

Dragonflies and Damselflies (Odonata) of the Shenandoah Valley Sinkhole Pond System and Vicinity, Augusta County, Virginia

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INTRODUCTION

The Big Levels area of the George Washington National Forest along the west flank of the Blue Ridge Mountains in southeastern Augusta County, Virginia contains a diverse assemblage of sinkhole ponds (Carr, 1940; Mohlenbrock, 1990; Buhlmann et al., 1999; Fleming & Van Alstine, 1999). These wetlands were formed through localized dissolution and collapse of karst terrain (dolomite and limestone) and subsequent deposition of alluvial materials from nearby mountain slopes. Whittecar & Duffy (1992) provide details of the latter process. Results of palynological research at two of the largest ponds in the region indicate that some of the ponds have been continuously present during the past 15,000 years (Craig, 1969). Soils of the region are strongly acidic and many of the sinkhole ponds are also acidic (Downey et al., 1999). This area will hereafter be referred to as the Shenandoah Valley sinkhole pond system following the terminology of Buhlmann et al. (1999). Whereas the diverse and interesting flora of these ponds has been well documented (Freer, 1933; Carr, 1937, 1938, 1940; Rawlinson & Carr, 1937; Harvill, 1973; Wieboldt et al., 1998; Fleming & Van Alstine, 1999), the fauna has received relatively little attention (e.g., Buhlmann & Hoffman, 1990). Elsewhere in this symposium volume, Mitchell & Buhlmann (1999) document the amphibian and reptile fauna of the region. There are no published accounts of the invertebrate fauna of the Shenandoah Valley sinkhole pond system. Since 1992, I have sampled the aquatic insect fauna of many of these ponds. The purpose of this paper is to summarize the results of my surveys for dragonflies and damselflies (Odonata), which comprised the primary focus of my efforts.

Previous surveys of the Odonata fauna of the Shenandoah Valley sinkhole pond system were limited. Carle (1982) recorded only two species (*Aeshna tuberculifera* and *Sympetrum rubicundulum*) during a visit to the Maple Flats ponds on 2 October 1977. Field notes and specimens of former Division of Natural Heritage (DNH) zoologist Kurt A. Buhlmann indicate that he recorded a total of seven species (five collected) from one of the Maple Flats ponds on 3 June 1990; he collected one of these same species at another pond on 2 June 1991. Carle (1982) listed dragonfly (Anisoptera) records from a site that he referred to as Shenandoah Pond in Augusta County, Virginia. This corresponds to the locality known as Green Pond in Carr (1938, 1940), Quarles Lake (Green Pond) in Harvill (1973), and Quarles Pond in Buhlmann et al. (1999) and this paper. Former DNH biologists Christopher A. Pague and Thomas J. Rawinski collected a few dragonflies at Green Pond on 1 June 1990 and 2 July 1991. This boggy mountain pond lies near the crest

Table 1. Number of Odonata species documented at the various ponds in the Shenandoah Valley study area.

	Damselflies	Dragonflies	Total
Maple Flats ponds	21	34	55
Loves Run Pond	10	20	30
Quarles Pond	-	18	-
Green Pond	5	13*	18
Total	21	39	60

*Excludes *Leucorrhinia frigida*

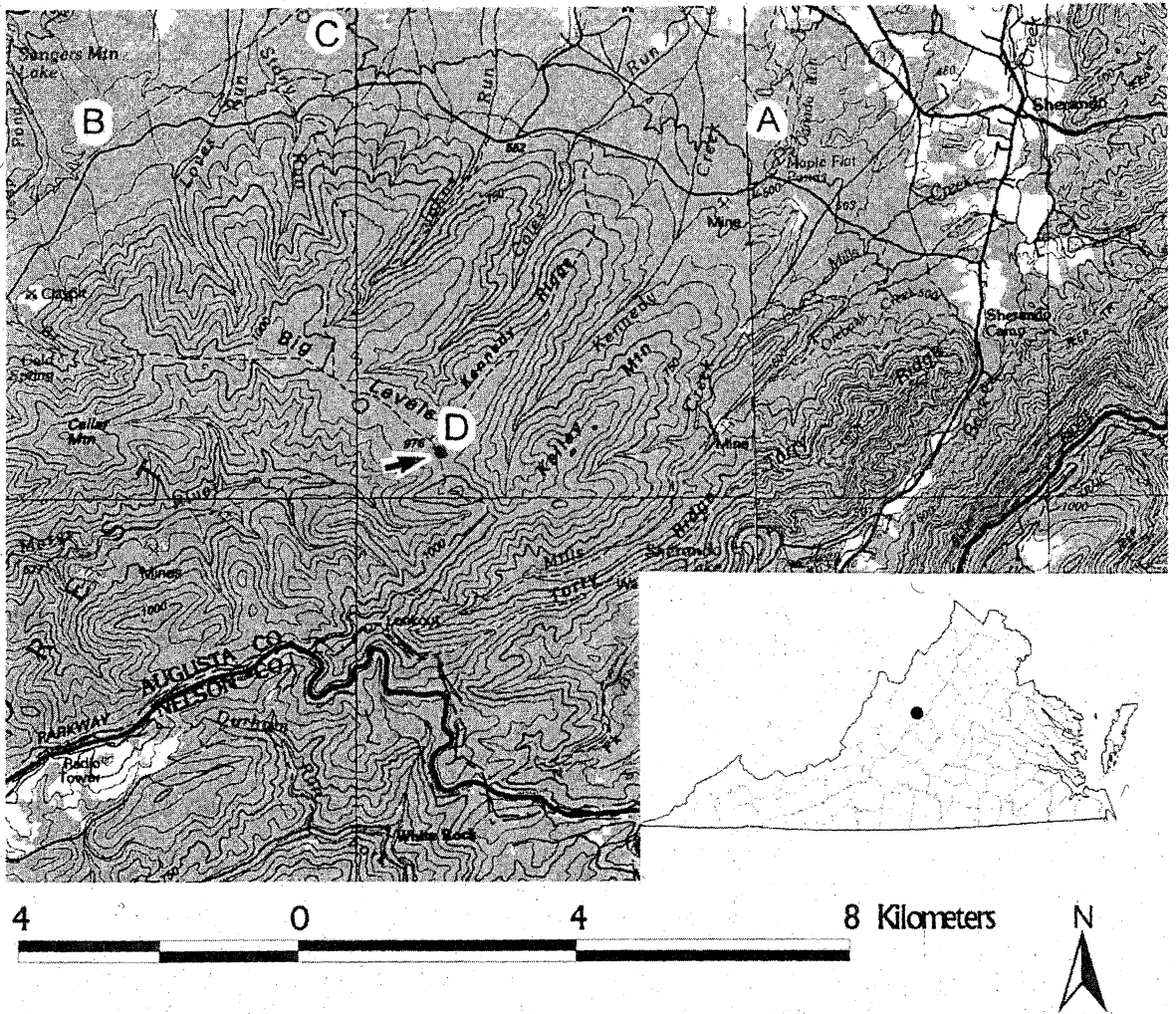


Fig. 1. Map of the study area showing primary survey areas (A = Maple Flats ponds; B = Loves Run Pond; C = Quarles Pond; D = Green Pond); inset indicates the location of the Shenandoah Valley sinkhole pond system within Virginia.

of Kennedy Ridge and is clearly labeled on the Big Levels U.S. Geological Survey topographic map; it is not equivalent to the Green Pond mentioned by Carr (1938, 1940) and Harvill (1973).

Elsewhere in the region, Surber's (1951) paper on the benthic fauna of the St. Marys River includes collection records of larval Odonata obtained from riffle habitats during 1935-37 that he identified only to the level of genus (i.e., *Aeshna*, *Lanthus*). His report of *Lanthus* sp. has been interpreted in recent years as *L. parvulus* by fisheries biologists from the George Washington National Forest, who now regard it as locally extirpated as a result of acid precipitation (M. Hudy, pers. comm.). This is a rare species in Virginia that has been confirmed only from

Highland and Montgomery counties (Carle, 1991; see also Roble et al., 1997 regarding an apparent record from Page County). However, I believe it is more likely that Surber's record is referable to either *Stylogomphus albistylus* (formerly placed in *Lanthus*) or *L. vernalis* (described by Carle, 1980). I do not know if these collections are extant to potentially resolve this issue.

