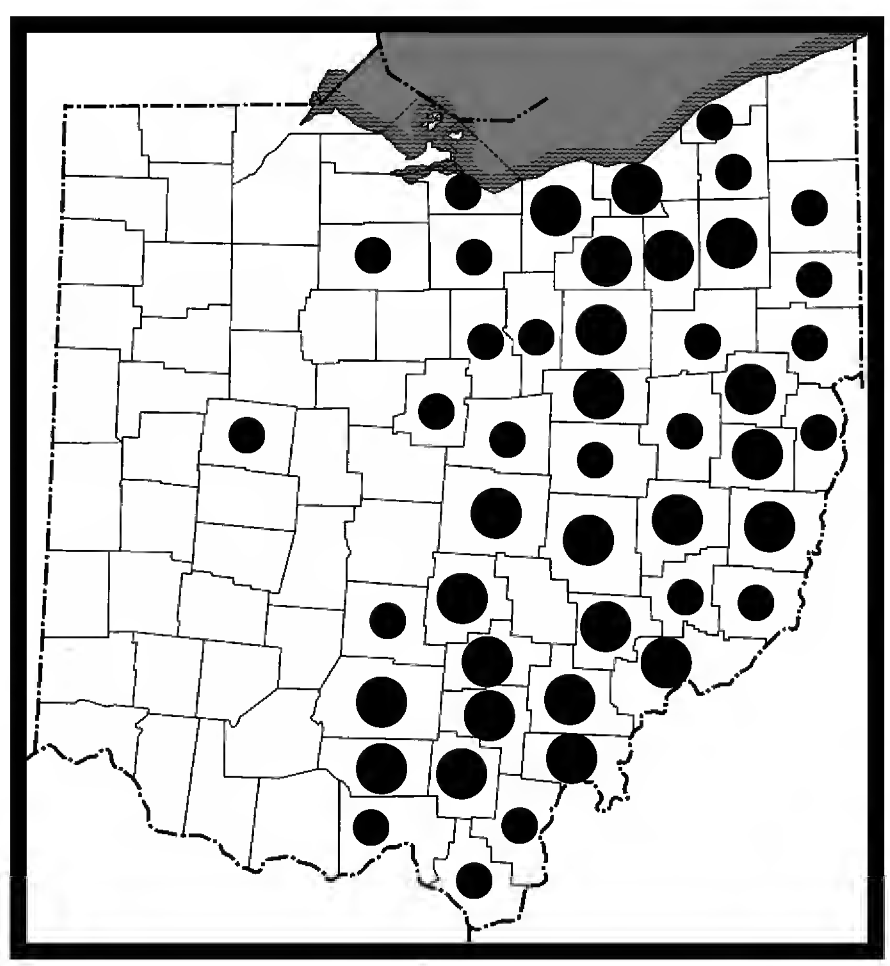

Figure 2. The 1914 emergence of Brood V in Ohio (drawn after Gossard, 1914). Large circles represent counties where at least two swarms and five scattered emergences were found. Small circles represent counties where only scattered emergences and at most only one swarm was recorded.

Ohio Biological Survey Notes 2: 49-51, 1999. © Ohio Biological Survey

The Decline of *Cicindela hirticollis* Say in Ohio (Coleoptera: Cicindelidae)

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Abstract. The current distribution of *Cicindela hirticollis* was determined by revisiting sites where *C. hirticollis* had been previously collected and by surveying likely sites along Lake Erie and the Ohio River. *C. hirticollis* was not found along the Ohio River or at any of the historical inland county localities. Along Lake Erie, *C. hirticollis* is restricted to beaches in Ottawa and Erie counties. Sand from beaches where *C. hirticollis* still occurs was compared to the beaches where *C. hirticollis* had been previously collected to help understand the causes of its decline. Habitat destruction caused by housing developments, changes to the shoreline, installation of irrigation ditches, and flood control has taken its toll on this sensitive beetle. For *C. hirticollis* to survive in Ohio, its remaining populations must be protected.

Introduction

Cicindela hirticollis Say (Figure 1) was once a common tiger beetle on the sandy beaches of our rivers and large lakes in the eastern United States. However, it has declined in recent decades and may be in need of protection. It was last seen in New Hampshire in 1958 and was last collected along the Ohio River in southwestern Ohio in 1911 (Graves and Brzoska, 1991; Kritsky *et al.*, 1996). It is a summer species and is easily identified by its slightly recurved humeral lunule. The purpose of this work was to determine its current status in Ohio.

Materials and Methods

To determine the current status of *C. hirticollis* in Ohio, we surveyed the historical localities listed by Graves (1988) as well as locations that could be potential sites. Sites were visited each year during a three year period to make sure that failure to find the beetle was not due to annual variations. Surveys were conducted using aerial nets. To determine if there was a substrate preference for *C. hirticollis*, sand samples were taken and analyzed for sand, gravel, and clay/silt composition.

Results

The survey results are shown on Figure 2. Open circles are sites where *C. hirticollis* had been collected in the past and the solid circles show where *C. hirticollis* is still present. Our survey found that *C. hirticollis* now occurs only along a 25 mile stretch of the Lake Erie shoreline. In Ottawa County, approximately 10 beetles were observed south of the public beach. In Erie County, approximately 25 beetles were observed on the private beaches east of Cedar Point and well over 100 beetles were observed at Sheldon Marsh State Nature Preserve. All observations were made during late June and early July.

The sand analysis is presented in Table 1. Composition is presented as percentage of the sample. Gravel is defined as particles larger than 2 mm, sand is defined as particles between 0.2 and 2 mm, and clay/silt is defined as particles less than 0.2 mm in size.

Discussion

Cicindela hirticollis has suffered a significant decline in Ohio during this century. In the past it was found along the Ohio River, along most of the Lake Erie shore, and inland in Darke, Lucas, and Huron counties. The causes of this decline are likely related to habitat destruction, development, and water control. For example, *C. hirticollis* was last collected in Hamilton

County in southwestern Ohio in 1911. Since that time seven locks and dams were constructed along the Ohio River that destroyed the sandy beaches and replaced them with mud banks (Kritsky *et al.*, 1998). In Darke County, most of the creeks have been modified into irrigation ditches with steep walls covered with vegetation. Only a few pockets of sand are still found in that western county and they are small and littered with trash and tires. In Lucas and Huron counties, the sandy creeks were filled in for the construction of interstate highways.

