

THE FOUR-TOED SALAMANDER (*HEMIDACTYLIUM SCUTATUM*) IN INDIANA: PAST AND PRESENT

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ABSTRACT. Currently listed as an endangered species by the Indiana Department of Natural Resources, the four-toed salamander, *Hemidactylum scutatum*, is found in widely separated populations at sites with specialized habitat conditions necessary for its reproduction. Its historical distribution in Indiana includes the northern two-thirds of the state. However, until recently, records had been few and largely limited to northern Indiana. From 2003 through 2010, we conducted surveys of potential sites for the salamander throughout the state and report the discovery of several new populations, some from counties where the salamander had not been previously reported. We summarize certain aspects of the natural history of this salamander, review historical records, report new records, list dates when nesting females with eggs were found, discuss nest sites chosen, and annotate where voucher specimens or photo vouchers are known to exist. In addition, we introduce an updated statewide distribution map and discuss relative abundance of the species and its conservation status in Indiana.

Keywords: County records, egg dates, *Hemidactylum scutatum*, Indiana, nesting locations, statewide distribution

Four-toed salamanders were first described by Coenraad Jacob Temminck and Hermann Schlegel in 1838 from a specimen collected near Nashville, Davidson County, Tennessee (Tilley et al. 2008; Adler 1989; Neill 1963). In the mid-1880s, these salamanders were discovered in Indiana near Brookville, in Franklin County (Hay 1886; Hughes 1886). Their distribution in eastern North America is broad, from Nova Scotia westward to Minnesota, and from northern Florida westward to Louisiana and Oklahoma (Petranka 1998; Harris 2005). Their distribution is most contiguous in the eastern and northern portions of their range, while in the southern and western parts of the range, populations are often widely separated from one another. The spotty distribution can be explained as being that of a boreal relict (Smith 1957; Thurow 1997; Harris 2005). This scenario would have the salamander pushed south by periods of glaciation only to move back northward as the ice sheets receded. After a northward expansion under favorable conditions, later periods of warmer and drier climate brought habitat changes that pushed it into small pockets of suitable refugia.

SOME ASPECTS OF LIFE HISTORY AND BREEDING HABITAT

The four-toed salamander (cover photo & Fig. 1) is Indiana's smallest salamander with an adult total length from six to nine centimeters. Generally, these amphibians live much of their adult lives in forested uplands where they can be found under cover materials such as leaf litter, logs and rocks (Bishop 1941; Minton 2001; Harris 2005).

Four-toed salamander females deposit eggs terrestrially, usually within a few centimeters above the water line in thick clumps of moss where wicking of water into the nesting materials helps moisten the eggs (Dunn 1926, Bishop 1941). Moss clumps are often at the bases of trees, on fallen logs and limbs, on hummocks of herbaceous vegetation (Fig. 2), or growing on soil or rock, but always adjacent to or surrounded by water (Bishop 1941). Sites chosen for nesting are often immediately adjacent to upland habitat, giving the salamanders direct terrestrial access to nesting sites, but others are well out into wetlands where the salamanders must swim to reach the nesting sites (Blanchard 1934a). In addition to mosses,



Figure 1.—Ventral view of adult *Hemidactylium scutatum*. It is the only salamander in North America having a white belly with scattered black spots. This individual is a gravid female. Cass County, IN. 14 April 2006.

other nesting materials sometimes used include sedge and grass clumps within the dead leaves from the previous year (Blanchard 1923; Bishop 1941), cavities within rotten logs standing in water (Blanchard 1922), and clumps of leaf litter adjacent to water (Breitenbach 1982; Thurow 1997).

A typical clutch (Fig. 3) ranges from 15 to 50 eggs, although there can be larger numbers (Petranka 1998; Harris 2005). They may also deposit their eggs in communal nests where the total complement of eggs is the result of two or more females. In such cases, only one female typically remains with the eggs (Breitenbach 1982). Females usually attend eggs until near the time of hatching (Blanchard 1934b). Eggs hatch in five to eight weeks (Petranka 1998). In all materials used, the eggs are positioned at steep angles above the water so that, upon hatching, the larvae can wiggle downward into the water where they spend an aquatic larval

period of three to six weeks (Petranka 1998; Harris 2005).

POPULATION SURVEYS

Due to its apparent rarity and the infrequency of new reports, this species is currently state-listed as an endangered species. Based on historical records, four-toed salamanders have always been one of the least frequently observed salamanders in Indiana (Minton 1972, 2001). Although several of the earliest records were from the central part of the state (Hay 1892), later records (Minton 1972) were more likely to be from northern Indiana. However, for decades there had been few new records. Forest fragmentation, artificial drainage of wetlands through tiling and ditching, and other man-made disturbances have caused reductions in four-toed salamander habitats in Indiana, likely contributing to the paucity of records. Some historical sites have been destroyed by such disturbances.



Figure 2.—Nest site at bottom left of photo in *Thuidium* moss on side of *Osmunda* fern hummock in red maple swamp. Kosciusko County, IN. 2 May 2008.

Beginning in the spring of 2003 and continuing through the spring of 2010, we conducted surveys throughout much of Indiana (Fig. 4) for the four-toed salamander. The first surveys were aimed at obtaining records from counties where it had not been reported. Later, efforts were expanded to search in counties where they had been reported, but where it had been decades since the last report. Other searches were made in an attempt to obtain solid

evidence of their occurrence in counties where there had been reports unsupported by photographs or voucher specimens. Occasionally, searches were made in counties where populations were known to be extant, but at locations not previously reported in those counties. Searches focused on looking in habitats that had high potential for suitable nesting sites (potential nesting areas, or PNAs). Suitable known natural areas were among the first sites



Figure 3.—Female *Hemidactylium scutatum* with eggs in root zone of *Thuidium* moss. Lagrange County, IN. 10 May 2009.

to be explored. Other sites were selected by examining topographic maps, soil surveys, and aerial photography.

We conducted surveys in March, April, and May when females were at nesting sites. Nesting females are concentrated in specific habitat niches, and are thus the easiest four-toed salamanders to find. In addition, finding nesting sites is important to conservation opportunities since nesting sites are critical for sustaining a population, and conservation efforts need to include the wetlands so critical to their survival. Searches usually lasted between one and two hours, although occasionally longer. We sometimes scouted PNAs in advance during late winter or early spring. At this time of year, mosses are often in their prime and easily visible since associated vegetation is dormant and does not obscure the terrain. For these reasons, the micro-topography of moss and sedge clumps and their relationship to available water sources is more easily determined.

RESULTS

We examined 90 sites in 45 counties (Fig. 4). Of these, 52 were judged to have suitable or marginally suitable habitat for nesting. Four-toed salamanders were found at 15 of these sites. We obtained new county records in seven counties: Allen, Fountain, Jefferson, Martin, Noble, Owen, and Parke. Our new records from Jefferson, Martin, and Owen counties have been previously reported (Casebere et al. 2004); the records from Allen, Fountain, Noble, and Parke counties are being reported here for the first time. We were successful in finding four-toed salamanders in Wabash County (first report since the late 1800s), Marshall County (first report since 1906), and Cass County (first report since 1930). In addition, we documented the salamanders in St. Joseph County where an earlier report (Minton et al. 1983) was undocumented.