STUDY AREAS

My primary study area was the Maple Flats pond complex, which ranges in elevation from 470 to 485 m (1540-1590 ft). I surveyed the following five ponds most frequently: Maple Flats North, Maple Flats South, Oak,

Twin, and Spring. The first two ponds, hereafter referred to as North and South, are man-made impoundments of Canada Run that were created in the 1950s (Buhlmann et al., 1999). Both have water control structures and are stocked with game fish. The original habitat of these areas included boggy wetlands that bordered Canada Run (Buhlmann et al., 1999); the west and south margins of South Pond are still somewhat boggy. During my visits to the Maple Flats area, South Pond was usually maintained at a high water level, whereas North Pond was often very low. Spring Pond is the most unique pond in the complex; it is a permanent, spring-fed pond that is typically covered by a profuse growth of golden club (*Orontium aquaticum*) (Rawlinson & Carr, 1937; Carr, 1940; Buhlmann et al., 1999; Fleming & Van Alstine, 1999). The pond covers approximately 2.5 ha and its maximum depth is about 1 m. At least two species of fish inhabit Spring Pond (Buhlmann et al., 1999). Oak and Twin ponds are seasonally fluctuating sinkhole ponds that often dry completely or nearly so in summer or fall. At full capacity, Oak Pond has a surface area of approximately 0.8 ha and a maximum depth of ca. 3 m. Twin Pond consists of two adjacent sinkholes (= Twin Pond North and South of Buhlmann et al., 1999) that are connected

when water levels are high; their combined surface area is approximately 1.2 ha and maximum depth is ca. 2 m.

My summary data for Twin Pond combines all observations made at both sinkholes. Oak and Twin ponds exemplify plant community type 1 of Fleming & Van Alstine (1999), which is not only the best represented community in the Shenandoah Valley sinkhole pond system, but also apparently endemic to this region and globally rare. The distinctive vegetation of this plant community is characterized by the presence of pin oak (*Quercus palustris*), panic grasses (*Panicum rigidulum* and *P. verrucosum*), and least spikerush (*Eleocharis acicularis*).

Two other wetlands in the Maple Flats area that I sampled less frequently were Split Level Pond (= Football Field Pond of Mohlenbrock [1990] and ponds 8 and 9 of Buhlmann et al. [1999]) and Horseshoe Swamp. The latter site consists of an extensive sedge marsh (ca. 1 ha; dominated by *Carex barrattii*, a rare species in Virginia) and an associated buttonbush (*Cephalanthus occidentalis*) pond area, a red maple (*Acer rubrum*)/highbush blueberry (*Vaccinium corymbosum*) acidic seepage swamp (ca. 1.5-2 ha) with an extensive carpet of *Sphagnum* moss and a small, semi-isolated boggy pond (also with some button-



Fig. 2. Photograph of Green Pond taken by the author on 18 June 1998. The dominant vegetation in the foreground is water sedge (*Carex aquatilis*) and three-way sedge (*Dulichium arundinaceum*). The former species is a northern disjunct, known in Virginia only from this site.

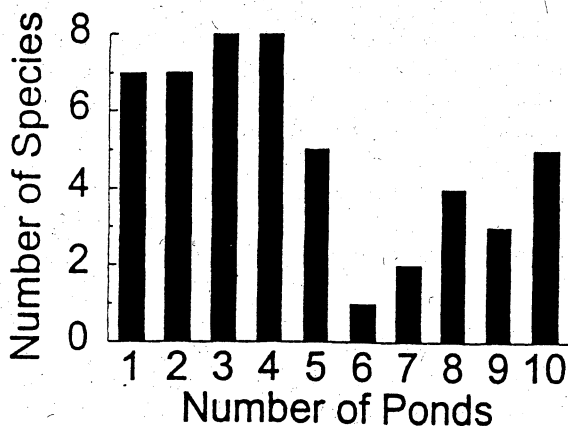


Fig. 3. Frequency of occurrence of Odonata species at study ponds ($n = 11$) in the Maple Flats complex.

bush). Fleming & Van Alstine (1999) identified the sedge marsh as a distinct plant community. For the purposes of data analysis and presentation, I divided Horseshoe Swamp into the following two sites: (1) sedge marsh and buttonbush pond; (2) seepage swamp and boggy pond. Split Level Pond covers about 1 ha and often dries completely in mid to late summer.

I made only 1-2 brief visits to ponds 2, 4, and 18 of Buhlmann et al. (1999). The former pond is also the site of Buhlmann's survey of 3 June 1990; his records are included in my summary tables. I did not survey for Odonata at Deep Pond (= pond 17 of Buhlmann et al., 1999), and never observed adult Odonata at Conical Pond (= pond 16 of Buhlmann et al., 1999) despite walking past this small, but deep sinkhole pond on numerous occasions. Detailed descriptions, photographs, and a map of all of the Maple Flats ponds are provided by Buhlmann et al. (1999); Fleming & Van Alstine (1999) contains a photograph of the buttonbush pond area at Horseshoe Swamp. Craig (1969) also provided a brief description of Spring Pond (reported as Hacks Pond), where he conducted a palynological study.

I conducted a total of six surveys for Odonata at the Loves Run pond complex, located ca. 11 km W of the Maple Flats pond complex (Fig. 1). All of my visits except the first were limited to a large sinkhole pond (ca. 1 ha; maximum depth ca. 2 m), hereafter referred to as the Loves Run Pond (= pond 21 of Buhlmann et al., 1999). The elevation of this permanent, heavily vegetated pond is approximately 550 m (1,820 ft). I also visited a nearby shallow, marshy pond (= pond 25 of Buhlmann et al., 1999) briefly on 20 June 1995. I did not visit any of the remaining smaller ponds in the Loves Run pond complex.

However, Anisoptera records from Quarles Pond (reported as Shenandoah Pond) that were summarized by Carle (1982) are also included in this paper. This shallow, privately owned pond is the largest pond in the Loves Run area (= pond 20 of Buhlmann et al., 1999); its elevation is approximately 506 m (1,660 ft) and maximum surface area between 3 and 4 ha. With one exception, the Quarles Pond records in Carle (1982) are based on voucher specimens collected during three surveys by Frank L. Carle (2 October 1977, 29 October 1978, and 13 June 1980) and one survey by Boris C. Kondratieff (17 July 1980). Sight records of *Anax longipes*, a large, distinctive dragonfly that is notoriously difficult to capture, were also obtained during the latter survey. No sight or collection records of damselflies (Zygoptera) from this pond were readily available for inclusion in this paper. Detailed descriptions and photographs of the three survey ponds in the Loves Run pond complex are provided by Buhlmann et al. (1999). Craig (1969) provides palynological data for Quarles Pond.

My final survey site was Green Pond (Fig. 2), a small, isolated, boggy mountain (elevation 976 m or 3,203 ft) pond along Kennedy Ridge in the Big Levels area. Water levels of this pond fluctuate considerably as a result of precipitation; maximum depth is about 1 m. The forest opening in which the pond occurs covers <1 ha. The pond contains abundant *Sphagnum* moss and is dominated by graminoid vegetation, particularly water sedge (*Carex aquatilis*) and three-way sedge (*Dulichium arundinaceum*). Green Pond is the only known Virginia locality for *C. aquatilis*, a northern disjunct (Wieboldt et al., 1998); these authors also provide a brief description of the pond. A dense mat of cranberry (*Vaccinium macrocarpon*) is limited to one side of the pond.

Table 2. Typical breeding habitat of the Odonata species documented at the various study areas.

	Ponds	Seepages	Streams
Maple Flats			
All species	48	0	7
Breeders	46	0	2
Loves Run	29	1	0
Quarles Pond	18	0	0
Green Pond	18	0	0
Total	52	1	7