Along the Lake Erie shoreline, development has greatly reduced the sandy beaches. Along eastern Lake Erie at Headland Dunes State Park and Nature Preserve and Geneva on the Lake State Park, break-walls have encouraged gravel deposition on the beaches, which changed the sandy beaches to a predominantly gravel shoreline.

Our analysis of the substrate composition showed that *C. hirticollis* has a very distinct sand preference. At all the sites where *C. hirticollis* is present the substrate analysis found high amounts of sand with little gravel and no silt. At sites where *C. hirticollis* has disappeared, the substrate analysis found gravel compositions ranging from 20 - 27%. This sandy preference was further verified by an analysis of the Indiana Dunes State Park beaches where *C. hirticollis* has been found for decades and is still present. Our substrate analysis revealed the same preference found in Ohio, a high sand percentage with little gravel and no silt or clay.

A large sand beach west of the Meldahl Lock and Dam on the Ohio River appeared to be a likely *C. hirticollis* habitat. However, three years of sampling has failed to find any *C. hirticollis*, although other tiger beetles, *C. repanda* Dejean and *C. cuprascens* LeConte, are common. The substrate analysis has revealed that this beach does not have the typical sand compositon found at other *C. hirticollis* sites, but rather a higher gravel and clay/silt composition.

Graves and Brzoska (1991) argued that *C. hirticollis* should be protected in Ohio if we are to maintain this species in the state. Fortunately, the largest population occurs in a state nature preserve and therefore is protected. Even though *C. hirticollis* is sensitive to human alterations of the beaches, we found it on public beaches at East Harbor State Park and along the residential beaches at Cedar Point, a fact which suggests that it can tolerate some human interaction.

Actions can be taken to promote *C. hirticollis* populations at East Harbor State Park. In 1996, we found a significant population on the restricted beach north of the public beach. Unfortunately, the beach was lost to erosion and in 1997 was replaced with large rocks rather than with sand. We have found that introduced sand in large quantities is attractive to tiger beetles and that they will eventually colonize the area. If the restricted area north of East Harbor State Park's public beach was restored to its previous sandy conditions, it is likely that *C. hirticollis* would return to its former numbers. If that were to happen, it would be one of the few success stories in tiger beetle conservation.

Conclusion

Cicindela hirticollis has suffered a significant decline in Ohio during this century and is now restricted to an approximately 25 mile stretch along Lake Erie. The causes of this decline are likely habitat alterations from road construction, flood control, irrigation, and development. The decline of *C. hirticollis* in Ohio is evidence that this beetle should be protected if we want to maintain this tiger beetle in the state. Its elevation by the Ohio Division of Wildlife from the special interest listing to threatened listing, and the presence of a large population in an already protected area promise that this tiger beetle will maintain a foothold in the state.

Acknowledgments

We thank the College of Mount St. Joseph for the use of vehicles and the Ohio Department of Natural Resources, Division of Wildlife for permission to survey state parks and state nature preserves and for funding through the Do Something Wild Income Tax Check-off grant program. We also thank Dr. Brian J. Armitage and the Ohio Biological Survey for encouragement and support of the Insect Survey of the College of Mount St. Joseph.

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Kritsky, Gene, A. J. Savage, Susan Reidel, and Jessee Smith. 1998. A survey of the summer tiger beetles of the Ohio River beaches in Ohio and eastern Indiana. Entomological News 109 (3): 165-171.

Table 1. Analysis of sandy substrate for percent composition of gravel, sand, and clay/silt.

Location	% gravel	% sand	% clay/silt
Sheldon Marsh Preserve*	0.34	96.92	2.75
East Harbor North Beach*	0.29	98.77	0.65
East Harbor South Beach*	0.02	97.70	2.28
Indiana Dunes St. Park*	0.19	99.80	0.18
Geneva on the Lake	21.65	78.32	0.03
Crane Creek State Park	24.75	74.76	0.46
Headlands State Park	27.57	71.37	1.06
Meldahl Lock and Dam	4.18	85.53	10.28

* Beaches with *C. hirticollis* populations

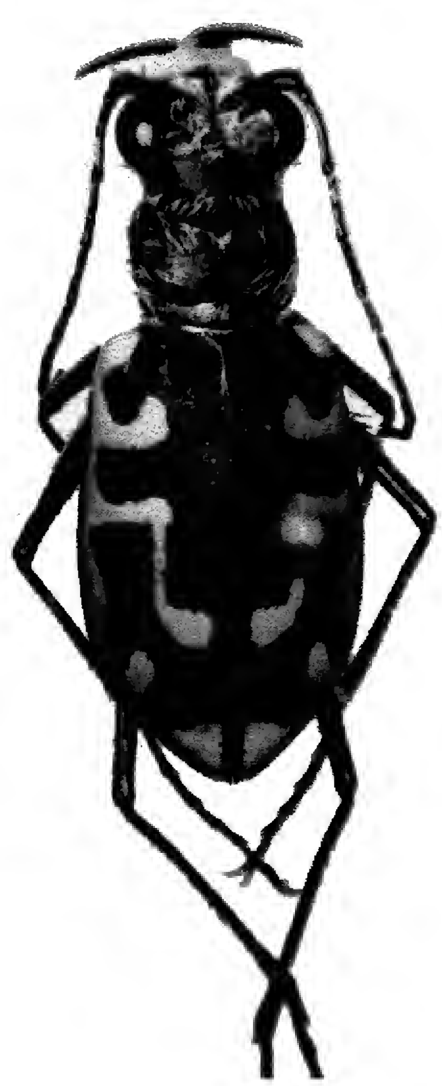

Figure 1. *Cicindela hirticollis* Say.