During the first year of our study, one salamander from each of the three new sites discovered was collected as a voucher specimen,

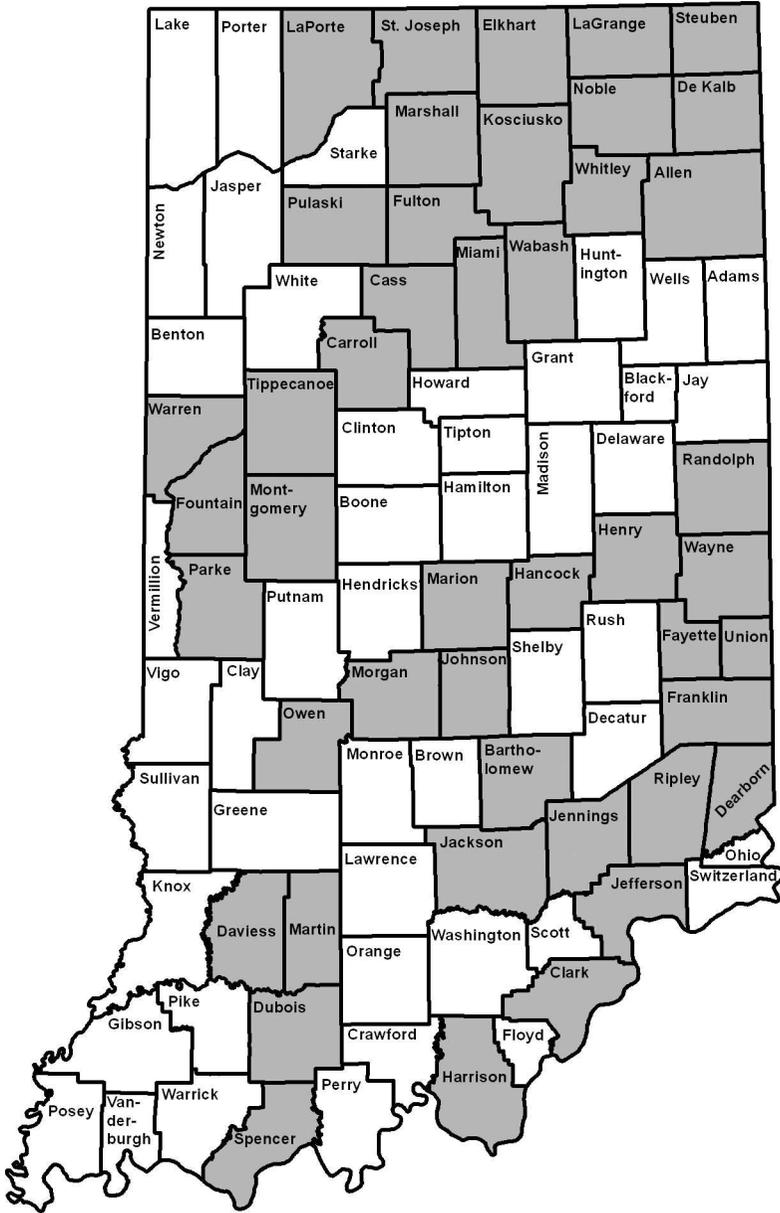


Figure 4.—Shading indicates 45 counties where 90 sites were surveyed for *Hemidactylum scutatum* (2003–2010).

and all three are deposited at the University of Michigan Museum of Zoology (Table 1). During the remaining seven years of our study, photo vouchers were taken instead of voucher specimens. All are on file at the Illinois Natural History Survey (Table 2). For a range map of the species in Indiana showing documented county records, see Figure 5.

We did not attempt to count the number of eggs in each clutch. We saw a few nests that may have been communal nests, but none seemed large enough to have been the product of more than two females. We have attempted to locate all voucher specimens and photo vouchers of the four-toed salamander from Indiana that are deposited in recognized

Table 1.—Four-toed salamander (*Hemidactylium scutatum*) voucher specimens from Indiana.

With the exception of three specimens collected by the authors, specimens were not examined. ANSP=The Philadelphia Academy of Natural Sciences, Philadelphia, PA; AMNH=American Museum of Natural History, New York, NY; BSU=Ball State University, Muncie, IN; CS=Chicago Academy of Sciences, Chicago, IL; SJCAM=St. Joseph College, Rensselaer, IN; FMNH=Field Museum of Natural History, Chicago, IL; UMMZ=University of Michigan Museum of Zoology, Ann Arbor, MI; USNM=Smithsonian National Museum of Natural History, Washington, DC

County	Date	Voucher specimens	Institution and collection number	Collector
Cass	20-Apr-1930	1	CS 9010	H.Gloyd
Franklin	c.1895	5	ANSP 10484-88	E.Hughes
Henry	19-Oct-1969	1	BSU (no number)	Unknown
Henry	17-Apr-1971	1	UMMZ 130881	J.List/S.Minton
Henry	1-Apr-1972	1	BSU; BSTC 822	Lank/J.List
Henry	7-Apr-1972	2	BSU (no number)	Lank/J.List
Jefferson	12-Apr-2003	1	UMMZ 229817	L.Casebere
Marshall	7-Oct-1906	4	USNM 42601-04	B.Evermann/H.Clark
Martin	8-Apr-2003	1	UMMZ 229816	L.Casebere/ M.Lodato
Morgan	8-Oct-1958	1	AMNH 64397	B.Bechtel
Owen	15-Apr-2003	1	UMMZ 229818	L.Casebere/ M.Lodato
Porter	25-Sep-1938	1	CS 5520	W.Necker/E.Falck
Porter	c.1938	2	CS 5689-90	W.Necker/E.Falck
Porter	16-Oct-1938	2	FMNH 30868-69	E.Falck
Porter	3-Nov-1938	1	FMNH 31521	E.Falck
Porter	28-Mar-1951	1	FMNH 64098	J.LaPointe
Porter	27-Mar-1954	1	UMMZ 110630	S.Minton
Porter	23-Sep-1985	1	FMNH 242268	A.Resetar
Starke	28-Apr-2001	2	SJCAM 249	R.Brodman
Steuben	23-May-1954	1	AMNH 182198	S.Minton

institutions. Table 1 lists the voucher specimens we were able to locate, Table 2 the photo vouchers. As a result of our study, we know that four-toed salamanders are more common in Indiana than previous data indicated. Nonetheless, it is still one of Indiana's least common salamanders, and many of its populations are believed to be small and vulnerable. For these reasons, we have chosen not to provide specific locations for the populations found during this study. This information is recorded in the files of the Indiana Natural Heritage Program, Indiana Department of Natural Resources, Indianapolis, Indiana.

DISCUSSION OF NESTING LOCATIONS AND HABITAT DESCRIPTIONS

Literature indicates that preferred nesting locations are within thick clumps of mosses (Petranka 1998), and our field studies show similar results. Mosses used by the salamanders in this study include nine species. Following the nomenclature of Crum (2004), they are: *Aula-*

comnium palustre, *Brachythecium rivulare*, *Bryhnia novae-angliae*, *Callicladium haldanianum*, *Climacium americanum*, *Isopterygium pulchellum*, *Mnium punctatum*, *Sphagnum spp.*, and *Thuidium delicatulum* (William McKnight, personal communication). By far, *Thuidium delicatulum* was most used, followed by *Sphagnum spp.* We estimate 80% of nests were in *Thuidium* or *Sphagnum*. Sedge hummocks surrounded by water were used for nesting at two sites, one in ephemeral pools in a flatwoods, and another in a groundwater seepage habitat. In one instance, a nest was found within a clump of soggy leaves adjacent to a shallow ditch.

Wetlands used as nesting sites by female salamanders generally fall within three habitat types: 1) ephemeral pools and ponds in flatwoods, 2) depressional ponds and swamps, usually within the context of morainal glacial terrain, and 3) groundwater seepage communities or seep springs. See Appendix I for further discussion of these habitats. Nomenclature for higher plants, including both common and

Table 2.—Four-toed salamander (*Hemidactylium scutatum*) voucher photographs from Indiana.