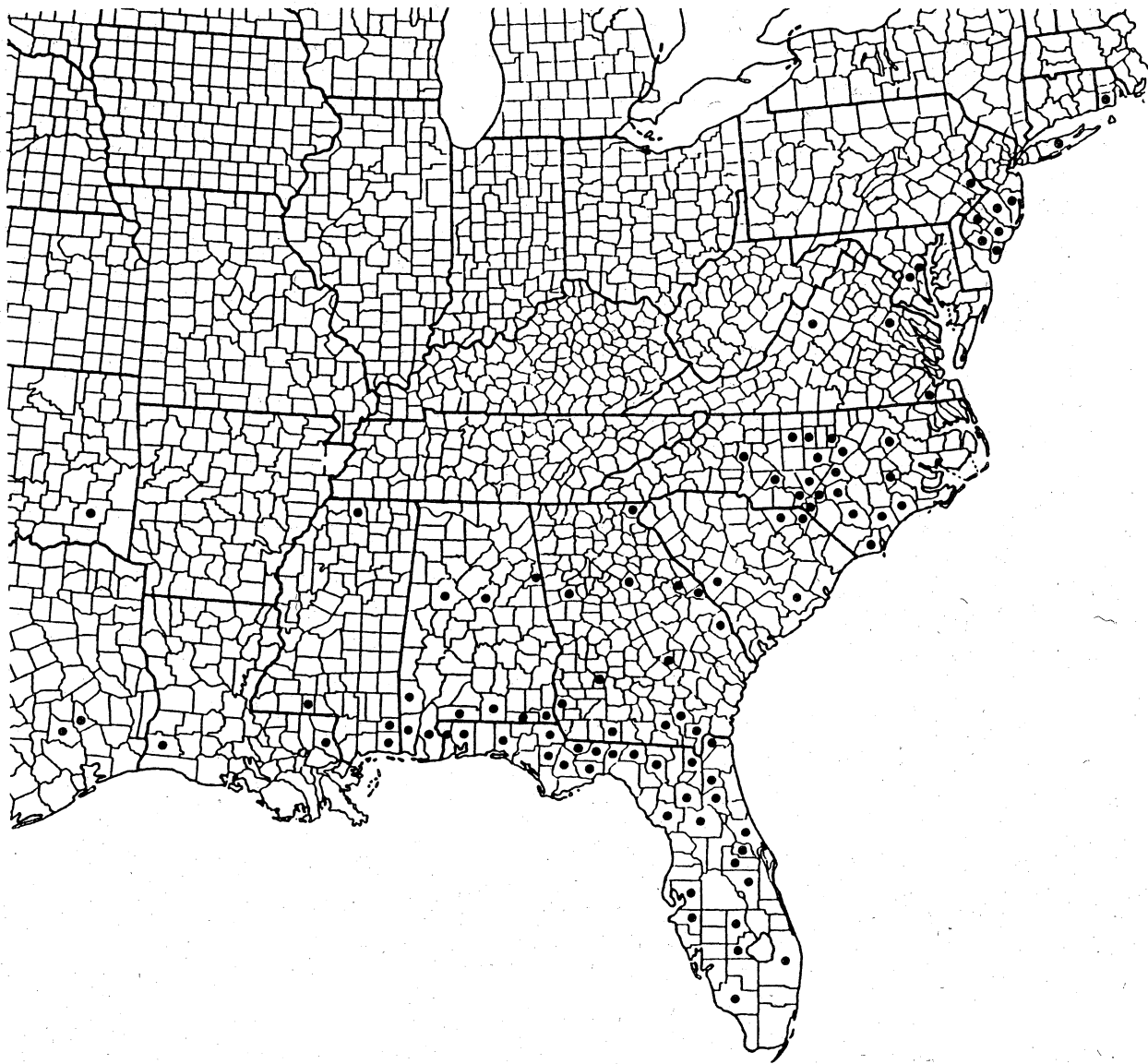


Fig. 4. Geographic distribution (by county) of the southern sprite (*Nehalennia integricollis*). See Appendix for data sources.

MATERIALS AND METHODS

I made 22 visits to the Maple Flats ponds between June 1992 and October 1998 during the flight season of adult Odonata; several ponds were visited on each trip, but only rarely did I visit all of the study ponds on the same date. I attempted to completely survey each pond that was visited for the presence of adult Odonata. The Loves Run Ponds were surveyed on six occasions (1995-98), with all but the first survey being devoted entirely to the largest sinkhole pond. I visited Green Pond three times (1992-98) during the months of June and July.

Most of my records are based on observations or

collections of adult specimens; some larvae and exuviae were also collected. Voucher specimens were captured with standard insect nets for positive identification and documentation of the fauna of the Shenandoah Valley sinkhole pond system. Specimens were identified using Carle (1982), Carpenter (1991), Dunkle (1990, 1991), Needham & Westfall (1955), Walker (1952, 1953, 1958), Walker & Corbet (1975), and Westfall & May (1996). The majority of the specimens have been or will be deposited in the Virginia Museum of Natural History and the National Museum of Natural History, Smithsonian Institution (USNM).

Table 3. Local distribution of Odonata in the Shenandoah Valley sinkhole pond system and vicinity, Augusta County, Virginia.

Species	Maple Flats pond complex ^a											Other Study Ponds				
	S	N	Oak	Twin	Spr	SL	HS Marsh	HS Bog	2	4	18	Total Ponds	Trails, roads	Loves Run	Quarles ^b	Green
<i>Calopteryx maculata</i> ^c	x	x	-	-	x	x	x	-	-	-	-	5	x	-		-
<i>Lestes congener</i>	x	x	x	x	x	x	x	x	-	-	-	8	x	x		-
<i>L. disjunctus australis</i>	-	-	-	-	x	-	x	x	-	-	-	3	-	x		-
<i>L. eurinus</i>	-	-	x	-	-	x	-	x	-	-	-	3	-	x		-
<i>L. forcipatus</i>	x	x	x	x	x	x	x	x	-	x	x	10	-	x		x
<i>L. rectangularis</i>	x	x	-	-	x	x	-	-	-	-	-	4	-	x		x
<i>L. vigilax</i>	x	x	-	-	x	-	-	-	x	-	-	4	-	x		-
<i>Argia fumipennis violacea</i>	x	x	-	-	-	-	-	-	-	-	-	2	-	-		-
<i>Chromagrion conditum</i>	x	x	-	-	x	-	x	-	-	-	-	4	x	x		-
<i>Enallagma aspersum</i>	x	x	x	x	x	x	x	x	x	-	-	9	x	x		x
<i>E. basidens</i>	x	-	-	-	-	-	-	-	-	-	-	1	x	x		-
<i>E. civile</i>	x	x	-	x	x	-	-	-	-	-	-	3	-	-		-
<i>E. divagans</i>	x	x	-	-	x	-	-	-	-	-	-	2	-	-		-
<i>E. doubledayi</i>	-	x	-	-	-	-	-	-	-	-	-	1	-	-		-
<i>E. exulans</i>	x	-	-	-	-	-	-	-	-	-	-	1	-	-		-
<i>E. geminatum</i>	x	x	-	-	-	-	-	-	-	-	-	1	-	-		-
<i>E. signatum</i>	x	x	-	x	-	x	-	-	-	-	-	4	-	-		-
<i>Ischnura hastata</i>	x	x	-	x	x	x	x	x	-	-	-	7	-	x		-
<i>I. posita posita</i>	x	x	x	x	x	x	x	x	-	-	-	8	-	x		x
<i>I. verticalis</i>	x	x	-	x	x	-	-	-	-	-	-	5	x	x		x
<i>Nehalennia integricolis</i>	x	-	-	-	-	-	-	-	-	-	-	1	x	-		-
<i>Tachopteryx thoreyi</i>	-	-	-	-	-	-	-	-	-	-	-	0	-	x		-
<i>Aeshna conscripta</i>	-	-	-	-	-	-	-	-	-	-	-	0	-	-		-
<i>A. mutata</i>	-	-	-	-	-	-	-	-	-	-	-	0	-	x		-
<i>A. tuberculifera</i>	x	-	-	-	-	-	-	-	-	-	-	1	-	-		-
<i>A. umbrosa umbrosa</i>	x	x	-	x	-	-	-	-	-	-	-	3	-	x		-
<i>Anax junius</i>	x	x	x	x	x	x	x	x	x	x	-	10	-	x		x
<i>A. longipes</i>	-	-	-	-	-	-	x	x	-	-	-	2	-	x		-
<i>Boyeria graffiana</i>	-	-	-	-	-	-	-	-	-	-	-	0	x	-		-
<i>B. vinosa</i>	-	-	-	-	-	-	-	-	-	-	-	0	x	-		-
<i>Epiaeschna heros</i>	-	x	-	-	-	-	x	-	-	-	-	3	-	-		-
<i>Gomphaeschna furcillata</i>	-	x	-	-	-	-	x	-	-	-	-	2	-	-		-
<i>Gomphus exilis</i>	x	x	-	-	-	-	-	-	x	-	-	3	x	-		-
<i>Cordulia shurtleffi</i>	-	-	x	-	-	-	x	-	-	-	-	2	x	x		-
<i>Epitheca cynosura</i>	x	x	x	x	x	x	-	-	x	-	-	4	x	-		-
<i>Somatochlora tenebrosa</i>	x	x	x	x	x	-	-	-	-	-	-	5	x	-		-
<i>Didymops transversa</i>	-	-	-	-	-	-	-	-	-	-	-	0	x	-		-

Table 3 (continued).

