Technical Report: Ohio's Primary Headwater Streams-
Fish and Amphibian Assemblages

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I. Introduction

This technical report summarizes the types of fish and amphibians that have been collected by Ohio EPA during surveys of primary headwater streams. Primary headwater habitat streams (PHWH) are identified by Ohio EPA as waterways that have a defined bed and bank with watershed area less than 1 mi^2 (256 ha; 633 ac; 2.59 km^2), that also have deep pools less than 40 cm (Ohio EPA, 2002). Primary headwater streams are the precursors to larger streams and rivers in Ohio. They have important water quality, ecological, and economic functions, including sediment and nutrient retention, refuge for native wildlife, energy dynamics, water supply, and aesthetics (Ohio EPA, 2000; Meyer and Wallace, 2001; Peterson et al., 2001). Other technical reports will summarize the benthic macroinvertebrate and physical/chemical habitat characteristics of primary headwater streams in Ohio.

From 1999 to 2001 the Ohio EPA conducted biological surveys of primary headwater streams in four different ecoregions of Ohio. In general, two types of fish and amphibian assemblages were identified from these streams:

(1) a community with reproducing populations of native cold water adapted species of fish [e.g., brook trout (*Salvelinus fontinalis*), redside dace (*Clinostomus elongatus*), central mottled sculpin (*Cottus bairdi bairdi*), brook stickleback (*Culaea inconstans*)] and/or salamander species with multi-year larval age classes adapted to cool permanent flowing water (species within the genera *Eurycea*, *Pseudotriton*, *Gyrinophilus*).

(2) a vertebrate community with resident populations of native fish and/or amphibians not identified above.

Those primary headwater streams with vertebrate species from assemblage number (1) above are referred to as **Class III-PHWH** streams by Ohio EPA (Ohio EPA, 2002). There are two defining characteristics of Class III-PHWH streams: they are associated with cold-cool groundwater recharge, and there is a permanency of flow throughout the year, either on the surface of the stream bed, or interstitially in the subsurface alluvium. A significant number of cool water adapted benthic macroinvertebrate taxa also are found in Class III-PHWH streams. A list of cool water benthic macroinvertebrate species found in Class III-PHWH streams is provided in Ohio EPA (2002). Fish species adapted to warmer water (such as the creek chub, *Semotilus atromaculatus*), salamander species with larval periods less than 12 months (such as *Ambystoma* and *Desmognathus*), or frog tadpoles also may be present in Class III streams, but it is the presence of reproducing populations of native fauna adapted to cold-cool perennial flowing water that is definitive. Class III-PHWH streams have <u>on average</u> daily water temperature less than 20^{o} C in summer months (July-August-September), even in isolated pools of water that are connected by interstitial groundwater flow (see Figures 11,12). They are warmer than other streams in winter due to groundwater inflow.

In many regions of Ohio, Class III primary headwater streams are precursors to larger streams that are designated Cold Water Habitat (CWH) in the Ohio Administrative Code. Cold Water Habitat-Native Fauna streams are defined in OAC Section 3745-1-07 B(1)(f)(ii) as: *"waters capable of supporting populations of native cold water fish and associated vertebrate and invertebrate organisms and plants on an annual basis"*. Ninety-one streams from the following major basins in Ohio are currently designated Cold Water Habitat: Ashtabula River, Central Ohio Tributaries, Chagrin River, Grand River, Great Miami River, Mahoning River, Muskingum River, Sandusky River, and Southwest Ohio Tributaries.

Those primary headwater streams that lack Class III vertebrate indicator taxa, but have resident populations of warm water adapted fish species, or salamander species with larval periods less than 12 months, are referred to as **Class II-PHWH** streams (Ohio EPA, 2002). The hydraulics of Class II streams is derived mostly from overland flow and infiltration of precipitation into the shallow subsurface alluvium, as opposed to the deeper and much colder water table origin of the Class III streams. The flow hydrology of Class II streams is more dynamic and variable than the permanent flowing and thermally stable Class III streams. Class II-PHWH streams may have permanent flow or intermittent flow at different times of the year. Isolated pools of water in summer months often contain aquatic species that are adapted to warmer water. Intermittent Class II streams are sometimes referred to as "summer-dry" or "temporary" streams, but they should not be confused with "ephemeral" streams. Ephemeral streams are normally dry, except during episodic rain or snow melt runoff. The daily summer water temperature of Class II streams is on average greater than 20^{o} C in August, and higher than Class III streams during August and September (see Figure 12).

Primary headwater streams that are normally dry (ephemeral), with no evidence of isolated pools of water, and no evidence of subsurface flow, are called **Class I-PHWH** streams (Ohio EPA, 2002). The definitive characteristic of the Class I-PHWH stream type is that they only flow during or after precipitation (episodic rain or snow melt conditions). Class I streams may have a limited number of invertebrate species present seasonally as water continues to infiltrate into a stream channel after a precipitation event. Class I primary headwater streams are harsh environments for most species of aquatic life, and only those species that require standing water for relatively short periods of time to complete life cycles would be able to survive and reproduce in these types of aquatic habitats. However, many different amphibians and other vertebrates such as small mammals and reptiles use the Class I-PHWH riparian corridors for feeding, or to migrate through the local landscape in search of breeding sites. Class I-PHWH flood plains would also serve to dampen the downstream movement of nutrients to larger streams. Thus the Class I-PHWH stream riparian zone can be an important part of the overall integrity of a forested ecosystem.

The type of biological community found in primary headwater streams can change abruptly from one PHWH stream class to another, such as when cold groundwater intercepts a dry stream channel (e.g., Class I to Class III). Other changes in species composition are gradual, such as when a cool Class III stream is sequentially diluted by warmer runoff water through the drainage network. Some primary headwater streams maintain the same type of biological community throughout their length. Field sampling techniques to distinguish the different classes of primary headwater streams are provided in the most recent revision of the Ohio EPA field evaluation manual for primary headwater streams (Ohio EPA, 2002). The NRCS 1:15,000 county soil maps can be used to conduct a desktop evaluation of the potential location of primary headwater streams across the landscape.

A growing percentage of primary headwater streams in Ohio have been modified by channelization, riparian alteration, mining, agriculture (drain tiles) and urban development (culverts). Habitat modification can have significant impacts on vertebrate populations in these headwater streams (Myer and Wallace, 2001). The water temperature of cool Class III streams can be raised to critical levels when riparian cover is removed, and species adapted to life in rocky substrate can be eliminated if stream channels are dredged. Modification of the integrity of the physical habitat of streams has been identified as a major cause of non-attainment of aquatic life uses in Ohio (Ohio EPA, 2000). Preliminary data from the Ohio EPA 2000 survey suggest that Class II-PHWH streams and channel modified Class II-PHWH streams have similar types of benthic macroinvertebrate communities. However, alteration of the geomorphology of headwater streams can have significant negative effects on the biology present in larger streams and rivers in the drainage network (Myer and Wallace, 2001).

The picture on the left is a channel modified ephemeral Class I-PHWH stream. Picture on right is a natural cool-water Class III-PHWH stream with constant flow that goes interstitial in summer. A breeding population of the northern two-lined salamander, *Eurycea bislineata*, was found in the Class III stream. Both streams from Medina County, Ohio.

II. Vertebrate Assessment Methods

Two different sampling methods were used by Ohio EPA to monitor the types of vertebrates found in primary headwater habitat streams: (1) pulsed DC electrofishing and, (2) qualitative rapid bio-assessment using nets. This report will summarize data collected from these two types of surveys.

Over the past two decades (1978-2000) the Ohio EPA has used electrofishing to quantify the fish community of 144 PHWH streams (212 sample locations) throughout Ohio. Sample reaches were from 75 to 150 meters along the stream reach. Electrofishing sample methods are detailed in the Ohio EPA (1989) bioassessment users manual. In addition, from 1999 to 2000, the Ohio EPA sampled 274 primary headwater streams in different ecoregions of Ohio using a rapid bio-assessment kick-net method (Anderson et al., 1999). For the year 2000 survey, 215 primary headwater streams were selected at random from 10 counties in Ohio identified as having potential for rapid population growth: Geauga, Medina, Wood, Fulton, Delaware, Union, Butler, Warren, Logan, Hocking (Figure 2). Sites were randomly selected from waterways identified on NRCS (SCS) county soil maps.

For the kick-net sampling, fish and frogs were collected along a 100-200 foot stream reach. Fish were identified to species in the field. No attempt was made to identify adult frogs or tadpoles to species; they were lumped together into a single taxonomic group. The presence of fish and frogs was recorded on field sheets. Voucher specimens were collected at select sites.

Stream salamanders were collected by lifting cover objects such as rocks, leaf litter, and woody debris while walking in a upstream direction along the stream reach. The search for salamanders included both the flowing water and stream bank habitats along the stream corridor. In a select number of streams (N=14), a semi-quantitative visual encounter

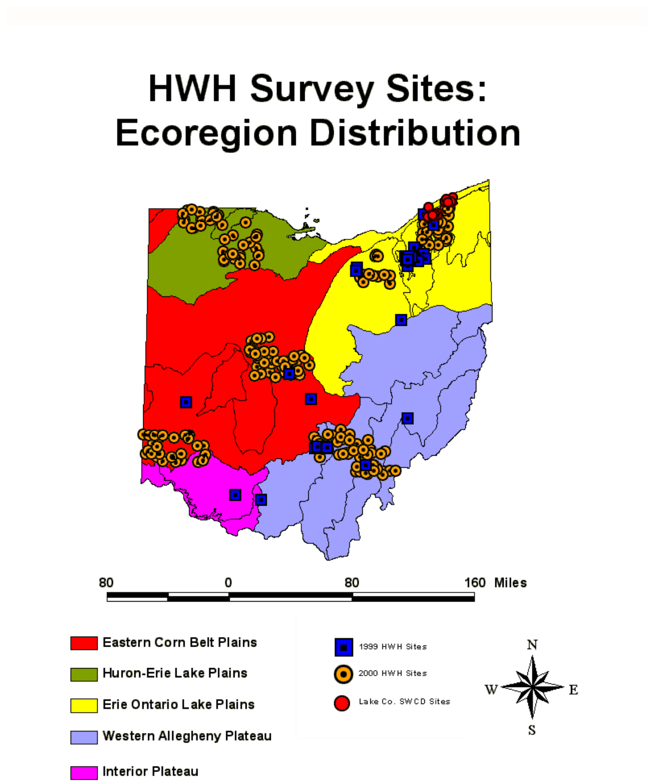


Figure 1. Map of 1999 and 2000 sample locations by ecoregion for primary headwater habitat streams in Ohio.

survey (VES, see Heyer et al., 1994) was used to quantify the densities of stream salamanders living along short stream transects. Stream transect lengths for the VES sampling were between 3-10 meters. An effort was taken to try to locate salamander larvae by careful observation while lifting microhabitat cover objects, since their presence is a direct indication that a reproducing population was present. Voucher specimens of salamanders were collected at most locations where they were encountered (maintained at Ohio EPA, Northeast District Office).

III. Results

1. Fish Assemblage (electrofishing sampling):

Forty three fish species have been collected from 144 primary headwater streams sampled by Ohio EPA at 212 locations using electrofishing. Figure 2 shows the relative proportions of the twenty-five most common species of fish collected during these electrofishing surveys.