INHS=Illinois Natural History Survey, KU=University of Kansas Natural History Museum			
County	Date	Institution and Collection No.	Collector
Allen	1-May-2004	INHS 2006a	L.Casebere
Cass	14-Apr-2006	INHS 2009a	N.Engbrecht/L.Casebere
Fountain	15-Apr-2005	INHS 2006c	L.Casebere
Henry	1-Apr-2006	INHS 2006d	K.Jones
Jackson	20-Apr-2001	KU slides 11833-34	V.Meretsky
Jackson	9-Apr-2006	INHS 2009h	L.Casebere/M.Lodato
Jefferson	5-May-2003	INHS 2004 a–b	D.Karns (Hanover College Herp Class)
Kosciusko	2-May-2008	INHS 2009b	L.Casebere/M. Lodato
LaGrange	3-Oct-1974	INHS 2009i	L.Casebere
LaGrange	7-May-2006	INHS 2009g	L.Casebere
LaPorte	22-Apr-2007	INHS 2009c	M.Lodato/L.Casebere
Marshall	27-Mar-2010	INHS 2010a	L.Casebere
Noble	13-Apr-2007	INHS 2009d	L.Casebere
Parke	23-Apr-2004	INHS 2006b	L.Casebere/M.Lodato/ T.Hulvershorn
Ripley	5-Apr-2003	KU slides 11904-05	S.Skilbred
St. Joseph	1-May-2008	INHS 2009e	L.Casebere/M.Lodato
Steuben	7-May-2006	INHS 2009j	L.Casebere
Tippecanoe	4-May-2005	INHS 2007c	K.Arvin
Wabash	20-Apr-2006	INHS 2009f	L.Casebere/J.Sweeten

scientific names, follows the USDA Plants Database (USDA, NRCS 2010).

CONSERVATION STATUS AND PROTECTION ISSUES

Wetlands that provide the specialized nesting requirements for four-toed salamanders are extremely limited in Indiana, and for that reason, populations are widely separated. Although upland forests adjacent to nesting habitats are an essential component of their overall habitat needs, this requirement is more easily met than is the requirement for suitable wetlands. Upland forests are widespread and relatively common, albeit highly fragmented. In addition, the salamanders seem to be less particular about the type and quality of upland habitat away from nesting sites (personal observation).

We know of 27 sites in 21 Indiana counties with extant populations of four-toed salamanders (Fig. 5). Other populations doubtless occur in Indiana, and we hope this report encourages searches for additional colonies. At the fall 2008 meeting of the DNR's Amphibian and Reptile Technical Advisory Committee (TAC), we presented data from our study and suggested that endangered species designation

for this salamander is probably not warranted. A vote by the TAC membership recommended that its status be changed from endangered to that of "special concern," but as of this writing that recommendation has yet to be adopted by the Natural Resources Commission.

A change in its official conservation status from state endangered to special concern must not obscure the fact that this salamander occurs in Indiana only in widely separated populations. In our estimation only a half-dozen populations are locally healthy and secure. Only two areas of Indiana have populations that may be large enough and close enough to each other that regularly occurring dispersal between neighboring populations may happen even on a small scale, and these are in opposite corners of the state. One is in the Indiana Dunes area and on the Valparaiso Moraine, both in Porter and LaPorte counties in northwest Indiana. The other is in the Illinoian till plain flatwoods of southeastern Indiana.

The prospect of additional populations being discovered in Indiana is probably best in the Northern Lakes Natural Region and the Northwestern Morainal Natural Region (Homoya et al. 1985). One area with much potential is on the Valparaiso Moraine in

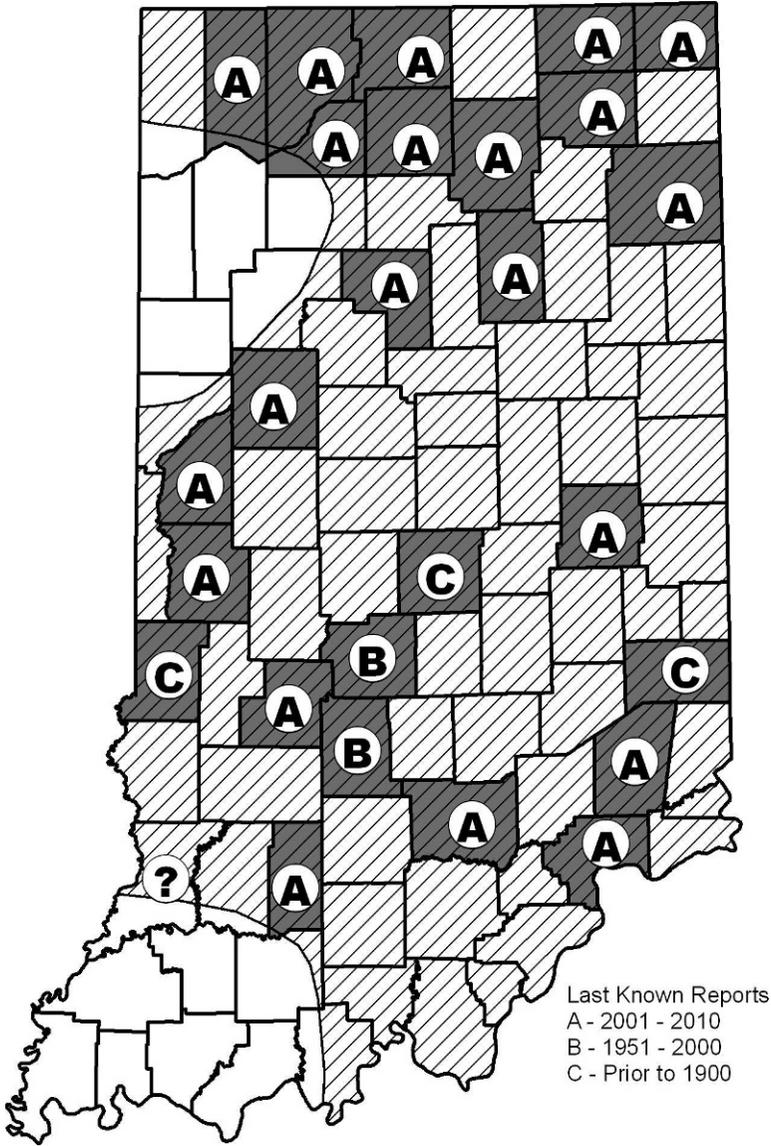


Figure 5.—Crosshatched area represents the presumed range of the four-toed salamander (*Hemidactylium scutatum*) in Indiana based on historical and recent records and on proximity to sites in neighboring states. Shading indicates counties where the species has been reported.

Porter and LaPorte counties, an area containing numerous wetlands within a rolling, glacial landscape. Unfortunately, the wildland/urban interface is rapidly expanding in that area and much woodland and wetland habitat is being lost. More populations, including new county records, are likely to be discovered in the Illinoian till plain flatwoods of southeastern Indiana. Although flatwoods with vernal ponds and pools are relatively common in Indiana's

central till plain, sites with the requisite moss component are largely lacking. Flatwoods in this region of the state may have four-toed salamanders, but it is more likely that this species will be found in groundwater seepage habitats or depressional swamp habitats in areas of glacial moraines.

Regardless of where they exist in Indiana, sites with four-toed salamanders are worth considering for permanent protection through

acquisition by private land trusts or government agencies. In most cases, sites with this salamander have botanical and zoological features that elevate them into an elite caliber of natural area.

For more information regarding land management practices for properties where four-toed salamanders are found, see Appendix II, "Conservation Practices for Landowners."