Species	Maple Flats pond complex ^a											Other Study Ponds				
	S	N	Oak	Twin	Spr	SL	HS Marsh	HS Bog	2	4	18	Total Ponds	Trails, roads	Loves Run	Quarles ^b	Green
<i>Celithemis elisa</i>	x	x	x	x	x	x	x	x	x	-	-	9	x	x	x	x
<i>C. fasciata</i>	x	x	-	x	-	-	-	-	-	-	-	3	-	-	-	-
<i>C. martha</i>	-	-	-	-	x	-	-	-	-	-	-	1	-	-	-	-
<i>C. verna</i>	-	-	-	-	x	x	x	x	-	-	-	4	-	-	-	-
<i>Erythemis simplicicollis</i>	x	x	-	x	x	x	x	x	-	-	-	7	x	x	x	x
<i>Erythrodiplax minuscula</i>	x	-	-	-	x	-	-	-	-	-	-	3	-	-	-	-
<i>Leucorrhinia intacta</i>	-	x	x	-	x	-	x	x	-	-	-	5	x	x	x	x
<i>Libellula auripennis</i>	x	-	-	x	x	-	x	-	-	-	-	4	x	x	-	-
<i>L. axilena</i>	-	x	x	-	-	-	x	-	-	-	-	2	x	x	-	-
<i>L. cyanea</i>	x	x	-	-	x	-	x	-	-	-	-	5	x	x	x	x
<i>L. deplanata</i>	x	x	x	-	x	-	-	-	x	-	-	5	x	-	-	-
<i>L. incesta</i>	x	x	x	x	x	x	x	x	x	x	-	10	-	x	x	-
<i>L. luctuosa</i>	x	-	-	-	-	-	-	-	-	-	-	1	x	-	-	-
<i>L. lydia</i>	x	x	x	x	x	-	x	x	-	x	-	8	x	x	x	x
<i>L. pulchella</i>	-	x	x	x	-	-	x	x	x	-	-	4	x	x	x	-
<i>L. semifasciata</i>	x	x	x	-	-	-	x	x	x	-	-	6	x	x	x	x
<i>Pachydiplax longipennis</i>	x	x	x	x	x	x	x	x	-	x	-	9	-	x	x	x
<i>Sympetrum rubicundulum</i>	x	x	x	x	x	x	x	x	x	-	x	10	x	x	x	x
<i>S. semicinctum</i>	-	-	-	-	-	-	-	-	-	-	-	0	-	-	-	-
<i>S. vicinum</i>	x	x	x	x	x	-	x	x	x	-	-	8	-	x	x	x
<i>Tramea carolina</i>	x	x	x	x	x	x	x	x	x	x	-	10	-	x	x	x
<i>T. lacerata</i>	x	-	-	x	-	-	-	-	-	-	-	2	-	-	-	-
<i>T. onusta</i>	-	-	-	-	-	-	-	-	-	-	-	0	-	-	-	-
Number of surveys	14	14	9	9	8	3	6	6	3	1	1	-	-	6	4	3+
Total species	41	34	21	22	29	16	27	26	13	6	2	52 ^d	3 ^e	34	18 ^f	18

^a S = Maple Flats South Pond; N = Maple Flats North Pond; Spr = Spring Pond; SL = Split Level Pond; HS-Marsh = Horseshoe Swamp (portion containing sedge marsh and associated pond area only); and HS-Bog = Horseshoe Swamp (portion containing acidic seepage swamp and nearby boggy pond).

^b No data available for Zygoptera.

^c Found primarily along Canada Run in the Maple Flats area.

^d Total species recorded at the Maple Flats pond complex.

^e Total species recorded only along trails or roads in the Maple Flats area.

^f Anisoptera only

RESULTS

I recorded a total of 55 species of Odonata in the Maple Flats area. The vast majority of these species are confirmed or probable breeders at this pond system. Five additional species were documented at the other study ponds in the Big Levels area, including two at Quarles Pond, one at Loves Run Pond, and one at Green Pond; the fifth species was recorded at both Quarles Pond and Loves Run Pond. The overall species diversity of the Odonata faunas at the various study sites is compared in Table 1. All but eight of the 60 species (87%) documented in the Shenandoah Valley sinkhole pond system study area are lentic breeders (Table 2). A detailed summary of the distribution of each species within the study area is provided in Table 3. The occurrence of a species at a particular pond does not necessarily mean that it breeds at that site; in some cases only a single individual of a given species was observed at the indicated pond. Some species were widely distributed in the study area, whereas others were found at only a few ponds (Fig. 3). The collective results of my surveys and records in Carle (1982) reveal that adult Odonata were present in the study area from late April through late October. Our observations produced record early or late flight dates for Virginia populations of 20 species of Odonata (Table 4); at least three of these (one early, two late) are apparently also rangewide record adult activity dates (see species accounts below).

Annotated Checklist

The following annotated checklist provides a brief summary of observations made on each species in the study area. Species known to breed at ponds in the study area are denoted by an asterisk (*). I define evidence of breeding as observations of one or more of the following: tandem pairs, ovipositing females, larvae, exuviae, or teneral adults. Suspected breeders are denoted by a plus sign (+); typically, I only observed patrolling males of these species. I am uncertain as to the local breeding status of one species (*Aeshna constricta*) that was recorded only at Quarles Pond by Carle (1982). Common names follow those recently adopted by the Dragonfly Society of the Americas (1996).

ZYGOPTERA (Damselflies)

Calopterygidae

Calopteryx maculata (Ebony Jewelwing)

This stream-breeding species is common along Canada Run in the Maple Flats area. I also observed several

adults at the outlet to Spring Pond (an unnamed tributary of Canada Run), as well as 1-2 individuals at several other ponds in the Maple Flats sinkhole complex.

Coenagrionidae

**Argia fumipennis violacea* (Variable [Violet] Dancer)

This predominantly stream-breeding species was fairly common at South Pond, where it apparently breeds. A lone male was noted at North Pond. I also observed an adult male *Argia moesta* (Powdered Dancer) on 18 June 1998 along a forest road near Green Pond, but presume that it had strayed from the nearby St. Marys River (see map in Surber, 1951) and have omitted this species from the summary tables.

**Chromagrion conditum* (Aurora Damsel)

This is an early spring species that was abundant at South Pond, including nearby forest trails. I only observed a few individuals at the other Maple Flats ponds where it was recorded. I collected a mated pair at Loves Run Pond on 10 June 1996, my only record for that site.

**Enallagma aspersum* (Azure Bluet)

This is the most widespread bluet in the Maple Flats area, but I often did not find it there in large numbers (typically <20 adults per pond). My highest count was ca. 1000 at the Horseshoe Swamp buttonbush pond on 13 June 1997 (ca. 500 more at the nearby boggy pond on this date), followed by approximately 100 adults at Oak Pond during visits on 30 August 1996 and 13 June 1997. The maximum number seen at Green Pond was 250+ adults on 25 July 1997. In contrast, this species is very abundant at the Loves Run Pond, where I observed at least 3,000 (perhaps as many as 5,000) adults on 20 June 1995. This is comparable to the density observed at another sinkhole pond farther north in the Shenandoah Valley by Tim E. Vogt on 25 May 1991 (Roble, 1994). Adults typically perched on the stems of emergent vegetation, or in the case of Twin Pond, on the heads of *Eriocaulon aquaticum*, a state-rare pipewort. I found one dead female captured in a spider web, another near death (19 September), and one dead (9 September), both of the latter floating on the surface of Oak Pond.

**Enallagma basidens* (Double-striped Bluet)

I observed a few individuals at South Pond in the Maple Flats area on several occasions, as well as in a gas pipeline right-of-way near Loves Run Pond. I found one dead male floating on the surface of South Pond on 21 October. This small species has greatly expanded its range during the past half century (Cannings, 1989; Dunkle, 1990).

+*Enallagma civile* (Familiar Bluet)

I suspect this species, which is common throughout Virginia, breeds in low densities in the Maple Flats area, where I recorded it only a few times.

**Enallagma divagans* (Turquoise Bluet)

My records for this species are limited to 13 June 1997, when I observed 6 males and 2 mated pairs at North Pond and several more adults at South Pond.

Enallagma doubledayi (Atlantic Bluet)

I captured one male at North Pond on 9 August 1994 (Roble, 1994), my only encounter with this species in Virginia during the past seven field seasons. The only other published locality record for Virginia is from Blacksburg (Gloyd, 1951), although Carle (1988) tallied 11 records for the state. Westfall & May (1996) stated that *E. doubledayi* occurs primarily in the southeastern United States, although it ranges north to Cape Cod, Massachusetts (Carpenter, 1991). Donnelly (1961) reported this species from two sites in Maryland near the District of Columbia on the basis of collections made in 1900 and 1916, but there are no recent records of *E. doubledayi* from that state (R. L. Orr, pers. comm.). Resener (1970) reported this species from one county (Taylor) in Kentucky, but this record may be based on a previously misidentified, pre-1950 specimen (C. Cook, pers. comm.). Glotzhober (1995) stated that both Ohio specimen records were obtained on the same date in 1897. The Atlantic bluet has not been recorded from Tennessee or West Virginia (Westfall & May, 1996), but it is fairly common in eastern North Carolina (R. D. Cuyler, pers. comm.).