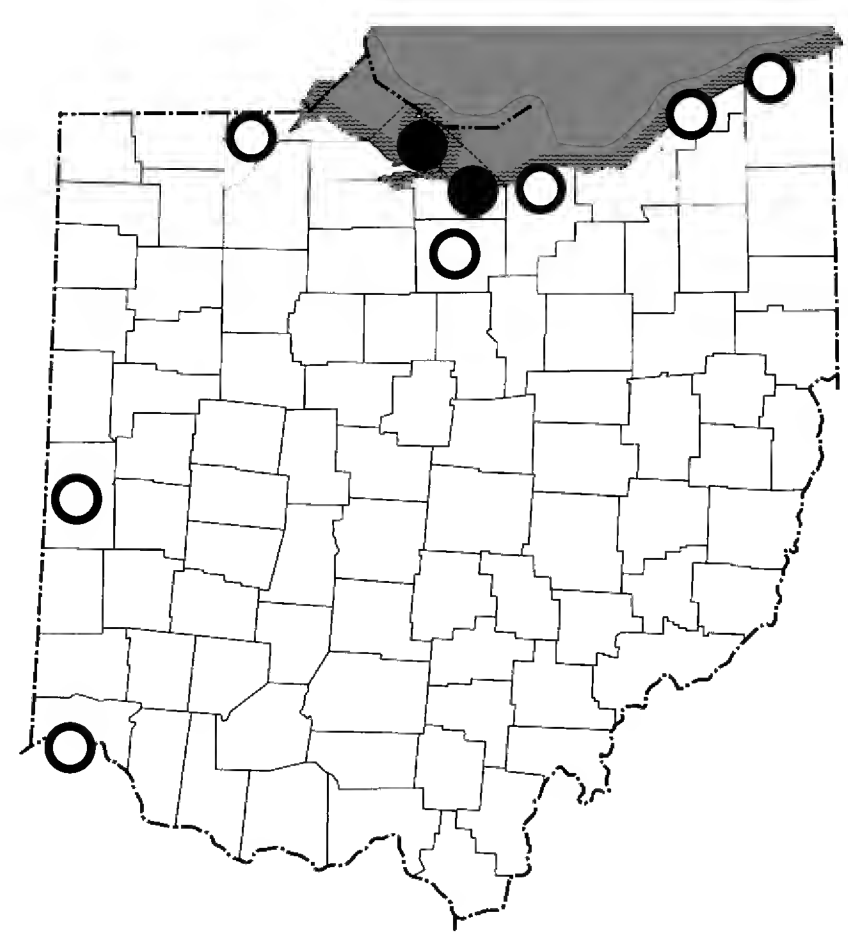

Figure 2. Distribution of *C. hirticollis* in Ohio. Solid circles represent counties with *C. hirticollis* populations and open circles represent counties where *C. hirticollis* has disappeared.

Ohio Biological Survey Notes 2: 53-62, 1999.

The Frequency of Occurrence and Relative Abundance of Ohio Stream Fishes: 1979 Through 1995

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Introduction

Ohio streams have a rich history of ichthyological investigations. Statewide distribution maps for game fish species were first reported by Wickliff and Trautman (1931). The first edition of *The Fishes of Ohio* published statewide distribution maps for all Ohio fish species for collections made during 1840 through 1955 (Trautman, 1957). This book was revised for collections made during 1956 through 1980—a period when fish populations in many streams were severely degraded by high levels of pollution and other environmental changes (Trautman, 1981).

Although these publications are excellent sources for the historical distributions, identification, and preferred habitats of Ohio fish, they do not provide quantitative frequency of occurrence or relative abundance information for current stream fish populations that have increased as the result of improved water quality (*e.g.*, Ohio Environmental Protection Agency [OEPA] 1992; 1995; 1996), become established through introductions, or continued to decline. The number of annual fish surveys has also increased since 1979 when OEPA began an intensive stream monitoring program (Figure 1). Additional stream surveys have also been conducted since 1979 by other state agencies and universities in search of rare and endangered fish species (Cavender and Rice, 1997; Sanders, 1995). The use of boat-mounted electrofishing gear also has added new records for fish species that inhabit large streams. With this study, we sought to answer the following questions.

1) How many fish species have been recently collected from Ohio streams?
2) What is the frequency of occurrence and relative abundance of each species?
3) What is the mean drainage area for each species?

Methods

Sampling Procedures

The majority of the data used in this study was collected by OEPA staff using one of two types of standardized electrofishing gear and methods designed for boatable or wadeable streams (OEPA, 1989). The two methods allow for effective sampling over a wide range of stream sizes (*i.e.*, small creeks to large rivers). The methods use two principal types of gasoline powered pulsed Direct Current electrofishing gear: 1) 1750 watt pulsator/generator combination (T&J Manufacturers) designed for smaller, wadeable streams; and, 2) boat-mounted 3500 to 5000 watt generators and pulsator combinations (Smith-Root Type 3.5 or 5.0 GPP units), with a straight electrode configuration for wider and deeper boatable streams. Sampling was conducted during the day except for in the Ohio and Muskingum rivers where night electrofishing was also used for improved catches (Sanders, 1992). Most OEPA electrofishing sites were sampled over a fixed distance of 200 meters in small to medium size wadeable streams and 500 meters in larger size boatable streams.