DISTRIBUTION RECORDS BY COUNTY

The following is a summary of four-toed salamander records in Indiana (in alphabetical order by county name) based on museum records, literature accounts, and our field work during this study. Most of these records are vouchered, either with specimens or by photographs, which are housed in established, curated collections. Un-vouchered records and reports believed to be valid are also referenced. These county accounts include, where appropriate, brief descriptions of natural features of salamander habitat and significant historical narratives on the study of this salamander in Indiana. New county records resulting from this study are also identified.

Allen County.—New county record. On 1 May 2004, Casebere found one nesting female in *Thuidium* moss on a tree root surrounded by shallow water in a depressional swamp forest surrounding a small lake. The swamp had an overstory of red maple (*Acer rubrum*) and silver maple (*Acer saccharinum*), with an understory of spicebush (*Lindera benzoin*), highbush blueberry (*Vaccinium corymbosum*), and common winterberry (*Ilex verticillata*). Photo vouchered (INHS 2006a).

Cass County.—First collected 30 April 1930 by Howard K. Gloyd from a fen community known to naturalists as Peabody Bog, a site that is now destroyed. The specimen is deposited at the Chicago Academy of Sciences (CS 9010).

At a site nearby visited by the senior author and Nate Engbrecht on 14 April 2006, we found a female in the process of laying eggs in *Sphagnum* moss at the base of a shrub. The site is a depressional shrub swamp dominated by common winterberry and set in morainal topography. Photo vouchered (INHS 2009a)

Fountain County.—New county record. On 15 April 2005 Casebere found one nesting female in a mixed-species clump of moss (*Mnium punctatum* and *Brachythecium* sp.) at

the base of a shrub in a seep spring at the bottom of a forested slope near the floodplain of a perennial stream. The site is largely dominated by willows (*Salix* spp.) and dogwoods (*Cornus* spp.) with abundant marsh marigold (*Caltha palustris*) and skunk cabbage (*Symplocarpus foetidus*). Photo vouchered (INHS 2006c).

Franklin County.—The four-toed salamander was first reported in Indiana from Franklin County. Edward Hughes, Curator of Ichthyology and Herpetology for the Brookville Society of Natural History, published on the herpetofauna of the county (Hughes 1886). For an account of this early Indiana natural history organization, see Fichter (1946). At the time of his report, Hughes had not personally observed the salamander in Franklin County: "I have never taken this Salamander in the county, but Mr. E.R. Quick informs me that in one or two locations they are not uncommon." During that same year, Oliver P. Hay published on the amphibians and reptiles of the whole state (Hay 1886). He reported, "The scaly salamander (*Hemidactylum scutatum*) is a rare animal, but has been reported from Franklin County." This is the only locality Hay mentions as having this species.

A few years later, Hay published an updated report on the reptiles and amphibians of the state (Hay 1892). This time, Hay reported records of four-toed salamanders from four counties. Regarding the Brookville area he says, "Mr. Hughes states that it was found in the moss at the roots of trees which stood near ponds. In this moss were also found the eggs. One of Mr. Hughes' pupils found about forty specimens, but did not secure them." This statement is significant because it not only clearly and correctly identifies the unique nesting habits of the four-toed salamander, but it is the first ever description of the eggs and nesting behavior for this species in North America.

We know of four published papers that attribute the first discovery of four-toed salamander eggs in moss to Indiana. The first is from Sherman Bishop (Bishop 1919) where he references Hay (1892) as the source of the information, but makes no mention that it was reported to Hay by Hughes. Another reference connecting the first discovery of eggs in moss to Indiana is that of Frank Blanchard (Blanchard 1923) where he cites Hay's report (Hay 1892)

and credits Hughes with the discovery. Yet another reference is that of E.R. Dunn (Dunn 1926) where he attributes the discovery to Hughes, but incorrectly cites Hughes' 1886 paper as being the source for that information. In fact, Hughes' paper makes no mention of the eggs of this salamander. It is only in Hay's 1892 paper where Hughes' reference to finding the eggs is noted. And finally, Sherman Bishop (1941) makes the same error in reference to Hughes' 1886 paper in regard to the first finding of eggs near Brookville. Bishop may have simply repeated Dunn's error. Collectively, the information in these four references is somewhat confusing, but in final analysis the evidence points to Indiana as the place where four-toed salamander eggs and nesting were first described.

Although Minton (1972, 2001) knew of reports for Franklin County, he was apparently unaware of specimens collected there. We learned that five specimens from the county are in the collection of The Academy of Natural Sciences of Philadelphia (ANSP 10484-88). Other than being identified as from Brookville, Franklin County, Indiana, no specific data on location, habitat, or dates of collection is given. Edward Hughes is listed as the collector.

Henry County.—A number of four-toed salamanders have been reported from this county over the last four decades, all from a single site just over two hectares in size. The site is a depressional swamp surrounded by upland forest and set within a morainal landscape. Woody vegetation in the swamp is largely buttonbush (*Cephalanthus occidentalis*) with some trees, including silver maple, black ash (*Fraxinus nigra*), green ash (*Fraxinus pennsylvanica*), swamp white oak (*Quercus bicolor*) and black willow (*Salix nigra*).

The Ball State University collection in Muncie, Indiana, contains four voucher specimens (Kamal Islam, personal communication). The first of these was collected 19 October 1969, but the collector is unknown, and three additional specimens were collected on two different dates in April 1972 by J.C. List and a Mr. Lank (see Table 1). There is also a specimen at the University of Michigan Museum of Zoology collected 17 April 1971 by Sherman Minton and J.C. List (UMMZ 130881).

Other recent sight records from this locale are 30 April 1978 by Lodato, S. Minton, and T.

Hulvershorn (Lodato photo collection); N. Engbrecht and R. Schmitt on 17 May 2005 (photo record in DNR Wildlife Diversity Section database; Sarabeth Klueh, personnel communication); and K. Jones on 1 April 2006 (Jones 2007), photo vouchered (INHS 2006d).

Jackson County.—The first report for this county is from a seep spring (Meretsky & Pyles 2001) on 20 April 2001. Photo vouchers (KU color slides 11833–834) document this report. The dot indicating its presence in this county in Minton (2001) represents this record, which the publisher added posthumously. Several kilometers from this site, we found four nesting females on 9 April 2006 at another seep spring. The moss at one of the nest sites was *Callicladium haldanianum*. Photo vouchers document this location (INHS 2009h). At both Jackson County seeps, smooth alder (*Alnus serrulata*) is one of the most common shrubs. Typically, it is localized and of uncommon occurrence in Indiana.

Jefferson County.—New county record. The first report from Jefferson County occurred on 13 April 2003 (Casebere et al. 2004). It was found in ephemeral pool habitat in an Illinoian till plain flatwoods. Two nesting females were found in *Thuidium* moss on fallen tree limbs surrounded by water. Vouchered (UMMZ 229817).

A second report for the county on 5 May 2003 by Daryl Karns and a Hanover College herpetology class (Casebere et al. 2004) was also from an Illinoian till plain flatwoods. Photo vouchered (INHS 2004a–b). In this same flatwoods, on 10 April 2008, Casebere, Andrew Hoffman, and Jason Larson found at least 20 nesting females. The most frequently used mosses were *Thuidium* and *Sphagnum*, but *Aulacomnium palustre* growing at the bases of meadowsweet (*Spiraea alba*) was utilized a few times. A few nests were found within sedge clumps (undetermined *Carex* sp.) among the dead sedge leaf material from the previous growing season. One nest was found within a pile of soggy tree leaf litter along the edge of a small ditch. Hoffman (personal communication) reported that a few days later he and Karns found additional nests, some within clumps containing both mosses and leaf litter.

Hoffman (personal communication) also reported that approximately 20 of about 50 nests observed in the Jefferson County flatwoods were concealed within “a *Polytrichum*-

Sphagnum mix located along shallow (presumably manmade) ditches.” Additionally, he reported finding gravid females at these flatwoods sites from early- to mid-March, under both clumps of mosses and fallen logs. He found females with eggs at the same sites as early as mid-March, and as late as mid-May.