Enallagma exsulans (Stream Bluet)

A male of this stream-breeding species that I captured at South Pond on 27 July 1995 was undoubtedly a stray from a stream in the Big Levels area (but probably not Canada Run).

**Enallagma geminatum* (Skimming Bluet)

I found a few adults, including a mating pair, at South Pond on 18 August 1993, my only records for this species.

**Enallagma signatum* (Orange Bluet)

My observations indicate that the orange bluet is uncommon in the Maple Flats pond area.

**Ischnura hastata* (Citrine Forktail)

This tiny species is also uncommon in the Maple Flats pond area, being most abundant in the Horseshoe Swamp marsh habitat.

**Ischnura posita posita* (Fragile Forktail)

The fragile forktail is perhaps the most common damselfly in the study area.

**Ischnura verticalis* (Eastern Forktail)

Considering how common and widespread the eastern forktail is in western Virginia, it is surprisingly uncommon in the study area.

**Nehalennia integricollis* (Southern Sprite)

My discovery of a small population of this species at South Pond was unexpected. The southern sprite is primarily a Coastal Plain species, with scattered records from the Piedmont, which ranges from southern Rhode Island and Long Island, New York south to Florida and west to eastern Oklahoma and Texas (Fig. 4). In Virginia, it is known only from two other counties (Roble, 1994). The only other record of *N. integricollis* from the Blue Ridge region is from Rabun County, Georgia, where two males were collected by Minter J. Westfall, Jr. on 12 June 1972 at a pond near Satolah (specimens in the Florida State Collection of Arthropods; W. F. Mauffray, pers. comm.).

I found adults of the southern sprite only along the boggy western shoreline of South Pond (mostly concentrated in a 15 m section) and a nearby forest trail in several different years of this study. Dominant vegetation along the pond edge in the area of their greatest density was *Sphagnum* sp., *Eleocharis smallii*, *Dulichium arundinaceum*, and (less so) *Carex gynandra*. I observed a maximum of 75 adults on any one visit, usually including both mature and teneral individuals.

Lestidae

**Lestes congener* (Spotted Spreadwing)

This is a late summer and fall species that I encountered in low densities (typically < 25 adults) at several ponds in the Maple Flats area. It was most abundant at South Pond, where at least 125 adults were observed on 21 October 1994. My earliest record was 10 June.

**Lestes disjunctus australis* (Common Spreadwing)

This subspecies is very similar to *Lestes forcipatus* and therefore difficult to readily distinguish in the field (Walker, 1952). I found only a few adults at Loves Run Pond and the Maple Flats pond complex; it was not recorded at Green Pond.

**Lestes eurinus* (Amber-winged Spreadwing)

This northern species is most common at Loves Run Pond, being decidedly scarce at Maple Flats and Green

Table 4. Seasonal distribution of Odonata at the Shenandoah Valley sinkhole pond system and vicinity, Augusta County, Virginia.

Month	Apr.	May	June	July	Aug.	Sept.	Oct.	Early and Late Flight Dates
Species	Period ^a	3	2 3	1 2 3	1 2 3	1 2 3	1 2 3	* = Extreme date for Virginia ^b
<i>Calopteryx maculata</i>			x x	x x	x x			10 June - 30 August
<i>Lestes congener</i>			x	x	x	x x	x x	10 June* - 21 October
<i>L. disjunctus australis</i>			x	x x	x			10 June - 30 August
<i>L. eurinus</i>			x x	x x x				10 June - 27 July
<i>L. forcipatus</i>			x x	x x x	x x x	x x	x	13 June - 21 October*
<i>L. rectangularis</i>			x	x x	x x x	x x		24 June - 26 September
<i>L. vigilax</i>			x x	x x	x x x	x x	x	10 June - 21 October*
<i>Argia fumipennis violacea</i>		x	x	x x x	x	x x		31 May - 19 September
<i>Chromagrion conditum</i>	x		x x x					29 April - 24 June
<i>Enallagma aspersum</i>		x	x x x	x x x	x x	x x x		31 May - 26 September*
<i>E. basidens</i>			x	x	x		x	13 June - 21 October*
<i>E. civile</i>				x	x		x x	13 July - 21 October*
<i>E. divagans</i>			x					13 June
<i>E. doubledayi</i>					x			9 August
<i>E. exulans</i>				x				27 July
<i>E. geminatum</i>					x			18 August
<i>E. signatum</i>		x	x	x	x			31 May - 9 August
<i>Ischnura hastata</i>		x	x x x	x x	x x x	x	x x	31 May - 21 October
<i>I. posita posita</i>	x	x x	x x x	x x x	x x x	x x x	x	29 April - 13 October*
<i>I. verticalis</i>	x	x	x x x	x	x x	x x x	x	29 April - 13 October*
<i>Nehalennia integricollis</i>				x x x	x x			6 July - 18 August
<i>Tachopteryx thoreyi</i>			x					18 June
<i>Aeshna constricta</i>							x x	2 October* - 29 October*
<i>A. mutata</i>			x x					10 June - 20 June*
<i>A. tuberculifera</i>							x x	2 October - 29 October*
<i>A. umbrosa umbrosa</i>				x	x x	x		25 July - 26 September
<i>Anax junius</i>	x		x x x	x x x	x x x	x x x	x	29 April - 13 October
<i>A. longipes</i>			x x	x x				10 June - 27 July
<i>Boyeria grafiana</i>					x			18 August
<i>B. vinosa</i>					x x			9 August - 18 August
<i>Epiaeschna heros</i>		x	x					31 May - 13 June
<i>Gomphaeschna furcillata</i>		x	x					31 May - 13 June*
<i>Gomphus exilis</i>			x x	x				3 June - 13 July
<i>Cordulia shurtleffi</i>	x		x x					29 April* - 20 June
<i>Epithea cynosura</i>	x	x x	x x					29 April - 13 June
<i>Somatochlora tenebrosa</i>				x x	x x	x x x		13 July - 26 September
<i>Didymops transversa</i>	x		?					29 April (- 13 June ?)
<i>Celithemis elisa</i>		x x	x x x	x x	x x x	x x		20 May - 26 September*
<i>C. fasciata</i>				x x				13 July - 27 July
<i>C. martha</i>				x	x			27 July - 30 August
<i>C. verna</i>		x	x x x	x x	x			31 May - 18 August*
<i>Erythemis simplicicollis</i>			x x x	x x	x x x	x x		10 June - 26 September
<i>Erythrodiplax minuscula</i>					x x x			9 August - 30 August
<i>Leucorrhinia intacta</i>	x		x x x	x				29 April* - 25 July*

Table 4 (continued).

Month	Apr.	May	June	July	Aug.	Sept.	Oct.	Early and Late Flight Dates
Species	Period ^a	3	2 3	1 2 3	1 2 3	1 2 3	1 2 3	* = Extreme date for Virginia ^b
<i>Libellula auripennis</i>			x x	x x	x x			10 June - 30 August*
<i>L. axilena</i>			x	x x				13 June - 27 July
<i>L. cyanea</i>			x x x	x x	x			10 June - 5 August
<i>L. deplanata</i>	x	x	x x	x				29 April - 8 July*
<i>L. incesta</i>			x x	x x	x x x	x x		10 June - 26 September
<i>L. luctuosa</i>			x	x	x			20 June - 18 August
<i>L. lydia</i>	x		x x x	x x x	x x x	x		29 April - 9 September
<i>L. pulchella</i>			x x	x	x	x x		3 June - 20 September*
<i>L. semifasciata</i>		x	x x	x x x				31 May - 27 July
<i>Pachydiplax longipennis</i>			x x x	x x	x x x	x		10 June - 26 September
<i>Sympetrum rubicundulum</i>			x x	x x x	x x	x x x	x x x	20 June - 21 October
<i>S. semicinctum</i>							x	29 October*
<i>S. vicinum</i>				x	x x x	x x x	x x	25 July - 29 October
<i>Tramea carolina</i>		x	x x x	x x	x x x	x		31 May - 9 September
<i>T. lacerata</i>			x		x x			18 June - 30 August
<i>T. onusta</i>				x				2 July*

^a 1 = 1st to 10th days of the month; 2 = 11th to 20th days; 3 = 21st day to the end of the month; no data for missing periods.