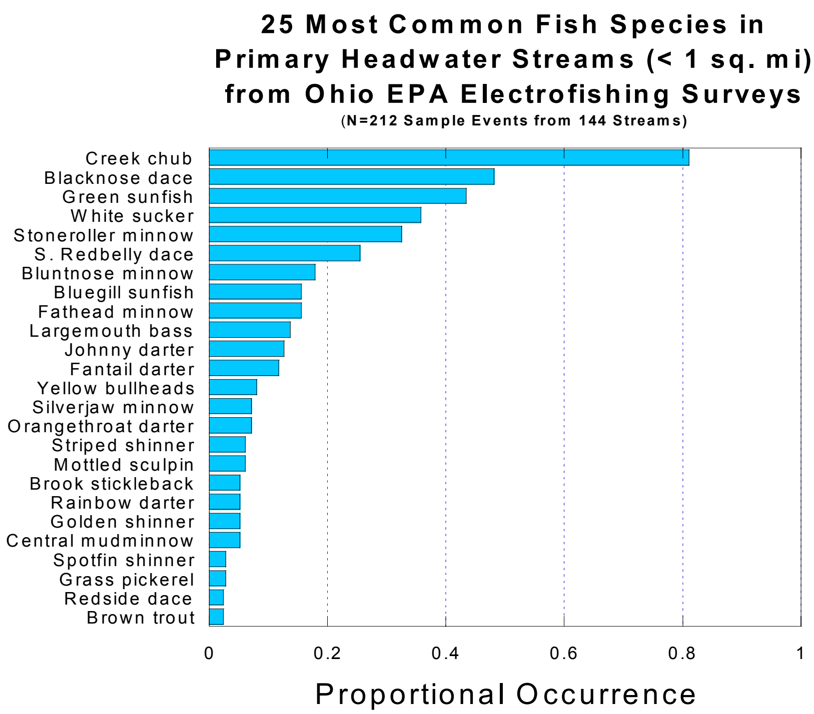


Figure 2. Twenty-five most common fish species collected by Ohio EPA in primary headwater streams (<1.0 mi^2) via electrofishing methods, 1978 to 2001.

The creek chub (*Semotilus atromaculatus*) was by far the most common fish species encountered, found in 172 (81.1%) of primary headwater streams sampled. The creek chub was also the dominant species based on relative numbers, with 26,758 individuals (51.6%) out of a total of 51,818 fish collected. The creek chub is known to be a pioneering species that migrates into the very smallest tributaries of a watershed during the spring breeding season (Trautman, 1981). It has a wide range of tolerance to variation in stream water temperature. While the creek chub is the dominant fish species in primary headwater streams less than 1.0 mi^2 drainage area, the bluntnose minnow, *Pimephales notatus*, is numerically dominant in larger headwater streams (1 to 20 mi^2 watershed size) from least impacted ecoregion reference sites in Ohio (Larsen et al., 1986)

Figure 3. The creek chub, the most common fish species in Ohio's primary headwater streams.

The relationship between "fish species richness" and the Index of Biotic Integrity (fish-IBI) at different PHWH drainage areas is shown in Figure 4. On average, 2 to 6 species of fish were found in primary headwater streams at watershed size between 0.2 mi^2 and 1.0 mi^2, with little change in fish-IBI as watershed size increases. Attainment of WWH fish-IBI biocriteria was documented in streams less than 1.0 mi^2 on average only about 25% of the time (Figure 4), most likely in streams having deeper pools of water. However, some of the streams that scored poorly using the fish-IBI measure of headwater integrity would have a diverse assemblage of cold-cool water adapted salamander and benthic macroinvertebrates present. Thus the fish-IBI technique is not a sufficient biological measure of the potential ecological integrity and health of PHWH streams in Ohio.

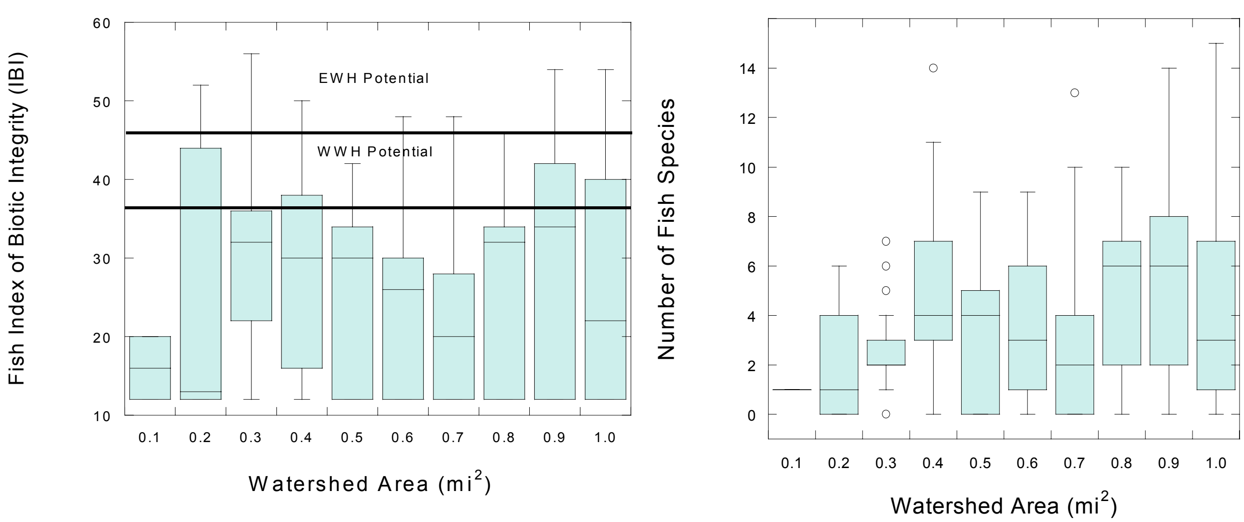


Figure 4. Number of fish species and fish Index of Biotic Integrity (fish-IBI) by watershed size in Ohio.

There is no significant relationship between fish-IBI and the QHEI (Qualitative Habitat Evaluation Index) in primary headwater streams (Figure 5). The very low R^2 value of 0.009 indicates that QHEI does not predict fish-IBI in headwater streams less than 1.0 mi^2 drainage area. Even where QHEI was above 60 points, no strong relationship with fish-IBI is seen (Figure 5). The data in Figure 5 suggest the Headwater Habitat Evaluation Index (HHEI) would be a more appropriate habitat assessment tool than the QHEI to predict the biotic potential of primary headwater streams (see Ohio EPA 2002 headwater assessment manual for information on the HHEI sample technique).

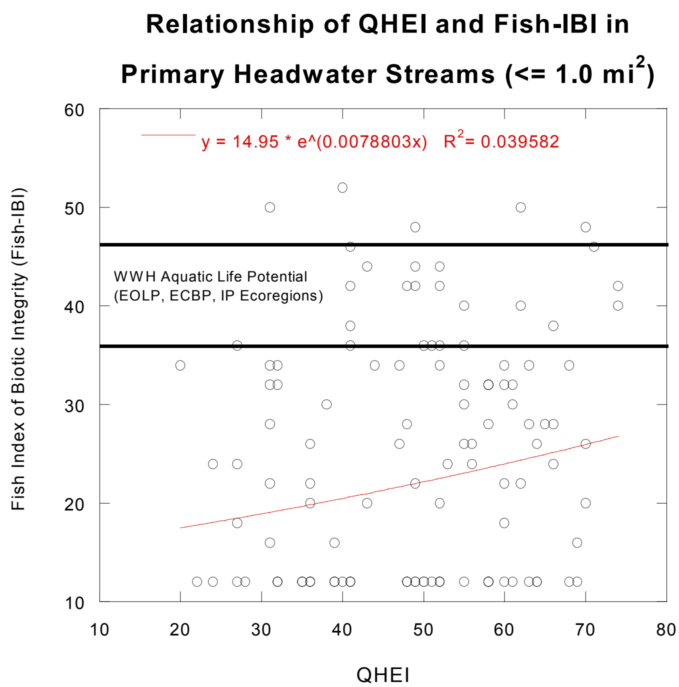


Figure 5. Relationship of the fish-IBI and QHEI in primary headwater habitat streams from Ohio.

There is, however, a significant positive association between "fish species richness" and fish-IBI in primary headwater streams in the different ecoregions of Ohio (Figure 6). Based on the Ohio EPA electrofishing data, a minimum of 4 fish species, none of which are coldwater indicator species, need to be present to reach attainment of the WWH fish-IBI biocriteria in a primary headwater stream (Figure 6). Although apparent attainment of WWH fish-IBI criteria has been documented with as few as 2 or 3 species of fish (Figure 6, EOLP ecoregion graph), all of those streams contained a reproducing population of the central mottled sculpin, which indicates that Cold Water Habitat, and not WWH, would be a more appropriate aquatic life use designation. Those headwater streams with 1-3 warmwater fish species can represent high quality lotic ecosystems (either Class II or Class III-PHWH streams) having a diverse assemblage of native benthic macroinvertebrates and amphibians.

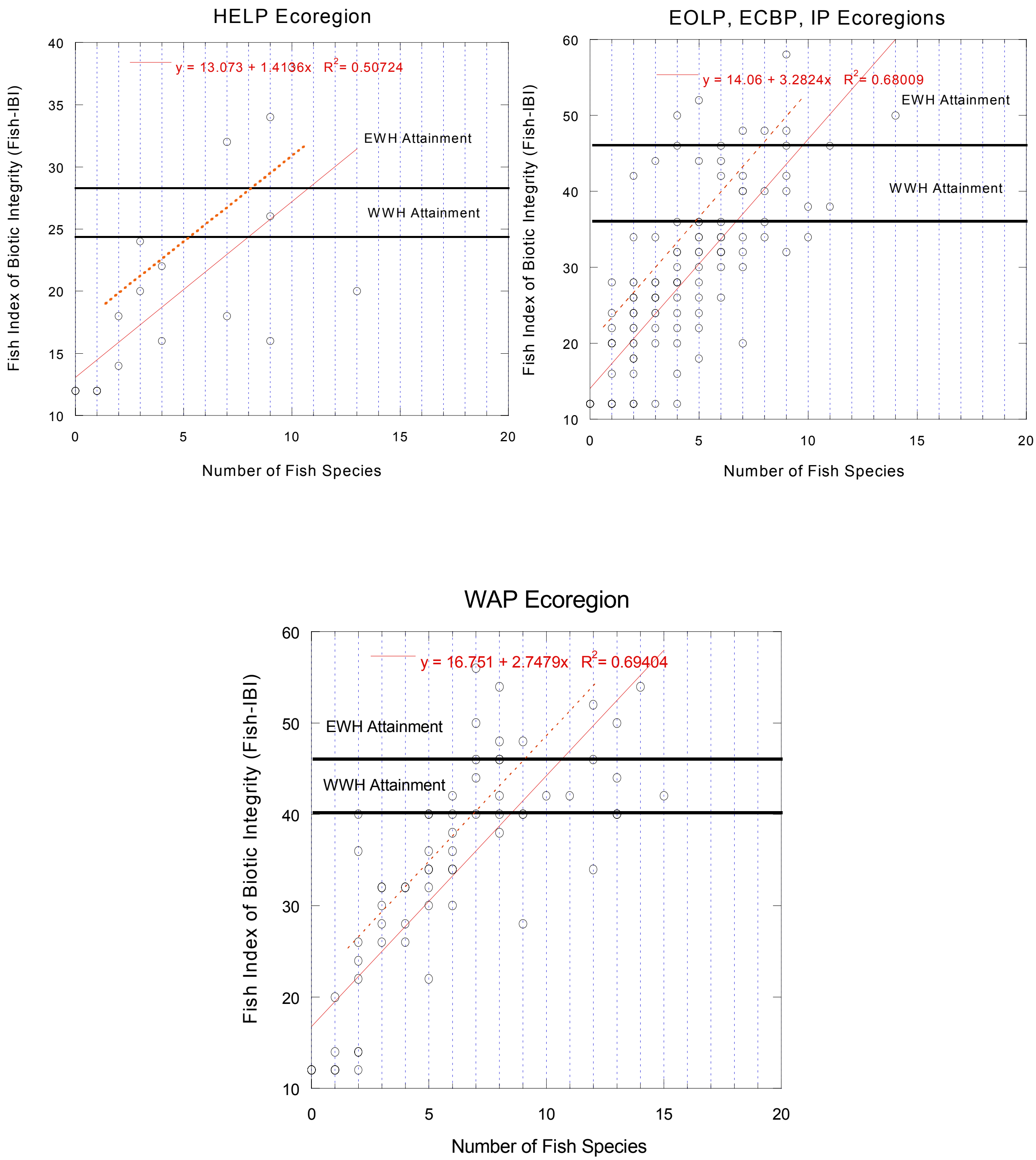


Figure 6. Association between fish-IBI and species richness by ecoregion in primary headwater streams in Ohio. Upper dotted line represents 75th percentile of the regression slope.