Knox County.—Among the earlier reports for the state was one by Gaines (1895) for Knox County. His entire account of this species is as follows: “*Hemidactylum scutatum* (Schlegel). Brown colored, and rough skinned. I have seen small ones, but never any with gill slits and have never seen it in the water. Like *A. punctatum* it has a prehensile tail.” Minton (1972) rejected this report as being “clearly based on the land form of the newt,” which is often brown colored, and which has rough, granular skin. Although Minton may have been correct in his assessment, arguments can be made that Gaines was correct as four-toed salamanders are brown, and their skin tends to be drier than other eastern plethodontid salamanders. Regarding its skin, Hay (1892) states, “Skin of the whole upper surface granulated.” Similarly, Bishop (1941) states: “The entire surface of the body has a finely pitted or granular appearance.” Therefore, it seems plausible that Gaines did find this salamander in Knox County. Unfortunately, he made no mention of the belly color and pattern, which would have helped clinch the identification. Without more conclusive evidence, Gaines’ Knox County report remains questionable. However, an extant population of four-toed salamanders is known from Lawrence County, Illinois (Anton et al. 1998) just across the Wabash River from Knox County, Indiana.

Kosciusko County.—The first record for this county came from Anthony Swinehart, who reported it to the Indiana Natural Heritage Program. It was found on 6 June 1995, and the “specimen was in a peat moss hummock.”

More recently, specimens were found under cover boards set out by personnel from DNR’s Wildlife Diversity Section (Randy Millar, personal communication). The cover boards yielded one individual on 8 September 2004 by Michael VanLaeken, and two individuals on 23 September 2004 by VanLaeken and Millar. On 14 April 2006, the senior author and N. Engbrecht visited a likely looking wetland near the cover board array to look for nesting females. No nesting individuals were found in the many *Thuidium* moss hummocks searched,

however, three juvenile four-toed salamanders were found. The habitat at this location is a red maple swamp surrounded by mixed hardwood forest.

On 2 May 2008, Casebere and Lodato visited the site where Swinehart had earlier reported the salamander. In a red maple swamp with abundant nesting habitat, we found four nests, three with attending females. All of the nests were in *Thuidium* moss. Photo vouchered (INHS 2009b).

LaGrange County.—On 3 October 1974, the senior author found two adult salamanders under a fallen log in a large swamp complex. Photo vouchered (INHS 2009i). In this same swamp on 10 May 2009, the senior author found two nesting females in *Thuidium* moss growing on buttressed tree roots in standing water. Overstory trees included red maple, swamp white oak, black ash, and American elm (*Ulmus americana*).

During 1978, the senior author found juveniles at a second LaGrange County location on several dates including 20 July, 6 August, 2 September, and 5 October. At this site, on 2 May 2008, Casebere, Lodato and Phil Bieberich found four nesting females and one juvenile. All four nests were in *Sphagnum* moss. The habitat at this site is a boggy marsh with many clumps of large, coarse-leaved sedges (*Carex* spp.), wool grass (*Scirpus cyperinus*), and Virginia chain fern (*Woodwardia virginica*). Much of it is open and has no shade for much of the day. Mosses, mostly *Sphagnum*, are abundant. Along the edge of the marsh, tree cover is mostly pin oak (*Quercus palustris*), black gum (*Nyssa sylvatica*), and red maple with much highbush blueberry in the understory. Adjacent to the marsh is upland oak forest. Photo vouchered (INHS 2009g).

LaPorte County.—Ken Mierzwa (2007) reported an adult four-toed salamander from LaPorte County in 1999 while doing wetland inventories. The habitat was described as a forested fen, but few other details are given. Excerpts from his field notebook sent via e-mail to the senior author in 2009 (personal communication) give the date as 14 October 1999. Further information from the notebook states:

South of lake grades into nice graminoid fen, then shrub fen, a little forested fen in S part of wetland. Steep to moderate slopes on three sides (E-S-W), w/large ravines, considerable

seepage in ravines, feeds wetland. In forested fen got a *Hemidactylium scutatum*.

Mierzwa has photos of this salamander in his personal files. The dot indicating its presence in this county in Minton (2001) represents this record which the publisher added posthumously.

On 22 April 2007, we found a nesting female in *Thuidium* moss growing at the base of a tree on the edge of a depressional swamp. Trees in the swamp were mostly red maple with some yellow birch (*Betula alleghaniensis*), and shrubs including highbush blueberry, spicebush, and common winterberry. Photo vouchered (INHS 2009c).

Marion County.—Marion County was one of the four counties from which O.P. Hay (1892) reported this species, with the record attributed to W.P. Hay, and the locality as “Irvington.” This report contains no other information—date of the sighting, specific location, or habitat information. There is no mention of a voucher specimen, and none are known to exist. Due to the expansion of Indianapolis, it is unlikely that this salamander still exists in Marion County.

Marshall County.—In their two-volume report on Lake Maxinkuckee, Evermann and Clark (1920) reported four individuals of this salamander: “These were obtained October 7, 1906 under logs in a dry woodland near the tamarack swamp west of the lake.” They were collected and the specimens are in the U.S. National Museum (USNM 42601-04). The area where these were taken has been destroyed.

Elsewhere in the county on 14 March and 27 March 2010, the senior author found seven individuals in a depressional swamp surrounded by hardwood forest. The swamp was dominated by black ash, red maple, and swamp white oak with buttonbush, highbush blueberry, common winterberry, and swamp rose (*Rosa palustris*) in the understory. Five of the salamanders were gravid females; two eluded capture. There were no eggs present on these early dates, but all seven were in *Thuidium* moss adjacent to water in ideal position for ovipositing. Photo vouchered (INHS 2010a).

Martin County.—New county record. On 8 April 2003, we found ten nesting females (Casebere et al. 2004) in a seep spring that emerges from the base of a sandstone cliff. Nesting sites were mostly in *Thuidium* moss, or in mixed clumps of *Thuidium* with other

mosses. The mossy nesting sites were on fallen limbs or at the bases of shrubs or trees, either standing next to or surrounded by water. Some of the sites were next to slowly moving water in seepages, or quiet pools of water. Parts of this wetland are shaded with overstory trees, whereas some less shaded parts are dominated by shrubs or herbaceous vegetation. There is both upland mixed forest and creek bottomland forest adjacent to the seep. This site is the only known extant Indiana population in an unglaciated part of the state. Vouchered (UMMZ 229816).

Monroe County.—In his account of this salamander, Minton (1972, 2001) mentioned that Shockley had seen several specimens from a Monroe County bog that has since been inundated by Monroe Reservoir. However, in neither edition of his monograph did Minton plot the locality for Monroe County on his distribution map. Perhaps the lack of a voucher specimen or photograph was behind the decision not to plot the locality. To have mentioned it in his monograph, Minton must have believed the report was credible. The site in Monroe County was known as Baxter’s Bog, and it was the focus of several studies by Indiana University faculty and students. A master’s degree thesis by Claude Davis (1951) mentions several salamanders from the site, some of which Clarence Shockley had identified as four-toed salamanders. Baxter’s Bog was a groundwater seep spring habitat with smooth alder among the dominant shrubs. Therefore, from a plant community standpoint, it was probably similar to the seep spring habitats in Jackson County that are known to have extant populations of smooth alder and four-toed salamanders. Baxter’s Bog differed from the Jackson County salamander sites in that it was situated in an unglaciated area of the state.

The authors are aware of recent reports of this salamander for Monroe County, but we know of no specimens or photographs to substantiate the reports.