^b Exceeds or equals early or late date reported by Carle (1982), Roble (1994), Roble & Hobson (1996) or Roble et al. (1997); see species accounts for more details.

Pond. I observed at least 300 adults at Loves Run Pond on 20 June 1995.

**Lestes forcipatus* (Sweetflag Spreadwing)

My observations indicate that this is the most common spreadwing in the Maple Flats pond complex. My highest counts (300+ adults) were obtained at Spring Pond on 18 August 1993 (including 40+ mated pairs) and 27 July 1995. On 18 June 1998, Paul Bedell and I observed Cedar Waxwings (*Bombycilla cedrorum*) preying on teneral spreadwings, presumably *L. forcipatus*, at Green Pond. On 27 July 1995, I observed a mature female *L. forcipatus* preying on a teneral fragile forktail (*Ischnura posita*). A male *L. forcipatus* was observed clasping a female *L. congener* at Twin Pond on 30 August 1996. Shortly before dusk on 19 September 1994, I collected what appeared to be a nearly dead mating pair of *L. forcipatus* from the surface of this same pond.

Westfall & May (1996) reported that the known flight period of *L. forcipatus* throughout its range extends from 4 April to 22 September. My latest record (as reported previously in Roble, 1994) was 21 October, when I found one female at Spring Pond. This species was common at that pond on 26 September of the same year.

**Lestes rectangularis* (Slender Spreadwing)

Only a few scattered individuals of this elongate species were found at Loves Run Pond and in the Maple Flats pond area.

**Lestes vigilax* (Swamp Spreadwing)

I encountered relatively few individuals of the swamp spreadwing during my surveys. This species was most common at Spring Pond (>100 adults observed on several dates), where I found it as late as 21 October.

ANISOPTERA (Dragonflies)

Petaluridae

Tachopteryx thoreyi (Gray Petaltail)

My only record for this large, primitive dragonfly that breeds in seepage habitats was an adult that I observed momentarily along a forest trail near Loves Run Pond on 18 June 1998. This species may breed in seeps near this pond as well as additional seeps near Spring Pond and Horseshoe Swamp, but I did not observe adults in these other areas and larval surveys were not conducted at any seepage habitats. This species was previously recorded

Table 5. Species diversity of Odonata in the Maple Flats ponds area and vicinity (Big Levels) as compared to the Odonata fauna of Virginia.

FAMILY	MAPLE FLATS	BIG LEVELS	VIRGINIA	PERCENT
Calopterygidae	1	1	7	14.3
Lestidae	6	6	10	60.0
Coenagrionidae	14	14	37	37.8
Total Zygoptera	21	21	54	38.9
Petaluridae	0	1	1	100.0
Aeshnidae	8	10	16	62.5
Gomphidae	1	1	39 ^a	2.6
Cordulegastridae	0	0	5	0.0
Corduliidae	3	3	19	15.8
Macromiidae	1	1	5	20.0
Libellulidae	21	23	43 ^b	53.5
Total Anisoptera	34	39	128	30.5
Total Odonata	55	60	182	33.0

^aExcludes one reported but unconfirmed species

^bExcludes two accidental species

from Augusta County by Carle (1982), who captured a female near the Calfpasture River about midway between West Augusta and Deerfield.

Aeshnidae

Aeshna constricta (Lance-tipped Darner)

Carle (1982) reported that he collected single males on 2 October 1977 and 29 October 1978 at Quarles Pond, one of only two known sites for this northern species in Virginia (Fig. 5). This darner ranges south to Kentucky and Tennessee, but there are no records for North Carolina (Trogon, 1961; Resener, 1970; Huggins & Brigham, 1982; Bick, 1997; R. D. Cuyler, pers. comm.).

**Aeshna mutata* (Spatterdock Darner)

This spring and early summer species was recorded at both Loves Run Pond and Quarles Pond. I observed 4-6 adult males at the former site on 20 June 1995 (two collected), but saw only 1-2 on 10 June 1996 and none on 18 June 1998. The former record establishes a new late date for this species in Virginia, exceeding the date listed in Carle (1982, 1991) by a full week. Beatty & Beatty (1969) reported that females of this species preferentially oviposit in spatterdock (*Nuphar lutea* ssp. *advena*), which accounts for its recently coined common name. This aquatic plant is absent at Loves Run Pond, but Carr (1938,

1940) stated that it is dominant at Quarles Pond (reported as Green Pond). Carle (1982) indicated that he collected 35 adults (28 ♂, 7 ♀) and 25 exuviae of *A. mutata* at the latter site on 13 June 1980. The Quarles Pond population of this species is one of the largest known rangewide (F. L. Carle, pers. comm.). Carle (1991) recommended *A. mutata* for threatened status in Virginia, but it remains unprotected in the state. The spatterdock darner has been recorded from a total of seven sites in four Virginia counties (Fig. 5). It is widespread but very local in the northeastern and midwestern portions of the United States.

+*Aeshna tuberculifera* (Black-tipped Darner)

Carle (1982) reported that he collected adults at the Maple Flats ponds (= North and/or South Pond; F. L. Carle, pers. comm.) on 2 October 1977 (1♂, 1♀) and at Quarles Pond on 29 October 1978 (1♂). My only records of *A. tuberculifera* were two males that I captured at South Pond on 21 October 1994. This northern species may breed in the study area. Halverson (1984) reported that it has a 2-year life cycle in the mountains of Virginia; his study sites were small (5-15 m diameter), man-made, fishless ponds on the George Washington National Forest. This species has been recorded from a total of eight counties in Virginia (Fig. 5) and ranges south to western North Carolina (Cuyler, 1984). There are no records for Kentucky or Tennessee (Trogon, 1961; Resener, 1970; Bick, 1997).

+*Aeshna umbrosa umbrosa* (Shadow Darner)

The shadow darner was recorded several times at the Maple Flats ponds, but only a few individuals were seen on each occasion. I suspect that it breeds in the area in low density. A lone male was observed at Loves Run Pond on 30 August 1996. The only individual of this species that I observed at Green Pond (25 July 1997) was an adult female that was apparently the subject of an attempted mating by a male *Anax junius*. I netted them as they were struggling in a sedge clump along the shoreline of this pond. Surber's (1951) report of *Aeshna* nymphs from the St. Marys River presumably refers to this species. Walker (1958) stated that, unlike most species of *Aeshna*, *A. umbrosa* prefers shady habitats and typically breeds in streams or ditches rather than lakes or ponds. However, Halverson (1984) documented this species breeding in small mountain ponds in Rockingham County, Virginia.

**Anax junius* (Common Green Darner)

This species is common in the Big Levels area, and was recorded at virtually every study pond. I observed a group of four males tumbling to the surface of Split Level