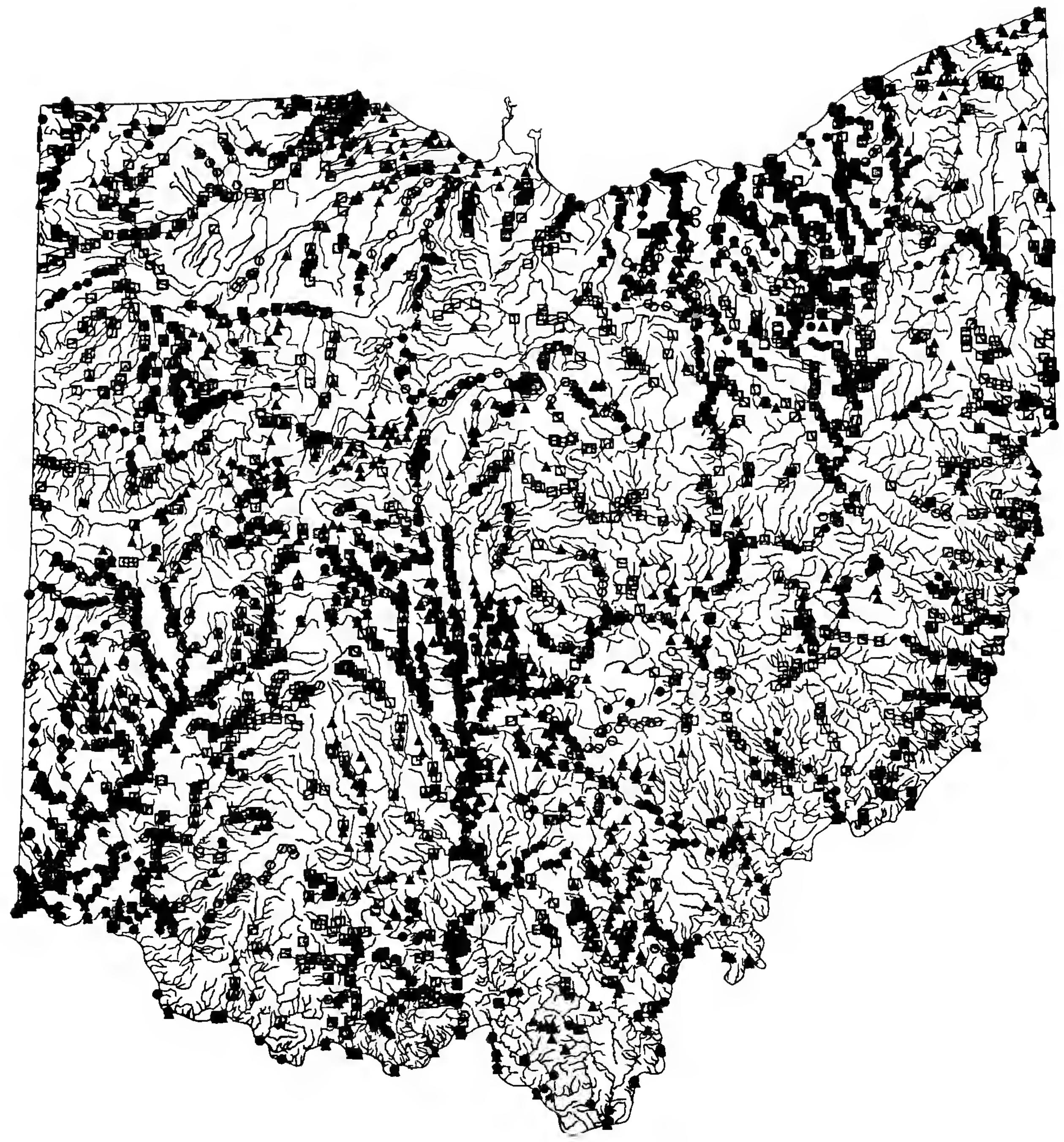

Figure 1. Ohio ECOS fish sampling locations (multiple symbol types) for surveys conducted during 1979 through 1995.

Additional surveys were conducted by staff from the Ohio Department of Natural Resources Division of Natural Areas and Preserves (ODNAP) and The Ohio State University Museum of Biological Diversity (OSUMBD) using nylon seines or electrofishing gear. Electrofishing gear consisting of a 1750 watt generator wired to a catch-net was generally employed on medium to large streams. Seines were also used in the larger streams in conjunction with electrofishing. Smaller streams were primarily sampled with seines. Night sampling was done almost exclusively with seines. Most of the seines used in these surveys were 1.8 m X 3.6 m with 30.2 mm or 28.6 mm ace mesh and 1.8 m X 3.0 m with 30.2 mm ace mesh. All seines employed during these surveys were of nylon construction with a double weighted lead line. Sampling efforts were not standardized between the various surveys particularly those that were targeting specific species, such as the eastern sand darter, *Ammocrypta pellucida,* and northern madtom, *Noturus stigmosus.* All available habitats were sampled at most sites until no new species were encountered. All fish collected during a sample were identified to species and released. Vouchers of rare and difficult to identify species were preserved in formalin and deposited at the OSUMBD.

Data Base Query and Additional Records

A computer program was written to query Ohio ECOS (a statewide multi-agency biological database maintained by the OEPA)[1] by fish species for stream locality records collected during 1979 through 1995. The software consisted of FoxPro for Windows version 2.6 using DBF format files. The search was limited to data collected by the OEPA Ecological Assessment staff, including the Ohio River surveys conducted for the Ohio Department of Natural Resources Division of Wildlife (ODOW) (Sanders, 1995), and miscellaneous records from the ODNAP and the OSUMBD. All available data (other sources and records through 1997) were included for rare species collected from less than or equal to five streams (*e.g.*, White, 1987). Only a few selected hybrids that were collected for the period 1979 through 1995 were included because of the difficulty in identification. This study excluded all records for fish collected in Lake Erie, inland lakes, and ponds (*i.e.*

[1] For data requests and information about Ohio ECOS, contact Dennis Mishne, Division of Surface Water, Ohio Environmental Protection Agency, 4675 Homer Ohio Lane, Groveport OH 43125.

Table 1. List of Ohio's stream fishes and their frequency of occurrence and relative abundance based on sampling conducted during 1979 through 1995.