The probability of reaching full attainment of a WWH fish-IBI in a primary headwater stream differs by ecoregion (Figure 6). In the EOLP, ECBP, IP, and HELP ecoregions, a WWH fish-IBI is predicted by the presence of 5 species of fish; an EWH fish-IBI is predicted by 8 species. In these ecoregions, PHWH streams with fewer than 5 warmwater adapted fish species, and no Class III cold-cool water bioindicators, would meet the definition of a Class II- PHWH aquatic life use designation. In the non-glaciated WAP ecoregion, a WWH fish-IBI is predicted by 7 species of fish; a EWH stream by 9 species. The data from Figures 5 and 6 suggest that "fish species richness" may be a reliable predictor of the potential for a primary headwater stream to attain either WWH or EWH aquatic life uses. Presence of cold water fish in a PHWH stream is always a definitive indication that the stream has Class III-PHWH stream potential.

2. Fish Assemblage (qualitative rapid bioassessment sampling):

The proportional occurrence of fish, salamanders, and frogs found in the 215 primary headwater streams sampled during the 2000 survey is given in Table 3. Site locations were based on a random selection of streams from SCS soil maps in 10 Ohio counties. Ninety-nine (46.1%) of the streams contained no evidence of aquatic life and where classified as either Class I-PHWH streams, or non-stream waterways. Fish were collected in 42 of the 116 (36.2.9%) streams where standing or flowing water was present. Fish were associated with amphibians, either salamanders or frogs in 27 of the 116 streams with water (23.4 %). Amphibians with no fish species were found in 33 streams (28.4 %). Invertebrates alone (no vertebrate species present) were found in 41 streams with water (35.3 %), which underscores the importance of using benthic macroinvertebrates to determine aquatic life use status in primary headwater streams.

Table 3. Relative proportion of major taxonomic groups from 215 randomly selected primary headwater streams in Ohio. Data from 2000 qualitative survey. For example, 15 of the 215 sampled streams (7%) contained only fish and benthic macroinvertebrate taxa (data from the 8th column). Percentages do not add to 100% due to rounding error.

Fish		**X**				**X**	**X**	**X**				**X**	**X**	**X**		**X**
Salamanders			**X**			**X**			**X**	**X**		**X**	**X**		**X**	**X**
Frogs				**X**			**X**		**X**		**X**		**X**	**X**	**X**	**X**
Invertebrates					**X**			**X**		**X**	**X**	**X**		**X**	**X**	**X**
# Streams	**99**	**0**	**0**	**0**	**41**	**0**	**0**	**15**	**0**	**8**	**16**	**13**	**0**	**9**	**9**	**5**
% of Streams	**46%**				**19%**			**7%**		**4%**	**7%**	**6%**		**4%**	**4%**	**2%**

X = Taxa species present in a primary headwater stream

The relative proportion of vertebrate taxa found in PHWH streams differs by ecoregions. A higher than average percentage of primary headwater streams with salamander species were found from the WAP ecoregion, whereas, no Class III salamander species were found in the HELP ecoregion of northwest Ohio. Benthic invertebrates were found in 100% of the PHWH streams sampled that contained water (Table 3).

As was found with the statewide electrofishing surveys, the creek chub was the most common species collected during the rapid bio-assessment net surveys. Appendix Table 2 lists fish species found in PHWH streams by Ohio EPA from 1999 to 2001. The creek chub was found in 20 of the 39 (51.3%) PHWH streams where fish were observed (Table 2). It was the only fish species found at 11 of 39 locations (28.2%). The bluntnose minnow and western blacknose dace were the next most common species, at 19.4 % and 10.4 % respectively. The bluntnose minnow was the lone fish species in 3 of 39 streams (7.7%); blacknose dace was the lone species in 2 of 39 streams (5.1%). These observations are to be expected since the creek chub, blacknose dace, and bluntnose minnow are classified by Ohio EPA as pioneering species and/or headwater species (Ohio EPA, 1989). A significant number of primary headwater streams contained only a single species of fish (41.0 %) with the creek chub being the single species most likely to be found. These observations indicate that the fish-IBI concept of a "well balanced community of fish species" does not apply to a large percentage of primary headwater streams (e.g., less than 1.0 mi^2 drainage area) in Ohio if only one or at most two fish species are present naturally.

Three of the four cold water indicator fish species present in Ohio were collected during the 1999-2000 qualitative survey, however, they were not common (Table 2). Where coldwater fish species were found, they were coexisting with cool water adapted salamander species that have multiyear larval periods (genera *Eurycea*, *Gyrinophilus*, *Pseudotriton*), and a diverse community of benthic macroinvertebrates including cool water taxa. It was observed that many Class III-PHWH streams did not contain coldwater fish, likely due to physical habitat constraints such as shallow depth of deep pools, and rock ledges. In addition, the geographic ranges of coldwater fish does not extend to all counties of Ohio where Class III-PHWH streams are located (Trautman, 1981). Thus an important finding of the Ohio EPA survey was that salamander species with multi-year larval periods replace coldwater fish as the dominant vertebrate predator in many cool water primary headwater stream habitats (see Class III-PHWH salamander species list in Table 5).

In general, the results of the year 2000 rapid bio-assessment of fish using nets agree with the results obtained from the more extensive electrofishing surveys. The same species of fish were found to dominate primary headwater streams using both assessment methods (creek chub, blacknose dace, bluntnose minnow). Green sunfish were also somewhat common, (compare Figure 2 and Table 4), most likely due to the large number of small private ponds that exist throughout Ohio.

Table 4. Table of fish species observed/collected in primary headwater habitat streams in Ohio, 1999 and 2000. Total of 67 streams sampled. Fish species in **bold** represent PHWH stream indicator species based on habitat preference. Fish in *italics* indicate cold water adapted Class III-PHWH indicator species. Yes indicates species associated with listed ecological category in Ohio EPA (1989) ; No indicates species not associated with that category.

Species (common name)	Percent (%) Occurrence	Pioneering Species	Headwater Species	Coldwater Species
Creek Chub	**(32.8)**	**Yes**	**No**	**No**
Bluntnose Minnow	**(19.4)**	**Yes**	**No**	**No**
Blacknose Dace	**(10.4)**	**No**	**Yes**	**No**
Rainbow Darter	(7.5)	No	No	No
Bluegill Sunfish	(4.5)	No	No	No
Johnny Darter	**(4.5)**	**Yes**	**No**	**No**
Stoneroller Minnow	(4.5)	No	No	No
Largemouth Bass	(2.9)	No	No	No
Fantail Darter	**(2.9)**	**No**	**Yes**	**No**
Greenside Darter	(2.9)	No	No	No
White Sucker	(2.9)	No	No	No
Green Sunfish	**(2.9)**	**Yes**	**No**	**No**
Redside Dace	***(1.5)***	***No***	***Yes***	***Yes***
Mottled Sculpin	***(1.5)***	***No***	***Yes***	***Yes***
Native Brook Trout	***(1.5)***	***No***	***No***	***Yes***
Rainbow Trout**	(1.5)	No	No	Yes
Goldfish**	(1.5)	No	No	No
Mudminnow	(1.5)	No	No	No
Orangethroat Darter	**(1.5)**	**Yes**	**No**	**No**

Fish species expected to occur in PHWH streams but not observed during 1999 and 2000 surveys.

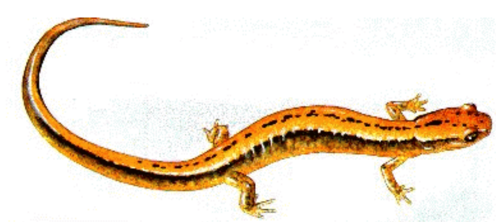
Species (common name)	Percent (%) Occurrence	Pioneering Species	Headwater Species	Coldwater Species
Creek Chubsucker	**—**	**Yes**	**No**	**No**
Southern Redbelly Dace	**—**	**No**	**Yes**	**No**
Rosyside Dace	**—**	**No**	**Yes**	**No**
Silverjaw Minnow	**—**	**Yes**	**No**	**No**
Fathead Minnow	**—**	**Yes**	**No**	**No**
Brook Stickleback	**—**	***No***	***Yes***	***Yes***
Brown Trout**	—	No	No	Yes

** = Non-Native Species

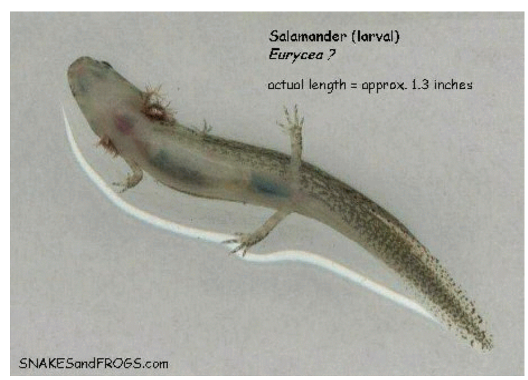
3. Salamander Assemblage:

Ohio has a diverse fauna of amphibians that include frogs, toads, and salamanders including newts. As a group, amphibians require a moist environment because they have a permeable skin that is sensitive to dessication. They are often found in or near water, or in moist forested areas such as leaf-litter, burrows, and under logs. Salamanders live in many different macrohabitats including forests, wetlands, riparian areas, ephemeral pools, permanent ponds, large rivers, and small primary headwater streams (Pfingsten and Downs, 1989). The most recent inventories of salamanders in Ohio by Pfingsten (1998) and Petranka (1998) indicate that 28 species or sub-species are present. These species are distributed within five taxonomic families (Cryptobranchus, Proteidae, Salamandridae, Ambystomatidae, Plethodontidae), each with its own evolutionary history and affinity to potential survival and reproduction in small primary headwater streams. Salamanders are the most abundant vertebrate predators in forests and their associated stream corridors in the United States (Burton and Likens, 1975; Hairston, 1987). They have many important ecosystem functions as predators of small invertebrates and as a source of high energy prey for birds, mammals, and reptiles (Burton and Likens, 1975; Hairston, 1987; Petranka, 1998).

During the Ohio EPA 1999-2001 survey, the most common salamander species found in primary headwater streams were from the lungless family Plethodontidae. Larvae of the two-lined salamander complex, (*Eurycea bislineata, E. cirrigera*), were numerically dominant in primary headwater streams throughout Ohio (Figure 8). The two-lined salamander was found in 54 of 61 (88.52 %) of all PHWH streams where salamanders were collected . Appendix Table 1 provides a complete listing of all PHWh streams where salamanders were found.



Adult two-lined salamander, *Eurycea bislineata* complex. Photo author unknown.