Morgan County.—Minton (1972) reported that Bechtel collected this salamander at Bradford Woods in Morgan County in 1959. One individual was found in a trench excavated to provide utilities to the Bradford Woods complex. This trench essentially became a large pitfall trap where Bechtel also found many frogs, snakes, and other species of salamanders.

In 2004, we visited parts of Bradford Woods with staff member James Rogers. The entrance road to the property crosses through a relatively small, disturbed fen, and some underground utilities are buried near the road. Based on our experience, the site does not appear to be prime habitat for four-toed salamanders. Thick mosses for nesting sites are lacking, and streams and pools of water for the larvae to live in are only minimally available. However, it appears to be the only possible location where the salamander could find anything approaching suitable nesting habitat. Searches in the fen during the nesting season were unsuccessful. We searched another Morgan County seep spring, this one with luxuriant moss habitat, but the salamander was not found.

The Morgan County specimen reported by Dr. Bechtel is the only vouchered collection of the salamander from the southern half of Indiana in the whole of the 20th century (1901–2000). Vouchered by Bechtel (AMNH 64397).

Noble County.—New county record. On 13 April 2007, the senior author found the salamander in a depressional swamp with an overstory of red maple and yellow birch, and an understory of highbush blueberry with lesser amounts of common winterberry and button-bush. Three nests were found, two with attending females. All nests were in *Sphagnum*. Upland mixed hardwood forest of oak and hickory (*Carya* spp.) surrounds the wetland. Photo vouchered (INHS 2009d).

Owen County.—New county record. On 15 April 2003, we found this salamander in a seep spring (Casebere et al. 2004) adjacent to upland forest of mixed hardwoods. An unattended nest of eggs was found in a clump of *Thuidium* moss next to a seepage rivulet with an adult salamander located several centimeters away within the same moss mat. Elsewhere, two nesting females were found, both utilizing *Thuidium* moss on tree roots, also next to a slow-moving rivulet. At this site, some areas are dominated by overstory tree cover, but much of the habitat is dominated by shrubs, mostly dogwoods and willows. Skunk cabbage and marsh marigold are abundant here. Vouchered (UMMZ 229818).

Parke County.—New county record. F. John Vernberg (1952) included the four-toed among the salamanders he collected in Parke and Tippecanoe counties. It is unclear whether he

was attributing its presence to one or both of these counties. No information was supplied in his paper that confirms the identity as the four-toed salamander. Minton (1972, 2001) was aware of Vernberg's paper since he refers to it in his discussion of other species of salamanders. However, he did not mention Vernberg's report of four-toed salamanders from these two counties, and he did not plot localities in these counties on his map. It is clear that Minton had doubts about these reports. In correspondence with the senior author (personal communication), Vernberg could not be certain that he had seen four-toed salamanders in Indiana, and he could not remember if voucher specimens had been collected.

Recently, four-toed salamanders have been confirmed from seep spring habitats in both counties. In Parke County, on 23 April 2004, Casebere, Lodato, and T. Hulvershorn found three nesting females, plus a fourth individual. One of the nests was in a moss clump of *Brachythecium rivulare* at the base of an ash tree and a hummock of skunk cabbage. Parts of the habitat are dominated by tree cover of ash and maple, and others are shrub dominated with dogwoods and willows. Skunk cabbage and marsh marigold are abundant here. Photo vouchered (INHS 2006b).

Porter County.—This salamander has been found at various places in the northern part of the county beginning at least as early as 1938 and continuing to the present. The first known records are of specimens collected in 1938 by W.L. Necker and E.G.J. Falck. From the 1950s, there are voucher specimens collected by Joseph LaPointe and Sherman Minton. A four-toed salamander was seen crossing a road on 28 March on a rainy night with the temperature in the low 50s Fahrenheit (LaPointe 1953). In one swamp complex in the county, David Beamer reports that female four-toed salamanders use sedge hummocks for nesting during springtime, and both adults and juveniles use these hummocks at other times during the year (personal communication).

Alan Resetar has observed this salamander in Porter County in each decade beginning in the 1970s and continuing to the present. In 1987, he conducted a reptile and amphibian study (Resetar 1988) in several northwestern Indiana counties, with the emphasis on state-listed species. During his study, a drift fence array was established in an area known to be

habitat for these salamanders. He found four-toed salamanders in each month from March to October except for July when the drift fence was closed. The habitat in the area of the drift fence was described as hydromesophytic forest (swamp forest), (Resetar 1988). Trees in the area included red maple, swamp white oak, pawpaw (*Asimina triloba*), and American hornbeam (*Carpinus caroliniana*), and herbaceous plants included skunk cabbage and marsh marigold.

There are several voucher specimens from this county collected by various individuals (Table 1).

Ripley County.—This salamander was found in Ripley County on 5 April 2003 (Skilbred & Meretsky 2003) in an Illinoian till plain flatwoods. Photo vouchered (KU color slides 11904–11905).

St. Joseph County.—Unconfirmed sightings from this county have been reported for over 20 years. Although no specimens or photos were known to exist, such reports were plausible since suitable wetlands and upland habitats are scattered throughout the county. Minton does not indicate any records for this county in his 1972 monograph. In an update on recent records of amphibians and reptiles of Indiana, Minton et al. (1983) reference “an unspecified locality in northwestern St. Joseph County.” However, no date, observer, or habitat information is given. In the second edition of his Indiana monograph, Minton (2001) does not show a record for this county. More recently, we were informed of a sighting of the salamander in the county by Ken Filipek, but no specimen or photos of it are available.

On 1 May 2008, we confirmed the salamander in the northwestern part of the county in an area of morainal topography with numerous depressional swamps. Three nests were found. One nest was in a mixed moss clump of *Climacium americanum* and *Bryhnia novae-angliae*; the other two nests were in *Bryhnia novae-angliae*. The nest sites were at the bases of shrubs surrounded by water. Overstory trees were mostly red maple; shrubs were mostly highbush blueberry and common winterberry. Photo vouchered (INHS 2009e).

Starke County.—Robert Brodman (2001) first found this salamander in Starke County on 28 April 2001 under cover in wooded habitat near a large wetland. This record is plotted in Minton (2001), but was added to the

map posthumously. Brodman has since found the salamander here several times. The uplands are on sand with an overstory of black oak (*Quercus velutina*), and the wetland includes forested swamp, shrub swamp, and open marsh. Trees in the swamp are mostly red maple; shrubs include highbush blueberry, common winterberry, spicebush, and poison sumac (*Toxicodendron vernix*). Although nesting females have not been recorded, suitable nesting sites are abundant. Vouchered by Brodman (SJCAM249).

Steuben County.—Minton (1972) first recorded this salamander from Steuben County on 23 May 1954. Vouchered (AMNH 182198). A second record occurred on 24 June 2002 when Department of Natural Resources naturalist Brad Bumgardner and others found a four-toed salamander under a log. On 7 May 2006, the senior author found a nesting female in *Thuidium* moss in a forested swamp of red maple, swamp white oak and black ash. Upland mixed hardwood forest surrounded the swamp. Photo vouchered (INHS 2009j).

Tippecanoe County.—This is the other county where Vernberg (1952) mentioned collecting the four-toed salamander (see also Parke County). The validity of Vernberg’s report was uncertain due to the lack of supporting documentation. However, the salamander is now confirmed for Tippecanoe County (Casebere & Arvin 2008) beginning on 4 May 2005 with a record by Kyle Arvin and subsequent records in the following days by Kyle and Delano Arvin and Rick Howard. All of these salamanders were found under cover in the same upland forest. On 14 May 2005, the senior author, along with Kyle and Susanna Arvin, and Joe and Kacie Ehrenberger, found a female salamander attending well-developed eggs in a clump of sedge and moss in a groundwater seepage wetland adjacent to the upland forest.