FAMILY common name (Scientific Name)	No. Streams[1]	No. Sites[2]	Mean Drain. Area[3]	Mean Rel. No.[4]	Max. Rel. No.[5]	No. Fish[6]	DOW Status[7]
CYPRINIDAE (carps and minnows)							
creek chub *(Semotilus atromaculatus)*	882	3,231	185	154	6,293	513,314	-
bluntnose minnow *(Pimephales notatus)*	758	3,908	730	109	11,846	522,650	-
central stoneroller *(Campostoma anomalum)*	754	3,082	461	185	10,960	650,967	-
striped shiner *(Luxilus chrysocephalus)*	594	2,558	407	69	1,640	184,725	-
blacknose dace *(Rhinichthys atratulus)*	545	1,385	92	110	3,524	153,602	-
silverjaw minnow *(Notropis buccatus)*	466	1,236	181	43	2,287	46,578	-
common carp *(Cyprinus carpio)*	438	2,851	2,222	26	2,723	95,019	Non-native
spotfin shiner *(Cyprinella spiloptera)*	373	2,284	1,508	57	5,620	159,199	-
fathead minnow *(Pimephales promelas)*	343	970	302	59	4,977	46,137	-
sand shiner *(Notropis stramineus)*	302	1,494	780	51	2,768	80,216	-
golden shiner *(Notemigonus crysoleucas)*	234	883	851	15	978	10,544	-
southern redbelly dace *(Phoxinus erythrogaster)*	210	345	12	57	1,077	13,946	-
rosefin shiner *(Lythrurus ardens)*	198	669	110	49	1,218	22,713	-
silver shiner *(Notropis photogenis)*	180	982	570	28	1,125	28,940	-
redfin shiner *(Lythrurus umbratilis)*	173	550	164	31	1,500	15,423	-
common shiner *(Luxilus cornutus)*	164	516	1,780	135	62	31,607	-
suckermouth minnow *(Phenacobius mirabilis)*	164	743	1,478	33	1,440	25,898	-
emerald shiner *(Notropis atherinoides)*	154	893	7,354	61	10,000	76,359	-
rosyface shiner *(Notropis rubellus)*	145	584	506	33	751	21,735	-
goldfish *(Carassius auratus)*	143	628	2,034	17	822	9,886	Non-native
common carp x goldfish hybrid	100	494	2,709	6	104	2,334	Non-native
river chub *(Nocomis micropogon)*	96	461	759	40	825	25,505	-
mimic shiner *(Notropis volucellus)*	82	283	1,473	22	734	6,308	-
redside dace *(Clinostomus elongatus)*	67	111	28	23	288	2,184	-
hornyhead chub *(Nocomis biguttatus)*	59	215	136	25	443	5,042	-
steelcolor shiner *(Cyprinella whipplei)*	47	281	1,990	20	750	8,474	-
bigeye chub *(Notropis amblops)*	36	97	730	24	278	2,179	-
rosyside dace *(Clinostomus funduloides)*	34	71	9	66	606	1,380	*Threatened*
bullhead minnow *(Pimephales vigilax)*	31	213	5,592	18	3,000	5,744	-
spottail shiner *(Notropis hudsonius)*	28	136	5,838	17	500	1,872	-
gravel chub *(Erimystax x-punctatus)*	21	169	2,881	29	1,260	5,204	-
silver chub *(Macrhybopsis storeriana)*	15	106	40,940	19	232	2,145	-
bigeye shiner *(Notropis boops)*	15	28	34	46	528	899	*Threatened*
ghost shiner *(Notropis buchanani)*	14	51	3,296	21	480	1,780	-
streamline chub *(Erimystax dissimilis)*	12	76	1,418	8	64	557	-
bigmouth shiner *(Notropis dorsalis)*	11	32	43	80	1,262	2,859	*Threatened*
grass carp *(Ctenopharyngodon idella)*	10	12	1,742	3	10	16	Non-native
tonguetied minnow *(Exoglossum laurae)*	7	39	127	15	78	695	*Threatened*
river shiner *(Notropis blennius)*	7	51	35,748	16	404	846	-
longnose dace *(Rhinichthys cataractae)*	5	14	36	79	225	903	-
channel shiner *(Notropis wickliffi)*	9	80	51,377	18	182	1,369	-
popeye shiner *(Notropis ariommus)*	2	8	207	83	408	191	**Endangered**

Table 1. List of Ohio's stream fishes and their frequency of occurrence and relative abundance based on sampling conducted during 1979 through 1995, con't.

FAMILY common name (Scientific Name)	No. Streams	No. Sites	Mean Drain. Area	Mean Rel. No.	Max. Rel. No.	No. Fish	DOW Status
CYPRINIDAE (carps and minnows), continued.							
pugnose minnow *(Opsopoeodus emiliae)*	2	6	206	2	8	95	**Endangered**
speckled chub *(Macrhybopsis aestivalis)*	1	3	39,472	1	1	3	**Endangered**
blacknose shiner *(Notropis heterolepis)*	1	2	17	1	1	2	**Endangered**
Mississippi silvery minnow*(Hybognathus nuchalis)*	1	1	26	2	2	1	**Endangered**
CATOSTOMIDAE (suckers)							
white sucker *(Catostomus commersoni)*	806	3,496	308	62	1,714	258,744	-
northern hog sucker *(Hypentelium nigricans)*	483	2,464	820	40	1,110	126,181	-
golden redhorse *(Moxostoma erythrurum)*	335	2,155	2,528	34	624	91,552	-
quillback *(Carpiodes cyprinus)*	171	1,158	4,296	9	407	9,932	-
black redhorse *(Moxostoma duquesnei)*	157	919	1,598	23	416	23,565	-
spotted sucker *(Minytrema melanops)*	154	806	1,553	11	419	9,895	-
silver redhorse *(Moxostoma anisurum)*	137	937	2,823	11	286	10,918	-
shorthead redhorse *(Moxostoma macrolepidotum)*	96	793	4,713	21	670	20,460	-
smallmouth buffalo *(Ictiobus bubalus)*	41	354	12,023	8	171	4,333	-
river carpsucker *(Carpiodes carpio)*	37	396	6,082	19	308	12,228	-
bigmouth buffalo *(Ictiobus cyprinellus)*	35	165	3,440	4	30	635	-
highfin carpsucker *(Carpiodes velifer)*	35	221	3,573	4	30	614	-
creek chubsucker *(Erimyzon oblongus)*	33	59	43	7	44	267	-
river redhorse *(Moxostoma carinatum)*	29	250	6,260	5	36	946	*Special Interest*
black buffalo *(Ictiobus niger)*	11	134	11,500	4	22	567	-
greater redhorse *(Moxostoma valenciennesi)*	6	32	746	7	43	174	*Threatened*
lake chubsucker *(Erimyzon sucetta)*	8	8	15	36	160	49	*Threatened*
blue sucker *(Cycleptus elongatus)*	4	9	5,170	4	10	31	**Endangered**
harelip sucker *(Lagochila lacera)*	0	0	992	0	0	0	**Extinct**
CENTRARCHIDAE (sunfishes)							
green sunfish *(Lepomis cyanellus)*	724	3,639	964	40	2,244	173,676	-
bluegill *(Lepomis macrochirus)*	635	3,251	2,100	26	906	99,919	-
largemouth bass *(Micropterus salmoides)*	552	2,707	2,077	11	414	30,364	-
rock bass *(Ambloplites rupestris)*	382	2,421	1,042	18	619	57,028	-
smallmouth bass *(Micropterus dolomieu)*	325	2,119	2,470	20	580	53,235	-
longear sunfish *(Lepomis megalotis)*	298	1,749	2,348	42	613	95,315	-
pumpkinseed *(Lepomis gibbosus)*	244	1,125	1,144	17	920	21,252	-
white crappie *(Pomoxis annularis)*	233	1,283	1,441	9	263	9,132	-
black crappie *(Pomoxis nigromaculatus)*	157	825	2,434	8	700	4,687	-
orangespotted sunfish *(Lepomis humilis)*	155	920	1,464	17	548	15,400	-
spotted bass *(Micropterus punctulatus)*	123	689	6,346	21	396	20,595	-
warmouth *(Lepomis gulosus)*	114	446	1,775	6	71	2,388	-
redear sunfish *(Lepomis microlophus)*	39	77 0	2,522	6	85	249	Non-native

Table 1. List of Ohio's stream fishes and their frequency of occurrence and relative abundance based on sampling conducted during 1979 through 1995, continued.