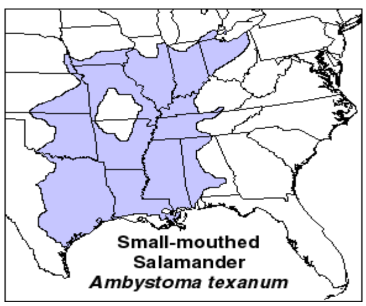


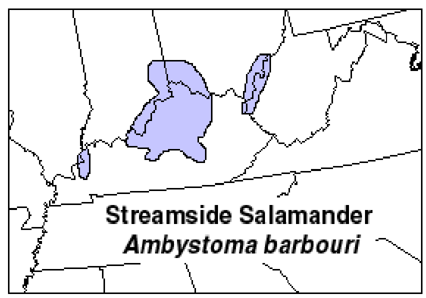
Larvae of *Eurycea bislineata* complex, note red external gills. Specimen from South Carlolina. Photo by: “snakeandfrog.com” with permission.

Figure 7. The two-lined salamander complex, the most frequently observed salamander species found in primary headwater streams in Ohio.

As a group, the Plethodontidae, or lungless salamanders, are unique vertebrates because they do not have lungs at any time during development. Diffusion of gases is across moist skin in both larvae and adults, and across gills in species that have a larval stage. Consequently, all species of lungless salamanders are found in environments with high humidity where the skin can be kept relatively moist for efficient gas exchange.

Salamander species from the Ambystomatidae family, commonly called mole salamanders, do have lungs and usually breed in ephemeral pools, wetlands, and ditches near forested areas. Adults live in the adjacent forest habitats during non-breeding times of the year, usually under logs or in burrows (Pfingsten and Downs, 1989; Harding, 1996; Petranka, 1998). However, one species from this family in Ohio, the streamside salamander *(Ambystoma barbouri)*, is known to reproduce in temporary flowing primary headwater streams in the southwest region of the state (Pfingsten, 1998). The streamside salamander is genetically related to the pond breeding small-mouthed salamander, *A. texanum* (Petranka, 1998), which is also known to use streams occasionally for reproduction and larval recruitment (Pfingsten and Downs, 1989; Harding, 1996; Petranka, 1998). See maps in Figure 8 for the distribution of these two *Ambystoma* species in Ohio. Other *Ambystoma* species have also been reported to breed in modified streams (Petranka, 1998). Thus the presence of larvae of any *Ambystoma* species in a primary headwater stream would be an indication that the stream should receive, at a minimum, a Class II-PHWH use classification for protection of aquatic life





http://www.npwrc.usgs.gov/narcam/idguide/index.htm#pig

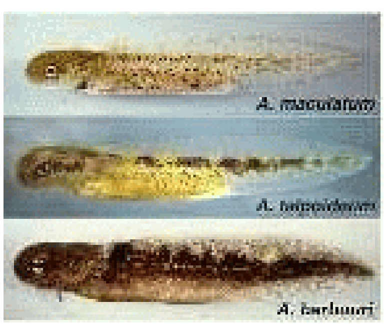


Photo by: David Patrichy.
Ambystoma larvae

Photo by: Eric Williams. The streamside salamander, *A. barbouri*

Figure 8. Location maps and photos of *Ambystoma barbouri* and *Ambystoma texanum* in Ohio.

Numerous *Ambystoma* species also have been collected from wetlands in Ohio as part of the Ohio EPA statewide wetland bioassessment project. More information about the Ohio EPA amphibian wetland monitoring program can be viewed at the following Ohio EPA internet site:

[http://www.epa.gov/owow/wetlands/bawwg/case/oh1macro.html]

The presence/absence of different types of salamander species can be used to determine PHWH stream class. The two most important diagnostic traits are the length of the larval period, and location of habitat sites used by females for deposition of eggs. Many salamander species from the lungless tribe Hemidacyliini (i.e, *Eurycea, Gyrinophilus, Pseudotriton*) lay eggs directly in flowing water, and have extended larval stages that last from 2-4 years in Ohio (Pfingsten and Downs, 1989). These species are adapted to perennial cool-cold flowing water as found in spring-fed habitats, and thus are excellent "bio-indicators" of the Class III-PHWH headwater stream type. Conversely, species from the subfamily Desmognathinae *(Desmognathus fuscus*, and *D. ochrophaeus*) do not have obligate aquatic egg laying habits--dusky females deposit egg clutches in moist streambank habitats, or in seepage areas under rocks, logs, or clumps of moss. In addition, the larval period for dusky salamanders is less than 12 months in Ohio, which would be adaptive for populations that reproduce along intermittent or ephemeral streams and exposed to stress from dessication. The larvae of both *Desmognathus* species may be found outside flowing water (Bishop, 1941; Petranka, 1998; personal observations of Robert Davic, Ohio EPA). *Desmognathus* larvae also have been collected from streams in the winter and spring that subsequently become completely dry in summer months (personal observations of Robert Davic, Ohio EPA). Thus the presence of larvae of either *Desmognathus* species in a primary headwater stream habitat, without the presence of Class III indicator salamander larvae, can at best suggest that a Class II PHWH stream is present.

Note white line from eye

Photo by: Eric Williams, Northern Dusky Salamander, (*Desmognathus fuscus fuscus*)

Salamander species with multi-year larval periods are adapted to life in perennial flowing cold-cool habitats. The origin of this constant flow is from deep groundwater aquifers or the "water table" (Pettyjohn and Henning, 1979). Habitats where this cold groundwater emerges to the surface are commonly called cold-water springs, or rheocrenes. This deep water table water is at a constant temperature seasonally when it emerges at the earths surface (about 15.0 ^{o}C), but gradually warms in summer after it combines with shallow subsurface water and is heated by the atmosphere. Primary headwater streams dominated by spring-fed flow have a lower "variance" of temperature fluxuations over an annual period than headwater streams that have flow derived from subsurface infiltration (see Figure 12).

Rheocrene habitats would be expected to harbor salamander species with multi-year larval periods such as the spring salamander, red salamander, and mud salamander. The two-lined salamander may also be found in rheocrenes, but tends to migrate much further downstream into the drainage network. Some rheocrenes may also provide a suitable habitat for the seasonal reproduction of *Desmognathus* species. Both of the *Desmognathus* salamander species found in Ohio (*D. fuscus*, *D. ochrophaeus*) are known to lay eggs in seepage habitats (Pfingsten and Downs, 1989).

During the Ohio EPA 1999-2001 survey, it was found that some streams had dry stream beds in summer with isolated pools of water that were connected by very slowly moving water. Larvae of the two-lined salamander (*Eurycea bislineata* complex) were collected from these interstitial flowing streams, along with a number of cool water adapted species of benthic macroinvertebrates. More commonly, cool-cold Class III-PHWH streams were found to have continuous flow on the surface of the stream bed annually, with no dry areas along the stream reach. Thus, three types of cool-cold Class III streams potentially exist across the landscape: (1) those with constant surface flow, (2) those with isolated pools of water connected by subsurface or interstitial flow, and (3) dry stream bed with only subsurface interstitial flow. We have only documented the first two flow conditions during our 1999-2001 survey.

Not all salamander species found in forests use primary headwater streams for reproduction, such as species from the genera *Plethodon* and *Aneides*. These genera lack an aquatic larval stage, and instead have "direct development" into an immature juvenile salamander from the embryo sac. Salamanders from the *Plethodon* and *Aneides* genera normally select terrestrial habitats for egg deposition such as moist logs and burrows within forests. No species of salamanders from the ancient families of Cryptobranchus, Proteidae, or Salamandridae are known to use PHWH streams as a habitat for reproduction in Ohio, nor are they collected from such streams (Pfingsten and Downs, 1989). These salamander species are found only in large streams, rivers, and lakes and ponds.

A list of salamander species found in Ohio that would be expected to use primary headwater streams for reproduction is given in Table 5. Two attributes of salamander life history were used to determine PHWH class indicator status: site selection for egg-deposition, and length of larval period. Not included in Table 5 are *Plethodon* and *Aneides* salamanders that may on occasion be found in headwater stream corridors (Pfingsten and Downs, 1989).

The above picture shows a summer Class III-PHWH stream with "interstitial" subsurface flow and hydraulic connection between isolated pools of cool water. A breeding population of the northern two lined salamander, *Eurycea bislineata*, was found in this stream. Medina County, Ohio.

Table 5. List of salamander species in Ohio that use primary headwater stream corridors as a habitat for egg deposition (oviposition) and larval growth. Species ordered from shortest length of larval period to longest. Life history data from personal observations of R.D. Davic (Ohio EPA), Harding (1997), Pfingsten and Downs (1989), Petranka (1998), Hulse et al.(2001). *Plethodon* and *Aneides* species with direct development not included in the table. When multiple species are collected in the same stream segment, the species with the highest numerical classification is used to indicate potential appropriate PHWH stream class (I, II, or III). **Only evidence of reproduction (larvae, eggs, or mixture of juveniles and adults) can be used to determine stream class.** Table by R. D. Davic, Ohio EPA.

Species	Microhabitat and Season for Egg Clutch Deposition+ PHWH Stream Class Indicator Type.	Length/Season of Larval period.
Four-toed salamander (*Hemidactylium scutatum*)	Statewide. Found in bog habitats, eggs usually found in moss (sphagnum) from March to May. Eggs may be found in slow moving headwater streams associated with bog habitat. Adults terrestrial. If evidence of reproduction found, a Class-II PHWH stream indicator species. Protected as a Special Interest species in ORC, Section 1531.25.	1-2 months (May to June). Pond type larval
Streamside salamander (*Ambystoma barbouri)*	SW Ohio only. Oviposition from January to March in headwater streams with few fish. Stream usually becomes intermittent during summer. Often in limestone type geology. Eggs found in water under rocks between December to March. If evidence of reproduction found, a Class II-PHWH stream indicator species.	2-3 months (March to May).
Mountain dusky salamander (*Desmognathus ochrophaeus*)	Extreme NE Ohio only. Oviposition near seepage areas, mostly from August to October. Known to breed in sub-surface habitats. Stream may become intermittent in summer. Adults will forage in riparian areas. If evidence of reproduction found , a Class II-PHWH stream indicator species.	1-3 months. Most common in September to November, but may occur in March-April in some Ohio populations.
Northern longtail salamander (*Eurycea longicauda)*	Statewide except northwest and north-central Ohio. Oviposition over winter in streams and seepage areas associated with rock outcrops or in sub-surface areas. Often in limestone or shale geology, around caves. If evidence of reproduction found, a Class II-PHWH stream indicator species. If 2 larval age classes present, then a Class III indicator.	4-5 months, (March to July), but may extend to 12-14 months in local populations. Larval period not well known for Ohio.

Table 5 continued. List of salamander species in Ohio that use primary headwater stream corridors as a habitat for egg deposition (oviposition) and larval growth Species ordered from shortest length of larval period to longest. Life history data from personal observations of R.D. Davic (Ohio EPA), Harding (1997), Pfingsten and Downs (1989), Petranka (1998), Hulse et al.(2001). *Plethodon* and *Aneides* species with direct development not included in the table. When multiple species are found in the same stream segment, the species with the highest numerical classification is used to indicate appropriate PHWH stream class (I, II, or III). **Only evidence of reproduction (larvae, eggs, or mixture of juveniles and adults) can be used to determine stream class**. Table by R. D. Davic, Ohio EPA.