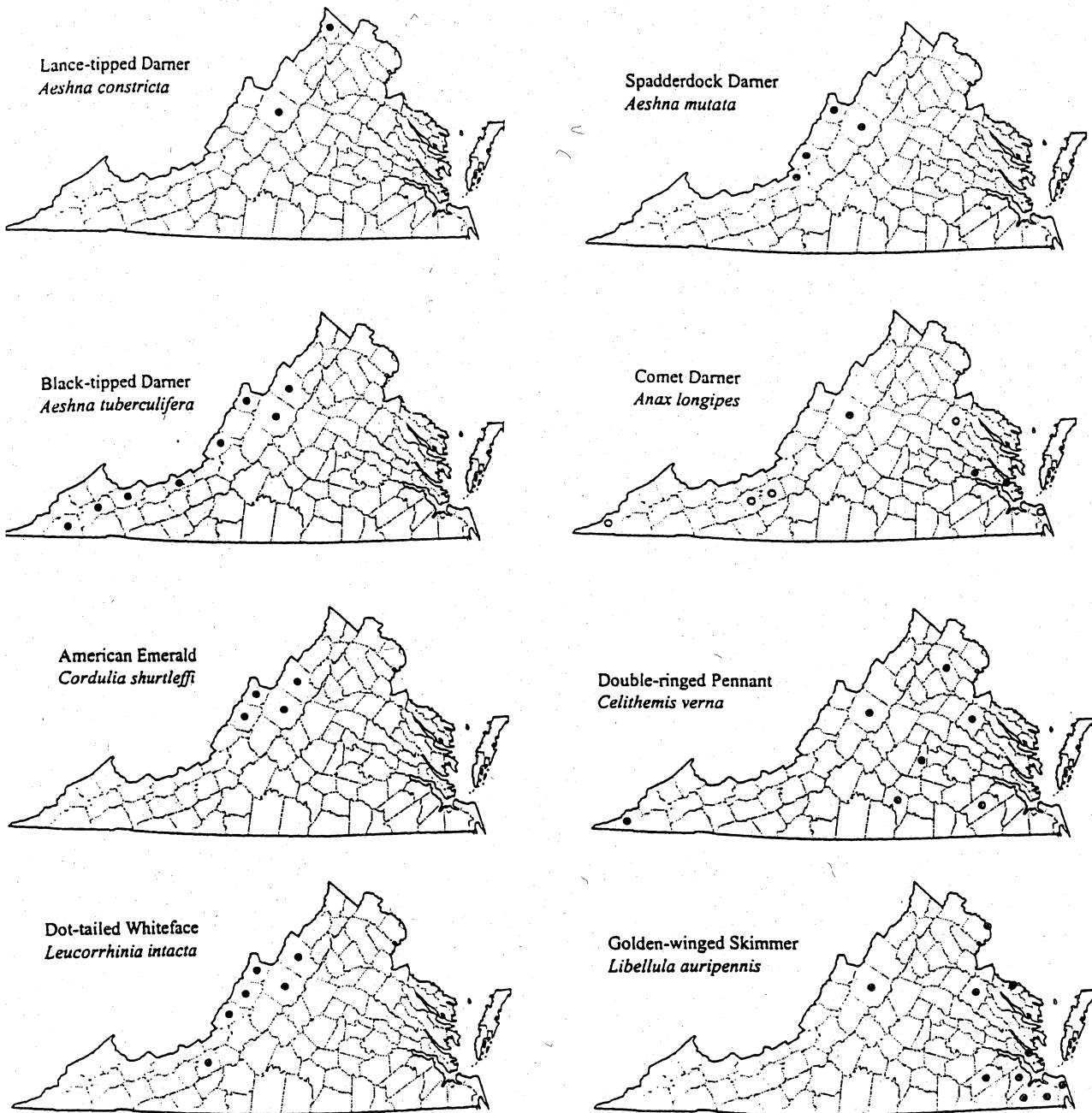


Fig. 5. Documented Virginia distribution (by county) for eight species of state-rare or uncommon dragonflies (Anisoptera) recorded in the Shenandoah Valley sinkhole pond system. Solid circles denote records supported by voucher specimens, half-filled circles signify photographic records, and open circles indicate records based solely on observations.

Pond at 1830 h on 13 July 1995, apparently as the result of a territorial skirmish. Exuviae were abundant at Loves Run Pond, particularly on the stems of highbush blueberry bushes that bordered the pond; they were found at heights of 0.2 to 2 m (most >1 m).

**Anax longipes* (Comet Darner)

Three males of this large, unmistakable dragonfly (males have bright red abdomens) were observed at Quarles Pond on 17 July 1980 by Boris C. Kondratieff (Carle, 1982). I observed up to 10 males during several June visits to Loves Run Pond (one collected); two were also seen at the nearby marshy pond on 20 June 1995. Single males were found on two occasions at Horseshoe Swamp. The comet darner has been recorded from only eight counties in Virginia (Fig. 5), mostly on the basis of sight records. The first records of this species from Pulaski and Montgomery counties are based on observations of single males made by C. Shay Garriock (pers. comm.) of the Virginia Department of Game and Inland Fisheries during 1997 (one date) and 1998 (two dates), respectively. Although *A. longipes* is not globally rare, this species is considered rare to uncommon in virtually all of the states throughout its range (e.g., Carle, 1979,

1989; Carpenter, 1991). It typically breeds in semipermanent, grassy ponds that lack fish (Dunkle, 1989).

Boyeria graefiana (Ocellated Darner)

This species typically inhabits rocky rivers and large streams. I captured a male at dusk on 18 August 1993 along Forest Service Road 42 (Coal Road) near South Pond. It probably breeds in the Big Levels area, but I did not attempt to locate any local populations.

Boyeria vinosa (Fawn Darner)

This is primarily a stream and river-dwelling species. Adults were seen at dusk along Forest Service Road 42 (Coal Road) near South Pond on several occasions. One adult was also found along a trail between North and South ponds on 9 August 1994. Like the preceding species, the fawn darner probably breeds in the Big Levels area, but I did not attempt to locate any local populations.

Epiaeschna heros (Swamp Darner)

I observed one adult of this large darner very briefly at North Pond on 31 May 1995. Two or three adults (1-2 ♂, 1 ♀) were also observed at Horseshoe Swamp on 13 June 1997. Halverson (1984) determined that *E. heros*

Table 6. Relative status (in Virginia) of the Odonata species documented in the Shenandoah Valley sinkhole pond system and vicinity. Data are expressed as the number of species followed by the percentage of total species in each row.

	Rare (S1-S2) ^a	Uncommon (S3)	Common (S4-S5)
Maple Flats ponds			
All species	7 (13)	12 (22)	36 (65)
Breeders	7 (14)	9 (19)	32 (67)
Loves Run	4 (13)	6 (20)	20 (67)
Green Pond ^b	1 (6)	2 (12)	14 (82)
Quarles Pond ^c	5 (28)	0 (0)	13 (72)
Shenandoah Valley ponds ^b (total)	9 (15)	13 (22)	37 (63)

^a Natural Heritage ranks (1-5 scale ranging from extremely rare to very common; based largely on the number of known and estimated populations in the state).

^b Excludes *Leucorrhinia frigida* due to the uncertain origin of the historical specimen and *Tramea onusta* which is classified as a vagrant or accidental species in Virginia.

^c Anisoptera only (data from Carle, 1982).

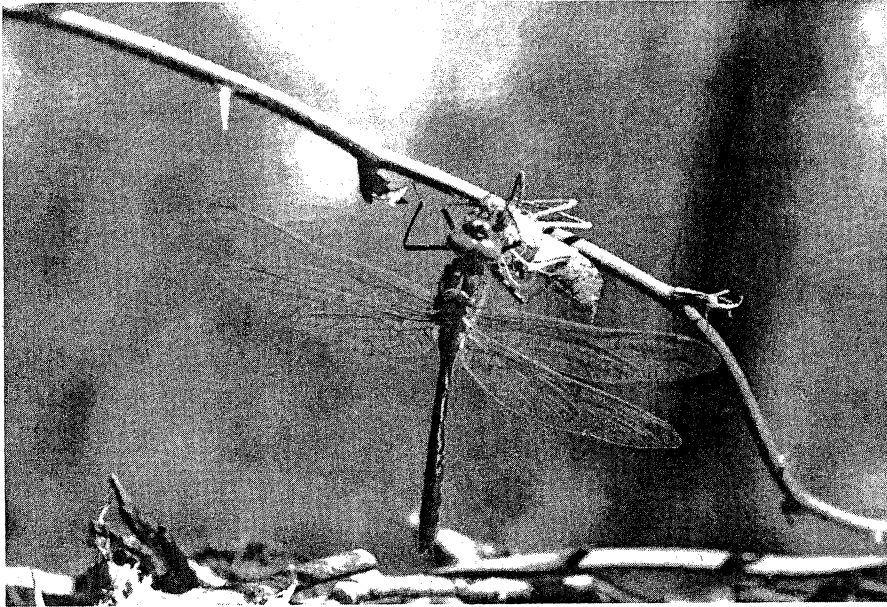


Fig. 6. Newly emerged adult male American emerald (*Cordulia shurtleffi*) beside its exuvia; photographed at Oak Pond on 29 April 1997 by the author.

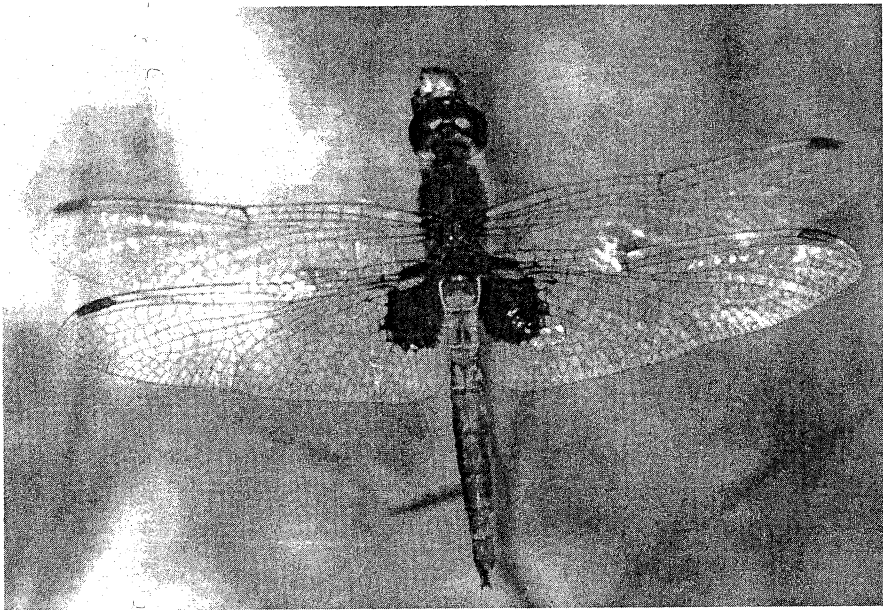


Fig. 7. Adult male Martha's pennant (*Celithemis martha*); photographed on Cape Cod, Massachusetts by Blair Nikula.

bred during only one of four consecutive years (and at low densities) at a series of small mountain ponds on the George Washington National Forest in Rockingham County. This species may breed in the study area, but is most abundant in Coastal Plain swamps (e.g., Roble & Cuyler, in press).