FAMILY common name (Scientific Name)	No. Streams	No. Sites	Mean Drain. Area	Mean Rel. No.	Max. Rel. No.	No. Fish	DOW Status
PERCIDAE (perches)							
johnny darter *(Etheostoma nigrum)*	647	2,297	203	32	2,600	68,751	-
fantail darter *(Etheostoma flabellare)*	486	1,436	158	34	968	49,360	-
rainbow darter *(Etheostoma caeruleum)*	426	1,637	779	46	1,343	72,713	-
greenside darter *(Etheostoma blennioides)*	421	2,048	638	39	1,071	90,089	-
blackside darter *(Percina maculata)*	277	1,033	278	9	133	9,083	-
logperch *(Percina caprodes)*	246	1,347	3,315	10	268	13,926	-
orangethroat darter *(Etheostoma spectabile)*	195	512	209	34	675	10,798	-
banded darter *(Etheostoma zonale)*	180	858	947	24	1,311	22,082	-
yellow perch *(Perca flavescens)*	90	397	1,400	9	291	3,254	-
walleye *(Stizostedion vitreum)*	56	240	5,973	4	50	747	-
sauger *(Stizostedion canadense)*	53	376	10,711	11	255	6,814	-
sauger x walleye *(S. canadense x S.vitreum)*	49	358	3,201	9	191	2,869	Non-native
variegate darter *(Etheostoma variatum)*	40	171	993	40	462	6,655	-
dusky darter *(Percina sciera)*	37	103	1,772	6	62	551	-
slenderhead darter *(Percina phoxocephala)*	16	90	12,096	5	31	572	-
eastern sand darter *(Ammocrypta pellucida)*	15	43	3,978	5	30	248	*Special Interest*
bluebreast darter *(Etheostoma camurum)*	10	51	1,577	11	90	497	*Threatened*
least darter *(Etheostoma microperca)*	9	28	17	52	470	455	*Special Interest.*
river darter *(Percina shumardi)*	5	30	60,951	10	50	251	*Threatened*
Tippecanoe darter *(Etheostoma tippecanoe)*	6	36	1,272	10	72	362	*Threatened*
channel darter *(Percina copelandi)*	3	31	57,298	4	36	110	*Threatened*
Iowa darter *(Etheostoma exile)*	3	3	50	2	2	5	*Special Interest*
spotted darter *(Etheostoma maculatum)*	3	5	545	11	30	105	**Endangered**
longhead darter *(Percina macrocephala)*	0	0	1,505	0	0	0	***Extirpated***
gilt darter *(Percina evides)*	0	0	52,800	0	0	0	***Extirpated***
crystal darter *(Ammocrypta asprella)*	0	0	33,798	0	0	0	***Extirpated***
ICTALURIDAE (catfishes)							
yellow bullhead *(Ameiurus natalis)*	536	2,159	332	11	366	25,637	-
black bullhead *(Ameiurus melas)*	286	695	353	7	373	3,838	-
brown bullhead *(Ameiurus nebulosus)*	180	576	731	18	2,300	4,218	-
channel catfish *(Ictalurus punctatus)*	164	1,303	5,055	13	336	19,841	-
stonecat *(Noturus flavus)*	145	584	721	7	192	4,466	-
brindled madtom *(Noturus miurus)*	71	217	533	6	73	1,268	-
tadpole madtom *(Noturus gyrinus)*	58	172	239	6	53	901	-
flathead catfish *(Pylodictis olivaris)*	43	482	10,283	5	48	2,416	-
mountain madtom *(Noturus eleutherus)*	5	14	5,114	45	306	541	**Endangered**
northern madtom *(Noturus stigmosus)*	5	11	3,841	7	23	305	**Endangered**
white catfish *(Ameiurus catus)*	1	1	3,190	2	2	1	Non-native
blue catfish *(Ictalurus furcatus)*	1	1	69,476	2	2	1	**Endangered**
Scioto madtom *(Noturus trautmani)*	0	0	554	0	0	0	**Endangered**

Table 1. List of Ohio's stream fishes and their frequency of occurrence and relative abundance based on sampling conducted during 1979 through 1995, continued.

FAMILY common name (Scientific Name)	No. Streams	No. Sites	Mean Drain. Area	Mean Rel. No.	Max. Rel. No.	No. Fish	DOW Status
CLUPEIDAE (herrings)							
gizzard shad *(Dorosoma cepedianum)*	272	1,972	3,674	105	19,998	288,499	-
alewife *(Alosa pseudoharengus)*	12	26	2,865	7	100	63	Non-native
skipjack herring *(Alosa chrysochloris)*	11	112	31,872	8	109	851	-
threadfin shad *(Dorosoma petenense)*	4	12	41,767	2	6	17	Non-native
ESOCIDAE (pikes)							
grass pickerel *(Esox americanus vermiculatus)*	237	926	225	8	126	7,962	-
northern pike *(Esox lucius)*	58	222	575	3	27	536	-
muskellunge *(Esox masquinongy)*	15	33	1,070	3	6	67	*Special Interest*
northern pike x muskellunge hybrid	5	6	5,999	3	5	12	Non-native
COTTIDAE (sculpins)							
mottled sculpin *(Cottus bairdi)*	228	590	130	87	2,260	51,613	-
CYPRINODONTIDAE (killifishes)							
blackstripe topminnow *(Fundulus notatus)*	156	539	209	35	1,490	11,733	-
eastern banded killifish *(F. diaphanus diaphanus)*	5	11	2,099	43	268	233	Non-native
western banded killifish *(F. diaphanus menona)*	4	8	32	11	14	80	**Endangered**
UMBRIDAE (mudminnows)							
central mudminnow *(Umbra limi)*	119	281	71	19	1,242	4,722	-
ATHERINIDAE (silversides)							
brook silverside *(Labidesthes sicculus)*	117	462	2,070	12	768	3,963	-
SCIAENIDAE (drums)							
freshwater drum *(Aplodinotus grunniens)*	114	833	7,321	24	1,193	26,170	-
PERCOPSIDAE (trout-perches)							
trout-perch *(Percopsis omiscomaycus)*	90	310	546	17	411	4,598	-
PETROMYZONTIDAE (lampreys)							
least brook lamprey *(Lampetra aepyptera)*	88	156	85	8	104	1,233	-
American brook lamprey *(Lampetra appendix)*	33	94	631	16	285	1,219	-
silver lamprey *(Ichthyomyzon unicupis)*	14	50	21,038	2	10	79	-
sea lamprey *(Petromyzon marinus)*	11	98	2,988	3	8	1,108	Non-native
northern brook lamprey *(Ichthyomyzon fossor)*	11	16	21	14	23	61	**Endangered**
mountain brook lamprey *(Ichthyomyzon greeleyi)*	3	9	376	23	78	123	**Endangered**
Ohio lamprey *(Ichthyomyzon bdellium)*	2	6	26,698	1	2	3	**Endangered**