Species	**Microhabitat and Season for Egg Clutch Deposition+ PHWH Stream Class Indicator Type.**	**Length/Season of Larval period.**
Northern dusky salamander (*Desmognathus f. fuscus*)	Statewide except northwest and north-central Ohio. Oviposition in streambank microhabitats or seepage areas, outside flowing water (June to August). Eggs not in flowing water, but streamside under rocks, logs, moss with brooding female. If evidence of reproduction found, a Class II-PHWH stream indicator species. May be found in Class III stream habitats.	9-10 months (September to May). No larvae in June and July. Young and old larvae may be found in streambank outside flowing water
Cave salamander (*Eurycea lucifuga*)	Extreme southwest counties of Ohio, at northern edge of geographic range. Oviposition from September to February within caves. If found, a Class III-PHWH stream indicator species. Very rare, classified as an Endangered Species in Ohio (ORC 1531.25).	Mostly 14-18 months with two larval age classes common in Indiana populations. Larval period not well known for Ohio.
Midland mud salamander (*Pseudotriton montanus diasticus*)	Extreme south central Ohio. Oviposition in autumn, embryos hatch in winter. Common in burrows; egg nests in cryptic underground sites. If evidence of reproduction found a Class III PHWH stream indicator species.	15 to 30 months, larval period not well known for Ohio populations.
Northern two-lined salamander (*Eurycea bislineata*)	North Central to North East Ohio. Common in perennial flowing PHWH streams. Oviposition from April to May, in shallow running water under flat rocks. May be found in dry streams with interstitial sub-surface flow. If evidence of reproduction found, a Class III PHWH stream indicator species. Known to migrate into higher order streams.	24 to 36 months in Ohio. Three distinct larval age classes observed in some populations.

Table 5 continued. List of salamander species in Ohio that use primary headwater stream corridors as a habitat for egg deposition (oviposition) and larval growth Species ordered from shortest length of larval period to longest. Life history data from personal observations of R.D. Davic (Ohio EPA), Harding (1997), Pfingsten and Downs (1989), Petranka (1998), Hulse et al.(2001). *Plethodon* and *Aneides* species with direct development not included in the table. When multiple species are found in the same stream segment, the species with the highest numerical classification is used to indicate appropriate PHWH stream class (I, II, or III). **Only evidence of reproduction (larvae, eggs, or mixture of juveniles and adults) can be used to determine stream class.** Table by R. D. Davic, Ohio EPA.

Species	**Microhabitat and Season for Egg Clutch Deposition+ PHWH Stream Class Indicator Type.**	**Length/Season of Larval period.**
Southern two-lined salamander (*Eurycea cirrigera*)	Southern portion of Ohio, considered a sub-species of *E. bislineata* by Petranka (1998). Same behavior as northern two-lined salamander. If evidence of reproduction found, a Class III-PHWH stream indicator species.	24 to 36 months in Ohio. Three distinct larval age classes in summer
Red salamander (*Pseudotriton ruber*)	Eastern portions of state, north to south. Oviposition from October to February, usually in sub-surface areas. Adults migrate away from streams in spring-summer, but overwinter in headwater springs. Associated with sandstone geology. If evidence of reproduction found, a Class III-PHWH stream indicator species.	24 to 36 months, may overwinter to a fourth year as larvae.
Spring salamander complex (*Gyrinophilus p. porphyriticus,* and *G. p. duryi*.	East to east-central and southern portions of the state. Oviposition in summer months, in sub-surface areas. Adults may forage away from streams, they have a propensity for a subterranean mode of life in cold-cool headwater springs. May be associated with caves. If evidence of reproduction found, a Class III-PHWH stream indicator species.	36 to > 48 months.

Photo by Jeff Davis: Larva of kentucky spring salamander, *Gyrinophilus porphyriticus duryi*. Found in extreme south-central counties of Ohio.

Estimating Salamander Density (VES Survey):

During the 1999-2001 survey, an attempt was made to estimate salamander population density for a small number (#=14) of primary headwater streams using a visual encounter survey (VES) method as outlined in Anderson et al. (1999). Sample plots lengths ranged from 3 to 10 m; plot widths included the flowing water habitat plus 1 m on each stream bank. Salamanders were captured using nets by moving in an upstream direction and carefully lifting cover objects. Salamanders were field identified, and returned to the stream. The search time, in minutes, was recorded.

The results of the VES surveys are given in Table 6. A total of six salamander species were collected from the 14 streams. The most common species was the two-lined salamander complex (*Eurycea bislineata, E. cirrigera*), with larvae being the most abundant age class. The average density for two-lined salamander larvae was 3.03 individual larvae/linear meter stream sampled; the average density of two-lined salamander juvenile and adult age classes was 0.52/linear meter. Densities of other observed salamander species are given in Table 6. The finding that salamander larval are more abundant in small headwater streams than either juveniles or adult age classes has been reported for other populations of the *Eurycea bislineata* complex in the northeast (Rocco and Brooks, 2001).

In one stream (NE-99-001), replicate VES surveys were conducted over a three year period from the exact same 10 m stream section at similar times of the year (June 6, 1997; June 28, 1998; June 24, 1999). Only two-lined salamander were present in this Class III stream. The results of the replicated VES surveys were as follows: (1997-2.90/linear m; 1998-2.90/linear m; 1999-3.60/linear m). These data, although limited, suggest that the population density of salamanders in this headwater stream was relatively stable over time. Stable population densities over time would be expected in a Class III-PHWH stream given the spring-fed hydrology that is present. Thus it would appear that there is a relatively low sampling error (coefficient of variation, CV) associated with using the Ohio EPA VES monitoring technique to estimate population densities of salamanders in PHWH streams.

During the summer of 2002, the Ohio EPA will begin to monitor stream salamander density using the "leaf refugia bag" approach of Pauley and Little (1998). Both natural and "artificial" leafs will be tested to see if this method can be used to provide a statistical approach for tracking long-term trends in the density of two-lined salamander larvae. The method of Pauley and Little (1998) uses plastic landscape netting with mesh size of 3-4 cm, cut to 45-50 x 30 cm sections. The mesh bags are filled with leaves and small rocks and placed into the flowing water of the stream. Large flat rocks are placed on top of the bags for support. The bags are left in the stream for 2 weeks, and colonized salamanders are recovered by shaking the leaf bag into a bucket. The leaf bag approach as been shown to provide estimates of stream salamander density similar to visual encounter surveys and electrofishing for the two-lined salamander (Jung et al., 2000; report available at):
http://journals.ohiolink.edu/local-cgi/send-pdf/020603125656250471.pdf

Table 6. Estimated salamander population densities from select primary headwater streams in Ohio using a Visual Encounter Survey (VES) sampling method.

Site	Date (m/d/y)	Time searched (min.)	Plot length (m)	Species	Number of individuals/m stream length	Total number ind.
NE-99-001	6/9/97	47	10	*E. bislineata* (larvae)	2.90	29
				E. bislineata (transformed)	0.50	5
NE-00-051	4/12/00	60	10	*E. bislineata* (larvae)	1.70	17
				E. bislineata (transformed)	0.80	8
				P. ruber (larvae)	0.10	1
NE-99-003	2/18/99	27	3.5	*E. bislineata* (larvae)	3.71	13
NE-99-010a	6/29/99	15	3	*E. bislineata* (larvae)	2.67	8
				E. bislineata (transformed)	0.33	1
				P. ruber (larvae)	0.33	1
NE-99-010b	5/12/99	75	10	*E. bislineata* (larvae)	5.30	53
				E. bislineata (transformed)	0.10	1
				P. ruber (larvae)	0.60	6
CD-99-001	6/15/99	40	4	*E. cirrigera* (larvae)	5.00	20
				E. cirrigera (transformed)	0.75	3
NE-99-011a	5/18/99	32	10	*E. bislineata* (larvae)	2.90	29
				E. bislineata (transformed)	0.30	3
NE-99-011b	5/19/99	39	10	*E. bislineata* (larvae)	2.30	23
				E. bislineata (transformed)	0.60	6
SW-99-001a	9/23/99	35	10	*E. cirrigera* (larvae)	1.40	14
				E. cirrigera (transformed)	0.91	11
				P. richmondi (transformed)	1.20	12
SW-99-001b	9/23/99	35	10	*E. cirrigera* (larvae)	4.40	44
				E. cirrigera (transformed)	2.30	23
NE-98-001	6/28/98	47	10	*E. bislineata* (larvae)	2.90	29
				E. bislineata (transformed)	0.10	1
NE-99-001	6/24/99	53	10	*E. bislineata* (larvae)	3.60	36
				E. bislineata (transformed)	0.20	2
MFLBC_trib	7/19/01	20	3	*E. bislineata* (larvae)	3.33	10
				D. fuscus (transformed)	1.67	5
				G. porphyriticus (larvae)	0.33	1
NE-01-014	7/10/01	60	9.1	*E. bislineata* (larvae)	0.329	3
				E. bislineata (transformed)	0.439	4

Figure 10 shows the seasonal growth rates and length of larval classes for the southern two-lined salamander, *E. cirrigera,* from populations collected in Green County by Duellman and Wood (1954). From June through November, three different age classes of salamander larvae are shown to be present. Throughout the year, at least two different age classes exist, showing the importance of having constant flowing water for the long-term survival of two-lined salamander populations. Primary headwater stream habitats that become summer-dry, with no flowing water, would not be able to support the type of larval growth pattern shown in Figure 10.

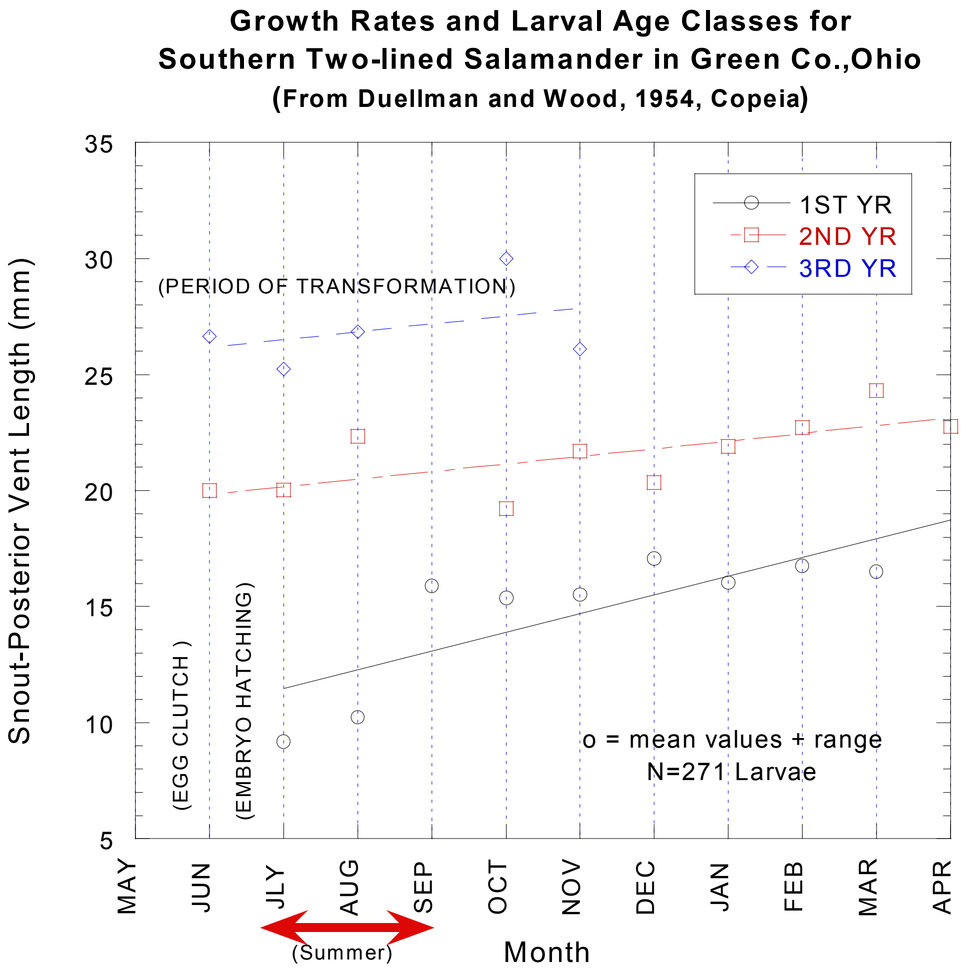


Figure 10. Larval period of southern two-lined salamander (*Eurycea cirrigera*) in Ohio. Adapted from data in Duellman and Wood (1954). Note: *E. b. rivicola* of Duellman and Wood is now recognized as *E. cirrigera*.