In this same wetland on 21 April 2007, we found four nesting females. This is one of the more interesting nesting sites we have seen. The preferred nesting sites here are sedge hummocks, two of the most common being bottlebrush sedge (*Carex hystericina*) and smooth-sheath sedge (*Carex laevivaginata*). Skunk cabbage and, especially, marsh marigold are also found on these hummocks, as well as purplestem aster (*Symphyotrichum puniceum*), roundleaf goldenrod (*Solidago patula*), joe pye weed (*Eupatorium* sp.), and arrowhead (*Sagit-*

taria sp.). Although some moss is present, it is a less significant component of the nesting sites. A moss in one of these hummocks was identified as *Isopterygium pulchellum*. The overall habitat here is open, with extensive portions in full sun for much of the day. The nest sites were mostly within fibrous root material of herbaceous plants in the sedge hummocks. Photo vouchered (INHS 2007c).

Vigo County.—Vigo County was one of the four counties that Hay (1892) reported as having this salamander, with the record attributed to Willis Blatchley. Blatchley published two papers (1891, 1900) on the reptiles and amphibians of Vigo County. In the first paper, he says: “Five specimens of this handsome little animal have been taken. One was found near the margin of a pond, on May 4, the others on two different occasions in late Fall, in dry woods.” In the second paper, in reference to his list of species found in the county, he states: “Examples of all are now in my private collection.” Based on these statements, it is almost certain that he had collected voucher specimens of the four-toed salamander.

As a graduate student at Indiana State University in the 1960s, David Rubin (1965) compared his findings of the herpetofauna of Vigo County to those of Blatchley some 70 years earlier. Rubin did not find four-toed salamanders, but he believes that Blatchley probably found them at “Sandhill,” one of his favorite collecting areas. Deming Park in Terre Haute includes part of Blatchley’s “Sandhill,” but it has been modified to the extent that it no longer provides habitat for the salamander (David Rubin, personal communication). Many of Blatchley’s herpetofaunal voucher specimens are housed at the Museum of Comparative Zoology (MCZ) at Harvard University. No four-toed salamanders were among the specimens MCZ loaned to Rubin when he was doing research for his M.A. project. Casebere’s query to MCZ in early 2009 did not reveal any four-toed salamanders collected by Blatchley. The whereabouts of his Vigo County voucher specimens of this salamander, if they exist, are unknown.

Wabash County.—Wabash County was one of four counties that Hay (1892) reported as having this salamander, with the record attributed to Albert B. Ulrey of Manchester College in North Manchester, Indiana. Although no Ulrey voucher specimens are known to exist today,

they apparently did at one time since Hay states, “The smallest specimen that I have seen is one from North Manchester, the total length of which is a little less than an inch and a half.” No location data, dates of collection, or habitat information are known for Ulrey’s report.

On 20 April 2006, Casebere and Jerry Sweeten found five nesting females in a seep spring habitat adjacent to an upland forest of mixed hardwoods in southwestern Wabash County. All of the nests were in *Thuidium* moss lining the edges of a shallow, slow-moving seepage stream. Overstory trees in the area of the seep were mostly red maple. Skunk cabbage was abundant in the herbaceous vegetation layer. Photo vouchered (INHS 2009f).

ACKNOWLEDGMENTS

For field assistance we thank Delano Arvin, Kevin Arvin, Kyle Arvin, Susanna Arvin, Phil Bieberich, Cliff Chapman, Steve Doud, Rich Dunbar, Joe Ehrenberger, Kacie Ehrenberger, Nate Engbrecht, John Ervin, Ken Filipek, Cassie Hauswald, Roger Hedge, Andrew Hoffman, Scott Holaday, Michael Homoya, Rick Howard, Thomas Hulvershorn, Michaele Klingerman, Jason Larson, James C. Lodato, Barry Miller, Shirley Needham, Harry Potter, Jeff Ray, Alan Resetar, James Rogers, Jerry Sweeten, and Mark Weldon.

The following individuals and institutions provided information about voucher specimens in their collections:

David Dickey (American Museum of Natural History), Ned Gilmore (The Academy of Natural Sciences of Philadelphia),

Kamal Islam and Kemuel Badger (Ball State University),

Paul Krusling (Cincinnati Museum Center, Museum of Natural History and Science), Alan Resetar (Field Museum of Natural History), Jose Rosado (Museum of Comparative Zoology at Harvard University), Ronald Richards (Indiana State Museum), Steve Sullivan (Chicago Academy of Sciences), and Rod Williams (Purdue University).

The following individuals provided input and contributed in various ways: Kraig Adler, David Beamer, Bernard Bechtel, Robert Brodman, Dennis Brown, Brad Bumgardner, Tim Cordell, Rebecca Dolan, Benjamin Eddy, Ken Filipek, Nick Harby, Cassie Hauswald, Roger Hedge, Ronald Hellmich, Max Henschen, Andrew Hoffman, Michael Homoya, Brian

Jennings, Daryl Karns, James Kiser, Sarabeth Klueh, Eric Knox, James List, John MacGregor, William McKnight, Vicky Meretsky, Ken Mierzwa, Randy Millar, Marcia Moore, Stephen Perrill, Christopher Phillips, Alan Resetar, James Rogers, David Rubin, Julie Schlesselman, Greg Schneider, Carl Strang, Chip Sutton, Thomas Swinford, F. John Vernberg, and John O. Whitaker, Jr.

Voucher specimens collected in 2003 were taken under the authority of Scientific Purposes Licenses (#2683 & #2712) from the Indiana Department of Natural Resources, Division of Fish & Wildlife.

The following individuals reviewed and edited drafts of the manuscript: Michael Homoya, Patricia Lodato, William McKnight, and Alan Resetar. Thanks to landowners too numerous to list for allowing access to their properties, both public and private. The senior author thanks the DNR Division of Nature Preserves for allowing him to conduct much of this study on work time.

APPENDIX I

DISCUSSION OF WETLAND NESTING HABITATS

Three wetland habitats chosen by female four-toed salamanders for egg laying will be discussed here in more detail, including discussion of associated flora. The three habitats are: (1)Ephemeral pools and ponds in flatwoods,(2)Depressional swamps and ponds, and (3)Groundwater seepages or seep springs.

1)Ephermeral Pools and Ponds in Flatwoods.—Thousands of hectares of the glaciated portions of Indiana are characterized by level terrain with inclusions of poorly drained soils. Slight depressions, especially in clay soils, retain water in pools that may last for weeks before drying up, and some deeper depressions have ponds that may hold water for a few months. Precipitation is the sole source of water input to these sites. They are often devoid of woody vegetation, but some contain water-tolerant trees or shrubs within them or along their edges. Buttonbush is a shrub commonly found in these places. For this discussion, flatwoods will be further subdivided into three types: A) Illinoian Till Plain Flatwoods, B) Boreal Flatwoods, and C) All other Indiana flatwoods.

A) Illinoian Till Plain Flatwoods: This variation of flatwoods exists in southeastern Indiana in the Muscatatuck Flats and Canyon Section of the Bluegrass Natural Region (Homoya et al. 1985)in an area characterized by Illinoian glacial drift. The

uplands in this area feature a flat landscape locally known as the “white clay flats” or the “crawdad flats.” The soils are poorly drained, acidic clays of the Avonburg-Cobbsfork series. This soil association exists in parts of Clark, Dearborn, Franklin, Jackson, Jefferson, Jennings, Ripley, Scott, and Switzerland counties (Chapman 1942). The Illinoian till plain soils produce a unique forest community that is known to exist only in southeastern Indiana and southwestern Ohio. The unique association of trees in these flatwoods includes American beech (*Fagus grandifolia*), tulip tree (*Liriodendron tulipifera*), white oak (*Quercus alba*), pin oak, swamp white oak, swamp chestnut oak (*Quercus michauxii*), black gum, sweet gum (*Liquidambar styraciflua*), and red maple. For more information on this interesting soil/forest association, see Braun (1936) and Chapman (1942).