Table 1. List of Ohio's stream fishes and their frequency of occurrence and relative abundance based on sampling conducted during 1979 through 1995, continued.

FAMILY common name (Scientific Name)	No. Streams	No. Sites	Mean Drain. Area	Mean Rel. No.	Max. Rel. No.	No. Fish	DOW Status
PERCICHTHYIDAE (temperate basses)							
white bass *(Morone chrysops)*	69	552	10,246	12	1,268	8,061	-
white perch *(Morone americana)*	33	169	2,991	40	3,500	5,555	Non-native
white x striped bass *(M. chrysops x M. saxatilis)*	12	57	37,454	7	33	397	Non-native
striped bass *(Morone saxatilis)*	4	34	61,686	6	43	203	Non-native
GASTEROSTEIDAE (sticklebacks)							
brook stickleback *(Culaea inconstans)*	69	132	29	28	805	3,432	-
threespine stickleback *(Culaea aculeatus)*	1	1		1	1	1	Non-native
LEPISOSTEIDAE (gars)							
longnose gar *(Lepisosteus osseus)*	46	328	9,955	4	123	1,352	-
shortnose gar *(Lepisosteus platostomus)*	3	5	13,443	3	8	11	**Endangered**
alligator gar *(Lepisosteus spatula)*	0	0	69,344	0	0	0	***Extirpated***
AMIIDAE (bowfins)							
bowfin *(Amia calva)*	28	91	4,875	4	24	269	-
SALMONIDAE (trouts)							
rainbow trout *(Oncorhynchus mykiss)*	26	91	1,137	14	426	1,052	Non-native
brown trout *(Salmo trutta)*	15	49	112	14	90	696	Non-native
brook trout *(Salvelinus fontinalis)*	8	8	0.3	2	10	151	*Threatened*
coho salmon *(Oncorhynchus kisutch)*	7	12	1,281	13	103	66	Non-native
chinook salmon *(Oncorhynchus tshawytscha)*	1	2		4	4	15	Non-native
HIODONTIDAE (mooneyes)							
mooneye *(Hiodon tergisus)*	8	110	23,704	4	18	321	*Special Interest*
goldeye *(Hiodon alosoides)*	2	3	22,541	2	4	4	**Endangered**
ANGUILLIDAE (freshwater eels)							
American eel *(Anguilla rostrata)*	8	8	2,654	2	2	8	*Threatened*
OSMERIDAE (smelts)							
rainbow smelt *(Osmerus mordax)*	5	6	4,629	2	3	8	Non-native
POECILIIDAE (livebearers)							
western mosquitofish *(Gambusia affinis)*	4	4	4,821	3	5	6	Non-native

Table 1. List of Ohio's stream fishes and their frequency of occurrence and relative abundance based on sampling conducted during 1979 through 1995, continued.

FAMILY common name (Scientific Name)	No. Streams	No. Sites	Mean Drain. Area	Mean Rel. No.	Max. Rel. No.	No. Fish	DOW Status
POLYODONTIDAE (paddlefish)							
paddlefish *(Polyodon spathula)*	5	10	68,263	1	1	50	*Threatened*
GOBIIDAE (gobies)							
round goby *(Neogobius melanostomus)*	1	1	10,000	4	4	2	Non-native
APHREDODERIDAE (pirate perches)							
pirate perch *(Aphredoderus sayanus)*	0	0	110	0	0	0	**Endangered**
GADIDAE (cods)							
burbot *(Lota lota)*	1	1	705	1	1	1	*Special Interest*
ACIPENSERIDAE (sturgeons)							
lake sturgeon *(Acipenser fulvescens)*	0	0	61,176	0	0	0	**Endangered**
shovelnose sturgeon *(Scaphirhynchus platorynchus)*	0	0	68,219	0	0	0	**Endangered**

[1] Total number of different streams in which each species was collected (*e.g.* Ohio River, Clear Creek).
[2] Total number of different sites/locations at which each species was collected.
[3] This value is a measure of the average size of stream collected from based on the average of the drainage area (square miles) of each collection site/location. OEPA uses drainage area instead of stream order for biological criteria calculations.
[4] The mean relative number is the average number of fish collected electrofishing a distance of 1.0 kilometer (km) using the boat method and 0.3 km using the wading method. It is OEPA's average catch-per-unit-effort (CPUE) based on the number collected per standardized distance electrofished.
[5] The maximum relative abundance is the highest relative abundance/CPUE for each species (see above).
[6] The total number of individual fish collected during 1979 through 1995.
[7] The current Ohio Department of Natural Resources, Division of Wildlife Conservation Status. **Endangered** denotes a native species or subspecies threatened with statewide extirpation. *Threatened* denotes a species or subspecies whose survival in Ohio is not in immediate jeopardy, but to which a threat exists. Continued or increased stress will result in its becoming endangered. *Special Interest* denotes a species or subspecies which might become threatened in Ohio under continued or increased stress or for which there is concern, but adequate information does not exist to determine its status. ***Extirpated*** denotes a species or subspecies that occurred in Ohio at the time of European settlement and has since disappeared from the state. **Extinct** denotes a species or subspecies that occurred in Ohio at the time of European settlement and has since disappeared from its entire range. Non-native denotes a species, subspecies, or hybrid that did not occur in Ohio at the time of European settlement, but has since invaded or been introduced into Ohio.