Figures 11 and 12 show seasonal changes in stream water temperatures and dissolved oxygen from numerous locations in Ohio where two-lined, spring, and red salamander larvae were collected, which are indicator species of a Class III primary headwater stream type. Figure 11 shows that the average summer temperature of a Class III stream with two-lined salamander larvae is less than 20 C^0, with values above 23.0 C^0 rarely encountered; average summer dissolved oxygen was greater than 6.0 mg/l. The scatter of points is due to a number of factors including diurnal fluxuations, and distance from cold spring water source. The data from Figure 12 indicates that Class III and Class II have similar stream water temperatures until the August and September time periods, with the Class III streams maintaining a cooler average water temperature in August and September.

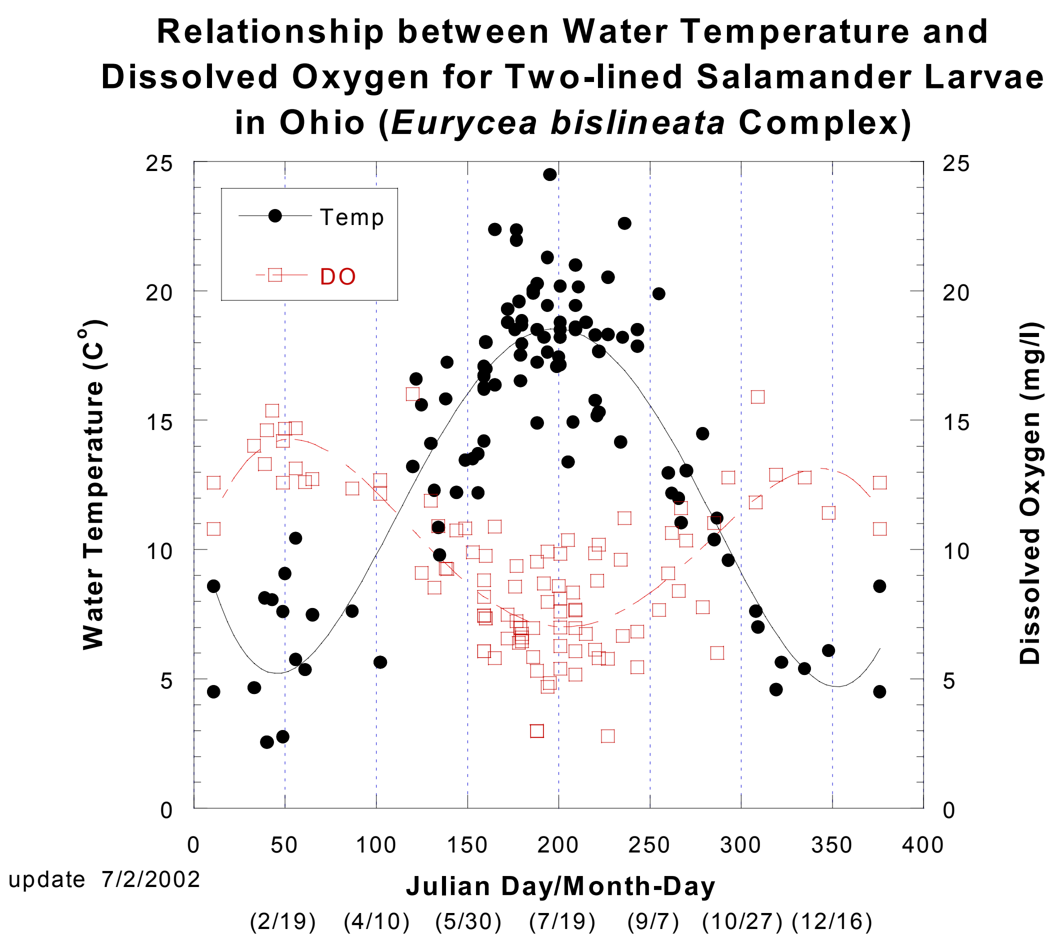


Figure 11. Seasonal changes in stream water temperature and dissolved oxygen at sites where first and second year larvae of the two-lined salamander were collected in Ohio (*Eurycea bislineata* complex). Lines are 4th degree polynomial regressions which gave the highest coefficient of variation (R^2) for each parameter. R^2 = 0.801 for temperature; R^2 = 0.644 for dissolved oxygen. Data updated as of July 17, 2002.

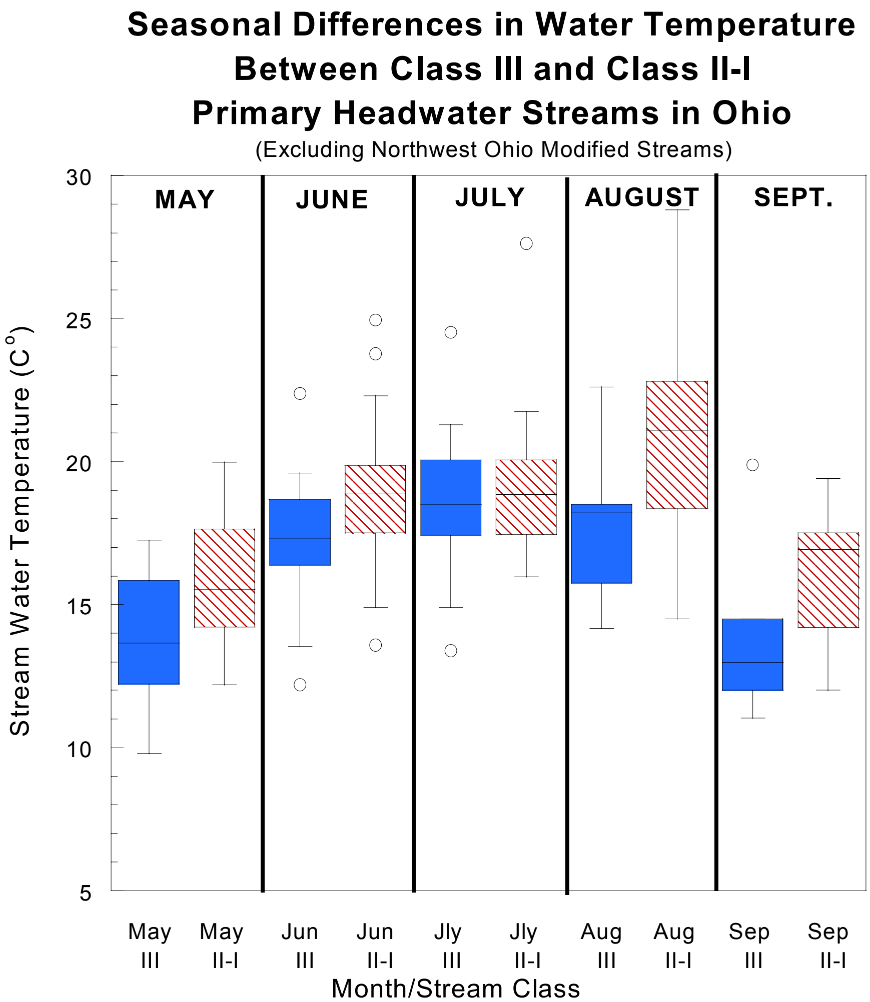


Figure 12. Seasonal changes in stream water temperature in Class III and Class II-I primary headwater streams, excluding modified northwest Ohio streams.

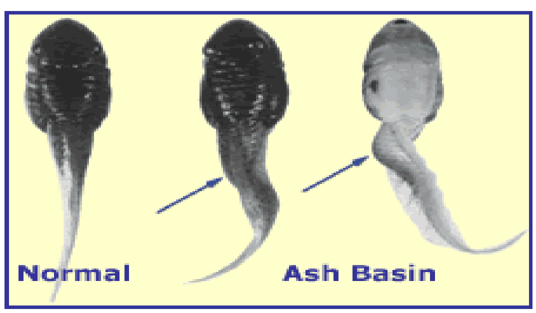
4. *Anuran (frog) Assemblage*:

A number of frogs were observed during this survey, however, no systematic attempt was made to record species or collect tadpole vouchers. During the random sampling of 215 streams, frogs were observed in 39 of 116 (33.6 %) streams that had standing or flowing water (Table 3, p. 9). Frogs were coexisting with salamanders in 14 (12.1%) of these streams. Frogs were found in PHWH streams from all four ecoregions of Ohio. A list of frog species that were positively field identified is presented in Table 7, however this list should not be viewed as a comprehensive indication of anuran species richness in primary headwater streams since tadpoles were not identified to species. No toads were observed at any PHWH stream during this survey.

Some frog species may be useful bio-indicators of PHWH stream type. For example, the bullfrog, *Rana catesbeiana*, has a tadpole stage greater than 12 months, which suggests that it is adapted to reproduction in aquatic habitats that do not become completely dry. Thus the presence of bullfrog tadpoles in a primary headwater stream would suggest that pooled water is present throughout the year, a characteristic of both warmer Class II-PHWH streams and cooler Class III-PHWH streams. The pickerel frog, *Rana palustris*, has a relatively short tadpole stage (3-4 months), but is known to reproduce in cooler ponds and "trout" type streams that are fed by groundwater springs, and in fens and swamps (Harding, 1997; Matson, 2002). Thus the pickerel frog may be found along cooler Class III primary headwater stream corridors, and may be a useful secondary amphibian indicator that cold groundwater springs are present in the nearby forested landscape.

A detailed listing of the anurans of Ohio, which includes natural history information, has been compiled by Dr. Timothy Matson, Curator of Vertebrates, Cleveland Museum of National History. (Matson, 2002 revision). The web page for this document is:

http://www.cmnh.org/collections/vertzoo/frogs/frogs.html



Picture showing effects of coal ash water on development of tadpoles. Similar effects would be expected on salamander larvae. Photo by:
http://www.parcplace.org/documents/GeneralHerpInfo/threats_to_amphibians_and_reptiles.htm

Table 7. List of anuran species observed from primary headwater streams in Ohio during 2000 survey. Tadpoles not identified to species, but listed to show reproductive use of stream.

Site #	Species	County	Date (m/d/y)	PHWH Class
CD-00-005	Frog-tadpole	Union	5-18-00	Class II, mod
CD-00-034	Frog-tadpole	Delaware	5-19-00	Class II, mod
SW-00-006	bullfrog	Warren	8-2-00	Class III
SW-00-009	spring peeper	Butler	8-9-00	Class II
SW-00-016	spring peeper	Butler	8-9-00	Class II, mod
SW-00-018	spring peeper	Butler	8-16-00	Class I
SW-00-036	Frog-tadpole	Warren	8-3-00	Class II
NE-00-008	Frog-tadpole	Geauga	6-9-00	Class II
NW-00-007	green frog	Fulton	7-13-00	Class II, mod
NW-00-019	Frog-tadpole	Wood	7-13-00	Class II, mod
NW-00-035	Frog-tadpole	Wood	7-14-00	Class II, mod

Acnowledgment: This report was authored by Robert D. Davic, Ph.D., Ohio EPA, Division of Surface Water, Northeast District Office. Questions and comments should be directed to him at (330) 963-1132 or at: robert.davic@ epa.state.oh.us

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Appendices

Photo Appendix

Some additional photos and range maps for Ohio salamanders. These were obtained from various internet web sites.