Ponded sites in these flatwoods often support lush growths of mosses at the base of trees, on fallen limbs and logs, and lining the edges of water pools. In addition to using moss nest sites in these flatwoods, the salamanders will sometimes nest within sedge clumps. Four-toed salamanders are a rather recent discovery in this area of the state with known populations in Jefferson and Ripley counties.

Due to the overall wet character of the soil surface in this region, we believe that, before forest fragmentation and artificial drainage took their toll, this region probably had the most contiguous populations of four-toed salamanders in the entire state. This may have been one of the few areas in Indiana where populations existed close enough to one another that dispersal between populations commonly occurred.

B) Boreal Flatwoods: In LaPorte County in northwestern Indiana, there is a variation of flatwoods that appears to provide suitable habitat. A natural community known as boreal flatwoods is found north of the Valparaiso Moraine in the flat, sandy lake plain. Soils are acidic sands, often with high organic content, and seasonally very wet. The plant communities in this area (especially the herbaceous layer) have strong boreal affinities. Trees include pin oak, black gum, red maple, tulip tree, paper birch (*Betula papyrifera*), and white pine (*Pinus strobus*). Shrubs include common winterberry and acidic soil indicators such as blueberry and huckleberry (*Gaylussacia* sp.). Woodland pools with ample quantities of thick mosses are common in this habitat, but, in spite of its promising appearance, diligent searches failed to turn up four-toed salamanders.

C) All other Indiana Flatwoods: Besides the two variations of flatwoods already discussed, other flatwoods are found throughout the remaining glaciated areas of Indiana, comprising extensive geographic areas of the state. In general, the ephemeral pools and ponds in these flatwoods lack the thick mosses required by the salamanders for

nesting, although some sites do provide suitable nesting habitat. Our searches included many of these flatwoods, but we were not successful in finding the salamander.

2) Depressional Ponds and Swamps.—For the most part, these are examples of glacial expression left in the wake of the Wisconsinan glaciation. Their water supply is largely from precipitation, but groundwater may contribute significant water inputs. Many are kettle holes (ice block depressions) left after the glacial retreat. Others may be depressions caused by gouging action as the glacier plowed its way across the landscape. Most are within or near glacial moraines where the surface topography is rolling and complex. Since the Wisconsinan covered about two-thirds of the state, depressional wetlands resulting from the glacier may be found rather far south in Indiana. However, they are most abundant in the northern parts of Indiana associated with the top three or four tiers of counties. In some places, depressional swamps develop as a result of other large-scale natural forces. Examples of this are the swamps on the downwind side of high dunes along the south end of Lake Michigan.

The sites where the salamander is found in depressional swamps are usually peat- and muck-filled basins with overstories mostly of red maple, but sometimes also of black ash, swamp white oak, yellow birch, or tamarack (*Larix laricina*). These sites may be very “hummocky” with abundant mosses growing on the sides of the fern and sedge clumps, and on the roots and bases of trees and shrubs. Shrubs common in these swamps include button-bush, highbush blueberry, common winterberry, chokeberry (*Photinia* spp.), nannyberry (*Viburnum lentago*), poison sumac, catberry (*Ilex mucronata*), spicebush, and swamp rose. *Thuidium* is one of the most abundant mosses, and *Sphagnum* mosses are locally abundant.

3) Groundwater Seepage Communities or Seep Springs.—These are wetlands where groundwater breaking to the surface in the form of seeps or springs provides the most significant source of water. If the flow is heavy enough, the waters form rivulets and small streams that move across the surface materials. Vegetation may be slow to decay in these soggy areas, so muck soils high in organic content may develop. These seepage areas are typically above the level of nearby streams or ponds, thus, a “perched” wetland develops since they are not at a low point in the terrain. Two herbaceous plants found in most seepage communities throughout Indiana used by four-toed salamanders are skunk cabbage, and marsh marigold.

Many of these seepage communities have lush gardens of thick mosses along the edges of slowly moving rivulets and next to shallow pools of water, at the bases of trees and shrubs, and on downed

logs and limbs. In such situations they provide suitable nesting sites for four-toed salamanders. Seepage communities may be open and largely composed of herbaceous vegetation, and thus more marsh-like, or they may be more or less shaded with woody vegetation forming a shrub-dominated or tree-dominated community. The waters may be acidic or basic, and if basic, the community is called a fen. Where the seepage communities support trees and shrubs, the woody species are generally similar to those described earlier for depressional ponds and swamps, although willow and dogwood species are more likely to be part of the shrub layer. Although usually found nesting in mosses in seepage communities, four-toed salamanders will sometimes nest among the fibrous roots and dead leaf materials of sedges and other herbaceous plants.

APPENDIX II

CONSERVATION PRACTICES FOR LANDOWNERS

Where populations exist, management to benefit four-toed salamanders should include the following practices:

- 1) High quality wetland nesting habitat is essential, especially those with abundant, thick-pile mosses such as *Thuidium* and *Sphagnum*. Drainage or other wetland reduction must be avoided, and measures that promote clean, pollutant-free waters are encouraged.
- 2) Grazing of livestock should be avoided in areas having this salamander. Land management practices that reduce or eliminate soil erosion and nutrient inputs are strongly encouraged.
- 3) Woodland habitat adjacent to wetland nesting sites is crucial, and maintaining or expanding forest cover is beneficial. Light to moderate timbering is acceptable, and timbering debris such as bark slabs, limbs and pieces of logs provide cover for the salamanders. Such debris within the wetlands themselves provides places for mosses to become established, thus providing nesting sites.
- 4) Where wetland and upland forest habitats are close to one another, but separated by agricultural or other disturbed landscapes, creating wooded corridors for dispersal between wetlands and forested habitats is strongly encouraged.
- 5) At sites known to have this salamander, it is possible to expand nesting cover by moving moss clumps to favorable locations next to water, especially where such nesting sites are lacking. Since *Thuidium delicatulum* is common and widespread in Indiana, and is the preferred moss

used for nesting in Indiana, it would be the moss of choice to use for this purpose.

- 6) Where ditches have been dug to drain wetlands, including (perhaps especially) wet flatwoods in southeastern Indiana, blocking the ditches so they do not drain woodland pools could greatly stabilize nesting habitat and help retain shallow water for longer periods of time. Where possible, creating earthen dams across such ditches in multiple places would create long, linear, artificial pools of water that could be lined with appropriate mosses along the edges, thereby expanding breeding habitat.
- 7) At a site in Jefferson County, suitable mosses have become established along the edges of shallow, manmade ditches and at a manmade pond, and are being used for nesting by female four-toed salamanders. For this reason, we believe creating new ponds for nesting would be a feasible practice. We are not aware of examples where this has been successfully employed specifically for this salamander, but it could be beneficial in places where the salamander exists in precariously low numbers. Such ponds have the potential to stabilize or increase local populations. Logs and limbs could be placed in manmade pools and along their edges, and *Thuidium* moss placed in strategic locations. It may take several years for such a wetland to mature in all appropriate aspects to become suitable nesting habitat. This practice would not be advised in high quality natural areas where disturbances could adversely affect significant features.

Partners in Amphibian and Reptile Conservation (PARC), through its regional affiliates, has published some "Habitat Management Guidelines" that are useful for private landowners, land managers, land trusts, and natural resource agencies (Habitat Management Guidelines).

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Manuscript received 12 October 2010, revised 31 January 2011.