Table 1 is not a complete list of Ohio fishes). Incidental catches from streams (*e.g.* whitetail shiner, *Cyprinella galactura*, and pacu, *Colossoma spp.*) during this study period were also excluded.

Although the authors are aware of recent changes in fish nomenclature, nomenclature follows Robins *et al.* (1991) for consistency. Subspecies listed by Trautman (1981) such as the northern and Ohio shorthead redhorse (*Moxostoma macrolepidotum macrolepidotum* and *Moxostoma macrolepidotum breviceps*, respectively) were not included except for the western and eastern banded killifish (*Fundulus diaphanus menona* and *Fundulus diaphanus diaphanus*, respectively) due to the western banded killifish's status as a state endangered species (ODOW, 1998). The listing order for species in Table 1 was completed by starting with the species collected in the most streams followed by all other species in that family in descending order followed by the next most frequently occurring species based on the total number of streams until all other stream species were accounted for. All other Ohio fish species previously reported in a stream by Trautman (1981) were also included for a historical perspective.

Results

The study revealed 13,164 fish collections from 4,919 sites were made in 961 Ohio streams during 1979 through 1995. A total of 4,792,712 fish of 153 species (26 families) were captured (Table 1). The most frequently occurring species (percent of 961 streams) were creek chub, *Semotilus atromaculatus* (91.6%), white sucker, *Catostomus commerson* (83.8%), bluntnose minnow, *Pimephales notatus* (78.9%), central stoneroller, *Campostoma anomalum* (78.4%), green sunfish, *Lepomis cyanellus* (75.4%), and johnny darter, *Etheostoma nigrum* (67.1%).

The most abundant species (percent of total catch) were central stoneroller (13.6%), bluntnose minnow (10.9%), creek chub (10.7%), gizzard shad, *Dorosoma cepedianum* (6.0%), and white sucker (5.4%). The species with the highest catch-per-unit-effort (CPUE) based on mean relative number[2] were gizzard shad (19,998), bluntnose minnow (11,846), and central stoneroller (10,960).

Species inhabiting the smallest streams (based on mean drainage area) were brook trout, *Salvelinus fontinalis*, rosyside dace, *Clinostomus funduloides*, and southern redbelly dace, *Phoxinus erythrogaster* (0.3, 9 and 12 sq. mi., respectively). Species inhabiting the largest streams were blue catfish, *Ictalurus furcatus*, paddlefish, *Polyodon spathula*, and river darter, *Percina shumardi* (> 60,000 sq. mi.). Because Ohio has more small streams than large streams, species inhabiting small streams tended to be collected more frequently than species inhabiting large streams. For example, creek chub with a mean drainage area of 185 square miles, were collected from 882 streams whereas longnose gar, *Lepisosteus osseus*, with a mean drainage area of 9,955 square miles, were collected from only 46 streams.

This study showed that nine historically occurring (in streams) fish species were not collected from any Ohio stream during the 1979 through 1995 period. The last reported stream collections for these species were harelip sucker, *Lagochila lacera* (Blanchard and Auglaize rivers in 1893); longhead darter, *Percina macrocephala* (Walhonding River in 1939); gilt darter, *Percina evides* (Maumee River in 1893); crystal darter, *Ammocrypta asprella* (Ohio River in 1899); Scioto madtom, *Noturus trautmani* (Big Darby Creek in 1957); alligator gar, *Lepisosteus spatula* (Ohio River in 1946); pirate perch, *Aphredoderus sayanus* (Auglaize River in 1942)[3]; lake sturgeon, *Acipenser fulvescens* (Ohio River in 1971); and shovelnose sturgeon, *Scaphirhynchus platorynchus* (Ohio River in 1939). The results of this study were used to revise the current status of Ohio's endangered, threatened, and special interest fish species. These revisions are listed in Table 1 (ODOW, 1998).

Discussion

Of the 162 fish species recorded from Ohio streams (Table 1), 143 are native (nine were not captured during the 1979 through 1995 study period) and 19 are nonnative. The results of this study along with observations by the authors show that the distribution and abundance of some fish species have increased, while others appear stable, and some have apparently decreased. Species that have expanded their range or returned to their pre-1955 distribution (Trautman, 1981) include many native large stream fishes such as the blue sucker, *Cycleptus elongatus*, greater redhorse, *Moxostoma valenciennesi*, river

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[2] The mean relative number is the average number of fish (used here by species) collected electrofishing a distance of 1.0 kilometer (km) using the boat method and 0.3 km using the wading method. It is OEPA's average catch-per-unit-effort (CPUE) based on the number collected per standardized distance electrofished.

[3] A re-introduction project by the ODOW is currently underway in the Auglaize River.

redhorse, *Moxostoma carinatum,* slenderhead darter, *Percina phoxocephala*, and channel darter, *Percina copelandi*. These increases are primarily attributed to improved water quality as the result of reduced pollutant loadings from point source discharges; however, the use of electrofishing gear and more intense field sampling has also added new records.

A number of non-native fishes such as the white perch, *Morone americana*, and goldfish, *Carassius auratus*, have also markedly expanded their distribution in streams. Although rosyside dace, *Clinostomus funduloides,* and longnose dace, *Rhinichthys cataractae,* have increased distributions as the result of more intense sampling, many species that inhabit small streams continue to decline due to the degradation of habitat resulting from excessive sedimentation, encroachment, culverting, channelization, suburbanization and other forms of hydromodification. One such species, the blacknose shiner, *Notropis heterolepis*, appears to have been recently extirpated. Another sensitive small stream species, the bigeye chub, *Notropis amblops*, continues to decline. Changes in occurrence and abundance for other Ohio stream fishes are also evident when data presented in Table 1 is compared with Trautman (1981).

Future changes in the distribution and abundance of Ohio stream fishes are dependant on the ability of environmental and natural resource managers not only to protect and restore water quality through successful point and nonpoint source pollution control programs, but the protection and restoration of stream habitats (*e.g.* protect and restore riparian forests, natural floodplains and wetlands; reduce sedimentation; remove dams; exclude livestock; other activities conducive to diverse, free-flowing habitats) as well.

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