Photo by: Robert Rold: Northern spring salamander
(Gyrinophilus porphyriticus porphyriticus)

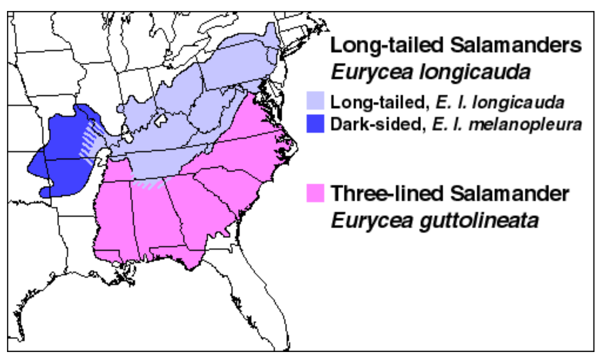
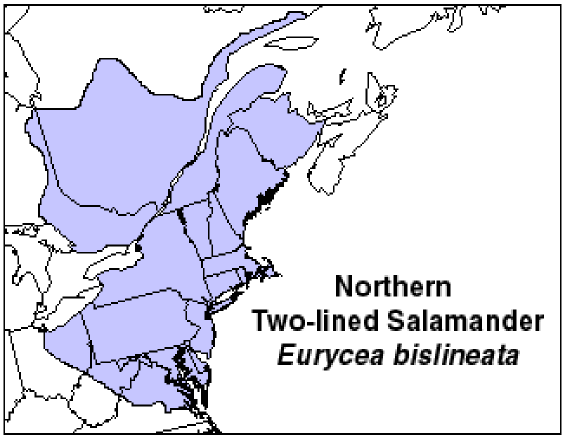
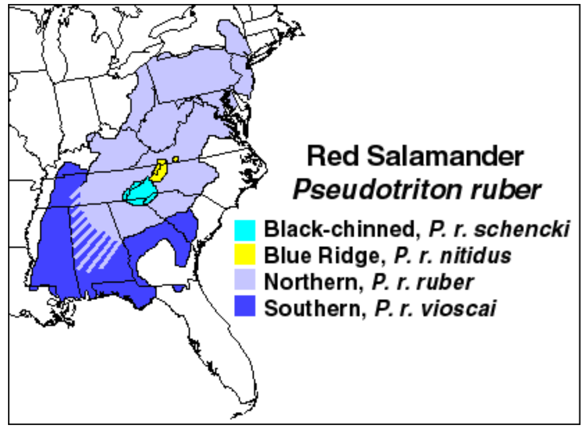
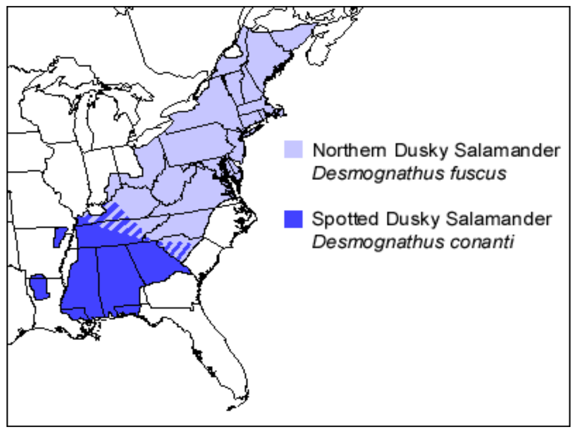
 

Photo by: Robert Rold Photography
Longtail salamander adult *(Eurycea longicauda longicauda)*

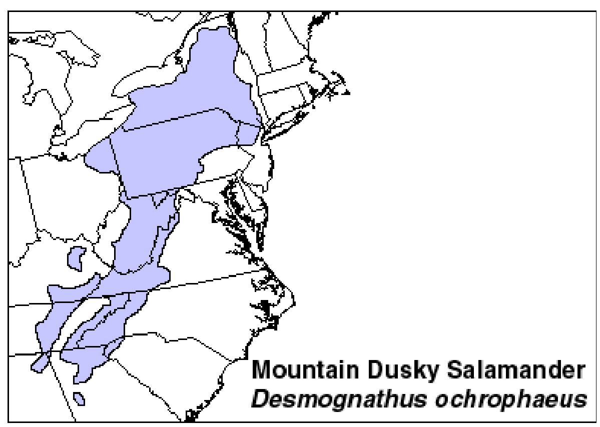
Distributional maps of selected species of salamanders found in Ohio primary headwater streams. All maps from UGSG internet site: http://www.npwrc.usgs.gov/narcam/idguide/index.htm#pig







Desmognathus fuscus fuscus, Photo from: http://www.ohiokids.org/ohc/nature/animals/reptile/dsalamander.html



Desmognathus ochrophaeus (common dorsal pattern in NE Ohio)
Photo credit: S. G. Tilley, J.D. Willson
http://www.bio.davidson.edu/Biology/herpcons/Herps_of_NC/salamanders/desoch.html

Photo by: http://www.snakesandfrogs.com/scra/salamanders/images/s2lined.jpg
Southern two-lined salamander *(Eurycea cirrigera)*

Photo by: Robert Rold Photography. Egg mass on underside of rock for southern two-lined salamander *(Eurycea cirrigera)*

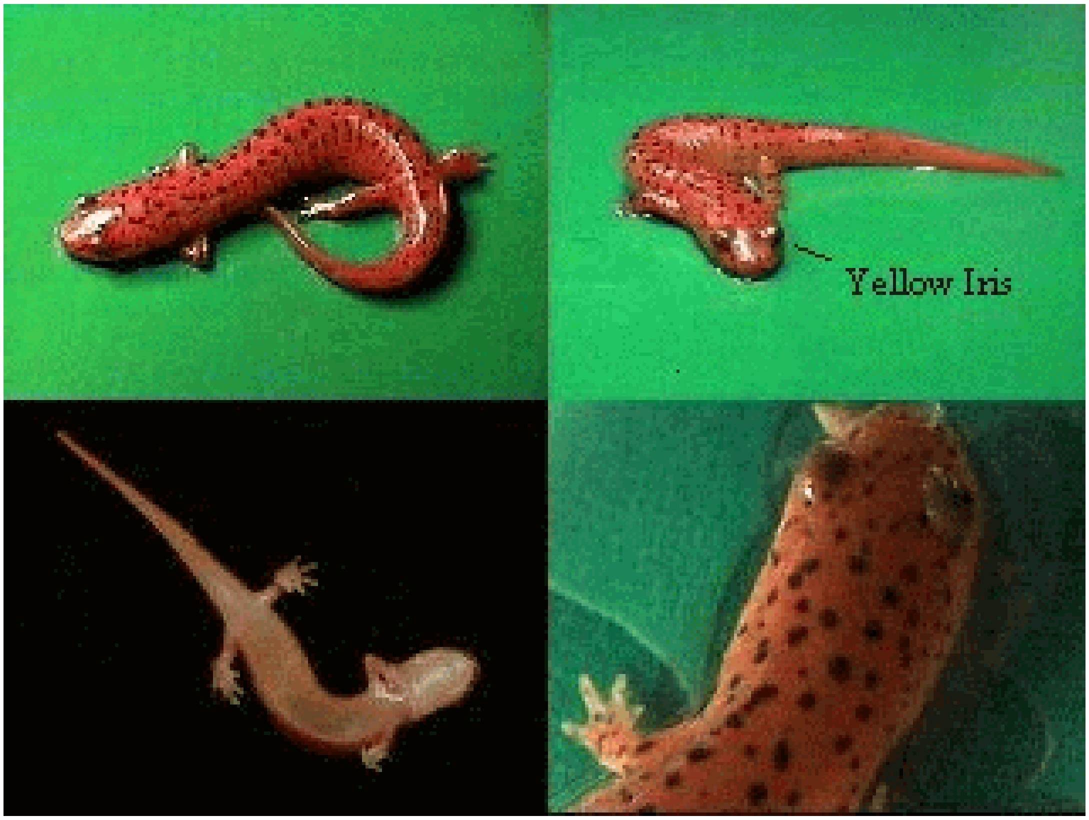


Photo by: http://www.snakesandfrogs.com/scra/salamanders/noreds.htm
northern red salamander; a young adult *(Pseudotriton ruber ruber)*

Photo by: http://biodiversity.wku.edu/salamanders/
kentucky spring salamander (transformed and larva)

Photo by: http://www.nsm.iup.edu/pha/photos/salamanders/mud.html
eastern mud salamander larvae *(Pseudotriton montanus montanus)*

Photo By: http://www.nsm.iup.edu/pha/photos/salamanders/spring.html
northern spring salamander

Appendix Table 1. Location of primary headwater streams in Ohio where amphibians (frogs, salamanders) and fish were collected during 1999 to 2001 surveys. X = taxa present, A = adult or juvenile, L = larvae. A list of fish species is provided in Appendix Table 2. Anurans were not identified to species. Streams where no vertebrates were observed are not included in this table.

County /Site	Latitude	Longitude	Date	ANURANS (FROGS)	SALAMANDER SPECIES	*E. bislineata*	*E. longicauda*	Ambystoma sp.	*D. fuscus*	*D. ochrophaeus*	*P. ruber*	*G. porphyriticus*	*P. cinereus*	*P. richmondi*	FISH SPECIES PRESENT
Delaware CD-00-004	*40.14007*	*-83.0114*	*17-May-2000*		*X*	*A*									*X*
Union CD-00-009	*40.2144*	*-83.4343*	*17-May-2000*		*X*			*L*							
Union CD-00-014	*40.1152*	*-83.1963*	*17-May-2000*		*X*			*L*							
Delaware CD-00-016	*40.21333*	*-83.037*	*18-May-2000*		*X*	*A*									*X*
Delaware CD-00-018	*40.14583*	*-82.90563*	*17-May-2000*	*X*											
Delaware CD-00-026	*40.2791*	*-82.9364*	*19-May-2000*		*X*	*L*									*X*
Delaware CD-00-028	*40.1754*	*-83.03239*	*17-May-2000*	*X*											
Delaware CD-00-034	*40.28157*	*-83.0365*	*19-May-2000*	*X*											
Delaware CD-00-044	*40.1589*	*-82.9941*	*17-May-2000*	*X*											
Union CD-00-045	*40.48094*	*-83.40336*	*18-May-2000*	*X*											*X*
Union CD-00-046	*40.4836*	*-83.3844*	*18-May-2000*	*X*											*X*
Delaware CD-99-001	*40.14714*	*-83.03039*	*15-Jun-1999*		*X*	*L*									
Delaware CD-99-002	*40.0879*	*-82.7776*	*08-Jul-1999*												*X*
Medina NE-00-001	*41.06809*	*-82.16265*	*8-Jun-2000*	*X*											*X*
Medina NE-00-003	*41.07684*	*-81.86655*	*16-Jun-2000*	*X*											
Medina NE-00-005	*41.00275*	*-81.787*	*16-Jun-2000*		*X*	*L*									*X*
Medina NE-00-006	*41.01628*	*-82.12047*	*7-Aug-2000*	*X*											
Geauga NE-00-010	*41.71443*	*-81.0293*	*15-Aug-2000*		*X*	*L*									*X*
Geauga NE-00-014	*41.42623*	*-81.1437*	*9-Jun-2000*	*X*											

County /Site	Latitude	Longitude	Date	ANURANS (FROGS)	SALAMANDER SPECIES	*E. bislineata*	*E. longicauda*	*Ambystoma* sp.	*D. fuscus*	*D. ochrophaeus*	*P. ruber*	*G. porphyriticus*	*P. cinereus*	*P. richmondi*	FISH SPECIES PRESENT
Geauga NE-00-025	*41.53737*	*-81.1604*	*27-Jul-2000*		*X*	*L*									*X*
Medina NE-00-038	*41.27472*	*-81.95574*	*8-Aug-2000*	*X*											
Geauga NE-00-039	*41.36762*	*-81.2898*	*9-Jun-2000*		*X*	*L, A*									
Geauga NE-00-045	*41.70375*	*-81.0415*	*15-Aug-2000*		*X*	*L*									
Geauga NE-00-047	*41.61614*	*-81.28233*	*17-Aug-2000*		*X*	*L*									*X*
Geauga NE-00-051	*41.45745*	*-81.3293*	*12-Apr-2000*		*X*	*L, A*				*A*	*L*				*X*
Summit NE-99-001	*41.30908*	*-81.45307*	*18-Feb-1999*		*X*	*L, A*									*X*
Summit NE-99-003	*41.34191*	*-81.48117*	*18-Feb-1999*		*X*	*L*									
Summit NE-99-008	*41.25738*	*-81.57761*	*5-May-1999*		*X*	*L*									*X*
Geauga NE-99-010	*41.55327*	*-81.23708*	*12-May-1999*		*X*	*L*					*L*				
Summit NE-99-011	*41.25836*	*-81.57931*	*18-May-1999*		*X*	*L*									
Summit NE-99-021	*41.25716*	*-81.57511*	*10-Aug-1999*		*X*	*L*									
Summit NE-99-024	*41.25588*	*-81.57689*	*11-Aug-1999*		*X*	*L*									
Summit NE-99-033	*41.24295*	*-81.5623*	*19-Aug-1999*		*X*	*L*									
Hocking SE-00-003	*39.49993*	*-82.5889*	*28-Jun-2000*		*X*	*L*									
Hocking SE-00-004	*39.8871*	*-82.7242*	*5-Jul-2000*	*X*	*X*	*L*									*X*
Athens SE-00-005	*39.41485*	*-81.8613*	*7-Jul-2000*	*X*	*X*	*L, A*									*X*
Athens SE-00-008	*39.43333*	*-82.0394*	*7-Jul-2000*		*X*	*L*									
Hocking SE-00-009	*39.53586*	*-82.39107*	*29-Jun-2000*	*X*											
Athens SE-00-011	*39.40388*	*-82.0367*	*20-Jul-2000*		*X*	*L*									
Athens SE-00-014	*39.27391*	*-81.9769*	*20-Jul-2000*		*X*	*L*									

County /Site	Latitude	Longitude	Date	ANURANS (FROGS)	SALAMANDER SPECIES	*E. bislineata*	*E. longicauda*	*Ambystoma* sp.	*D. fuscus*	*D. ochrophaeus*	*P. ruber*	*G. porphyriticus*	*P. cinereus*	*P. richmondi*	FISH SPECIES PRESENT
Hocking SE-00-015	39.514283	-82.28622	29-Jun-2000	X											
Hocking SE-00-016	39.392256	-82.42178	5-Jul-2000	X											
Athens SE-00-019	39.368383	-82.16842	7-Jul-2000	X											
Athens SE-00-023	39.29325	-81.9769	18-Jul-2000	X	X	L									X
Athens SE-00-024	39.245016	-81.8041	13-Jul-2000	X	X	L									
Hocking SE-00-025	39.515033	-82.6785	29-Jun-2000		X	L			A						X
Athens SE-00-028	39.200466	-81.9003	13-Jul-2000		X	L									
Hocking SE-00-030	39.461947	-82.5818	28-Jun-2000		X	L,A			A						
Athens SE-00-037	39.221416	-82.1051	13-Jul-2000		X	L									
Athens SE-00-038	39.23865	-81.7399	13-Jul-2000		X	L									X
Athens SE-00-039	39.5284	-82.073	7-Jul-2000		X	L									
Hocking SE-00-040	39.55286	-82.4086	29-Jun-2000		X	L									X
Athens SE-00-041	39.25415	-81.9664	3-Aug-2000		X	L									X
Hocking SE-00-043	39.578683	-82.5633	5-Jul-2000		X	L									
Athens SE-00-045	39.42345	-82.25	20-Jul-2000	X	X	L									
Hocking SE-00-046	39.5224	-82.3009	29-Jun-2000		X	L,A									
Athens SE-00-050	39.41485	-81.86128	3-Aug-2000	X											X
Adams SE-99-001	38.96666	-83.36	14-Jul-1999		X	L									
Hocking SE-99-002	39.447	-82.71339	28-Jul-1999		X	L									
Hocking SE-99-003	39.46333	-82.68628	3-Aug-1999		X	L			A						
Hocking SE-99-004	39.450783	-82.5831	10-Aug-1999		X	L			A		L				

County /Site	Latitude	Longitude	Date	ANURANS (FROGS)	SALAMANDER SPECIES	*E. bislineata*	*E. longicauda*	Ambystoma sp.	*D. fuscus*	*D. ochrophaeus*	*P. ruber*	*G. porphyriticus*	*P. cinereus*	*P. richmondi*	FISH SPECIES PRESENT
Hocking *SE-99-005*	*39.453888*	*-82.57361*	*10-Aug-1999*		*X*	*L,A*			*A*						*X*
Noble *SE-99-006*	*39.724722*	*-81.5875*	*7-Oct-1999*		*X*	*L*									
Brown *SE-99-007*	*39.00778*	*-83.67806*	*20-Aug-1999*		*X*	*L*									
Athens *SE-99-008*	*39.29833*	*-82.10361*	*07-Oct-1999*		*X*				*A*				*A*		
Warren *SW-00-006*	*39.560791*	*-84.248278*	*2-Aug-2000*	*X*	*X*	*L,A*									*X*
Butler *SW-00-009*	*39.551302*	*-84.601619*	*9-Aug-2000*	*X*											
Butler *SW-00-010*	*39.376125*	*-84.8071*	*16-Aug-2000*		*X*	*L,A*									*X*
Butler *SW-00-016*	*39.559947*	*-84.807886*	*9-Aug-2000*	*X*											*X*
Butler *SW-00-018*	*39.405636*	*-84.743514*	*16-Aug-2000*	*X*											
Butler *SW-00-019*	*39.309202*	*-84.5622*	*12-Sep-2000*		*X*	*L,A*									*X*
Warren *SW-00-021*	*39.376441*	*-84.0522*	*20-Jul-2000*		*X*	*L,A*	*A*	*L*							
Butler *SW-00-029*	*39.374119*	*-84.6123*	*22-Aug-2000*		*X*	*A*									*X*
Warren *SW-00-036*	*39.305794*	*-84.130214*	*3-Aug-2000*	*X*											*X*
Warren *Sw-00-045*	*39.320880*	*-84.071378*	*3-Aug-2000*	*X*											*X*
Warren *SW-00-046*	*39.531505*	*-84.259142*	*7-Aug-2000*		*X*	*L,A*									
Butler *SW-00-049*	*39.548377*	*-84.674803*	*30-Aug-2000*		*X*		*A*								
Preble *SW-00-052*	*39.708152*	*-84.5265*	*24-Aug-2000*		*X*	*L,A*									
Montgomery *SW-99-001*	*39.87377*	*-84.29507*	*23-Sep-1999*		*X*	*L*							*A*		
Warren *SW-99-002*	*39.548561*	*-84.98496*	*14-Oct-1999*		*X*	*L,A*	*A*							*X*	
Fulton *NW-00-002*	*41.67643*	*-83.9973*	*13-Jul-2000*	*X*											
Fulton *NW-00-004*	*41.66097*	*-83.99682*	*13-Jul-2000*	*X*											
Fulton *NW-00-007*	*41.61775*	*-83.97217*	*13-Jul-2000*	*X*											*X*
Wood	*41.29934*	*-83.87051*	*13-Jul-2000*	*X*											*X*

County /Site	Latitude	Longitude	Date	ANURANS (FROGS)	SALAMANDER SPECIES	*E. bislineata*	*E. longicauda*	Ambystoma sp.	*D. fuscus*	*D. ochrophaeus*	*P. ruber*	*G. porphyriticus*	*P. cinereus*	*P. richmondi*	FISH SPECIES PRESENT
NW-00-019															
Wood	*41.17902*	*-83.47362*	*14-Jul-2000*	*X*											
NW-00-035															
Portage	*West Br.*		*21-Nov-2000*		*X*	*L*			*L, A*						
RDD-001	*State Park*														
Mahoning	*Lowellville*		*13-Nov-1999*		*X*	*L, A*									
RDD-002															
Columbiana	*Cogentrix*		*19-Apr-2000*		*X*	*L, A*			*L, A*			*L*			
RDD-003	*trib*														
Summit	*Ice Box*		*25-Sep-2001*		*X*	*A*			*L, A*		*L*		*A*		
RDD-004	*Cave, CVNRA*														

Appendix Table 2. List of fish species collected during qualitative surveys of primary headwater streams in Ohio during 1999 and 2001 surveys. All fish were collected using dip-nets.

Site #	County	Date	Creek Chub	Bluntnose Minnow	Blacknose Dace	Stoneroller	Redside Dace	Rainbow Darter	Johnny Darter	Fantail Darter	Greenside Darter	Orangethroat Darter	Bluegill Sunfish	Green Sunfish	Largemouth Bass	Smallmouth Bass	White Sucker	Mottled Sculpin	Native Brook Trout	Rainbow Trout	Goldfish	Mudminnow
CD-00-004	Delaware	17-May-2000	X																			
CD-00-016	Delaware	18-May-2000		X		X																
CD-00-019	Union	17-May-2000						X				X										
CD-00-026	Delaware	19-May-2000											X									
CD-00-045	Union	18-May-2000		X																		
CD-00-046	Union	18-May-2000		X																		
NE-00-001	Medina	8-Jun-2000											X									
NE-00-005	Medina	16-Jun-2000	X																			
NE-00-010	Geauga	15-Aug-2000	X																			
NE-00-025	Geauga	27-Jul-2000			X																	
NE-00-036	Geauga	28-Sep-2000			X																	
NE-00-047	Geauga	17-Aug-2000						X		X										X		
NE-00-051	Geauga	12-Apr-2000																	X			
NE-99-001	Summit	18-Feb-1999	X		X																	
NE-99-008	Summit	5-May-1999	X		X																	
SE-00-004	Hocking	5-Jul-2000	X		X			X														
SE-00-005	Athens	7-Jul-2000	X																			
SE-00-022	Hocking	29-Jun-2000	X											X				X				
SE-00-023	Athens	18-Jul-2000	X					X		X												
SE-00-025	Hocking	29-Jun-2000	X																			
SE-00-038	Athens	13-Jul-2000	X		X																	
SE-00-040	Hocking	29-Jun-2000	X																			
SE-00-041	Athens	3-Aug-2000	X																			
SE-00-047	Hocking	5-Jul-2000	X																			
SE-00-050	Athens	3-Aug-2000	X																			
SE-99-005	Hocking	10-Aug-1999	X		X		X		X									X				
SW-00-006	Warren	2-Aug-2000	X																			
SW-00-010	Butler	16-Aug-2000	X								X											
SW-00-019	Butler	12-Sep-2000	X	X		X		X									X					
SW-00-025	Butler	3-Aug-2000	X																			
SW-00-029	Butler	22-Aug-2000		X							X											
SW-00-032	Butler	15-Aug-2000	X																			
SW-00-041	Warren	2-Aug-2000	X																			
SW-00-052	Preble	24-Aug-2000	X					X			X											
NW-00-005	Fulton	12-Jul-2000		X												X						
NW-00-007	Fulton	13-Jul-2000		X																		
NW-00-009	Wood	13-Jul-2000	X														X					
NW-00-011	Fulton	12-Jul-2000		X																		
NW-00-015	Wood	14-Jul-2000																				X
NW-00-019	Wood	13-Jul-2000		X					X													
NW-00-021	Fulton	12-Jul-2000		X																	X	
NW-00-025	Wood	14-Jul-2000	X	X					X													
NW-00-033	Fulton	13-Jul-2000		X																		
NW-00-037	Wood	14-Jul-2000		X																		