+*Gomphaeschna furcillata* (Harlequin Darner)

Two adult females were collected at North Pond on 31 May 1995. Subsequently, I discovered a small population at Horseshoe Swamp, although I did not confirm breeding there. Several patrolling males were observed near the swamp-marsh edge on 13 June 1997. This is a record late date for this species in Virginia, exceeding the flight period (8 April - 25 May) given by Carle (1982). I suspect that *G. furcillata* also breeds in pond 18, a swampy, *Sphagnum*-covered pond, but I only visited this site once during mid-summer (i.e., after the adult flight season) and did not sample extensively for larvae on that date. Most previous records of this species in Virginia are from swampy habitats in the Coastal Plain (Carle, 1982; Roble et al., 1997; Roble & Cuyler, in press).

Gomphidae

+*Gomphus exilis* (Lancet Clubtail)

This is the only clubtail that I documented in the study area. My observations indicate that it is uncommon at the Maple Flats ponds, but I suspect it breeds at several ponds in this complex.

Corduliidae

**Cordulia shurtleffi* (American Emerald)

A small population of this northern species inhabits the Maple Flats area, where it is near its southern range limit in eastern North America (see Fig. 5 for Virginia distribution). Breeding was confirmed at Oak Pond, where two teneral males (one recently emerged from its exuvia; see Fig. 6) were found on 29 April 1997. The previous early flight date for Virginia was 25 May (Roble et al., 1997). My April record also appears to establish a new early emergence date for this species, exceeding the rangewide flight period (2 May - 26 August) given by Needham & Westfall (1955), Walker & Corbet (1975), and Carle (1982). At least half a dozen males were also observed patrolling (feeding ?) in the acidic seepage swamp portion of Horseshoe Swamp on 13 June 1997. A larger population of *C. shurtleffi* inhabits the Loves Run Pond. Territorial males patrol just above the surface of this heavily vegetated pond and are difficult to observe and count. I estimated that at least 25 males were present during my survey of 20 June 1995, but noted only one and

2-3 males during subsequent, but less thorough surveys on 10 June 1996 and 18 June 1998, respectively. Carle (1982) did not record this species at Quarles Pond and I did not observe it at Green Pond.

**Epithea cynosura* (Common Baskettail)

This species is very common in the Maple Flats area in early spring. I observed numerous adults just prior to dusk on several occasions along Forest Service Road 42 (Coal Road) near South Pond. Two dead adults were found in spider webs.

+*Somatochlora tenebrosa* (Clamp-tipped Emerald)

Although breeding was not confirmed, I regularly encountered a few adults (maximum of 8/d; mostly females) of this species during my visits to the Maple Flats pond complex in late summer. They were observed at several ponds and along nearby forest trails. It is likely that a small resident population inhabits this area.

Macromiidae

Didymops transversa (Stream Cruiser)

One adult was observed while perched on a sapling branch along a forest trail near North Pond on 29 April 1997. This species probably breeds in Canada Run (possible sighting on 13 June 1997) and other streams in the Big Levels area.

Libellulidae

**Celithemis elisa* (Calico Pennant)

This species is common in the Maple Flats area and at Green Pond. I also found several adults in a gas pipeline right-of-way near Loves Run Pond, but saw only two males at the pond itself (different dates). My record for 26 September exceeds the previously reported (Roble & Hobson, 1996) late date for this species in Virginia by 13 days.

**Celithemis fasciata* (Banded Pennant)

A single male was observed at South Pond on 13 July 1995. Two weeks later I recorded this species at three ponds in the Maple Flats complex, including a mating pair and an ovipositing female at North Pond. These are my only records for this species in the study area.

**Celithemis martha* (Martha's Pennant)

My discovery of a small population of this species at Spring Pond was unexpected. I recorded eight adults (6♂, 2♀), including at least three tenerals, on 27 July 1995. Only two males were observed during a 0.5 h survey of the east end of this pond on 30 August 1996.

Martha's pennant (Fig. 7) is a Coastal Plain species which ranges from Nova Scotia to northern Virginia (Fig. 8). The Maple Flats population is both the most inland and the southwesternmost known locality for this species. Previous reports of *C. martha* from Ohio (Walker & Corbet, 1975) and the Carolinas (Huggins & Brigham, 1982) are not supported by voucher specimens and are believed to be erroneous (Glotzhofer, 1995; Roble & Hobson, 1996).

**Celithemis verna* (Double-ringed Pennant)

This species was documented at four ponds in the Maple Flats area; it was most common at Spring Pond and the buttonbush pond at Horseshoe Swamp (ca. 40 males on 13 June 1997 at latter site). I found two adults of each sex, including one live male, ensnared in spider webs. Available records indicate that *C. verna* is rare in Virginia (Fig. 5). Although it is typically regarded as an early summer species, my records for *C. verna* extend as late as 18 August, exceeding Carle's (1982) latest record for Virginia by two months. Orr (1996) also recorded *C. verna* on 18 August in Maryland. Both of our records establish a new rangewide late flight date for this species, which was previously recorded as 26 July (Needham & Westfall, 1955; Carle, 1982).

**Erythemis simplicicollis* (Eastern Pondhawk)

This species is fairly common in the Big Levels area, but not as abundant as it is in many other lentic habitats throughout Virginia.

**Erythrodiplax minuscula* (Little Blue Dragonlet)

During the first several years of my surveys, I obtained only two records of this diminutive dragonfly from the Maple Flats area; both (1♂, 1♀) were found along a forest trail beside South Pond. On 30 August 1996, I observed a total of five adults (1 mature ♂, 4 teneral ♀) at Spring Pond and the Horseshoe Swamp marsh, thus confirming breeding in the Maple Flats area.

Leucorrhinia frigida (Frosted Whiteface)

Needham & Westfall (1955) reported this boreal species from Virginia for the first time but did not provide detailed locality information. Carle (1982) listed a specimen that he obtained in Highland County on 18 June 1978, and a potentially dubious larval record from Louisa County (Voshell & Simmons, 1976), but he did not include any historical records. The source of the original Virginia record was a specimen in the collection of Cornell University (M. J. Westfall, Jr., pers. comm.). Handwritten label data associated with this specimen (uncertain text is noted in brackets) are: "Green Pond, N.d. [?]{U. of Richmond, Va.}VI 14 1938/Tray [Troy?]

Coll." (J. K. Lieberr, pers. comm.). Although the exact origin of this specimen may never be known, a review of Biggs (1974) reveals that the only "Green Pond" labeled on U.S. Geological Survey topographic maps of Virginia is in Augusta County. Specifically, it is the site treated as Green Pond in the present paper. However, as noted previously, Quarles Pond was referred to as Green Pond in the past by several botanists (e.g., Carr, 1938, 1940). Regardless of whether or not the Cornell specimen of *L. frigida* was collected at one of these two ponds, it appears that there is no resident population of this species at either site. Carle (1982) did not list this species for Quarles Pond and I did not observe it at Green Pond. This species is not included in the various summary tables in this paper.

**Leucorrhinia intacta* (Dot-tailed Whiteface)

Carle (1982) recorded this northern species at Quarles Pond on 13 June 1980. I captured one of two adult males observed at North Pond on 24 June 1992. A small population was subsequently (9 June 1995) discovered at Horseshoe Swamp by DNH botanist J. Christopher Ludwig. I observed this species there on several occasions (maximum of 40-50 males on 13 June 1997), and also recorded it at Oak and Spring ponds. Small populations of *L. intacta* also inhabit Loves Run Pond and Green Pond; my peak counts for both sites were ca. 25-30 males (plus a few pairs). Carle (1982) reported that the flight period of Virginia populations of this species extends from 17 May to 10 July; my records in the study area ranged from 29 April to 25 July.

I observed males of *L. intacta* chasing males of *Celithemis verna* on several occasions at the Horseshoe Swamp buttonbush pond on 13 June 1997. These species are similar in size, which may account for this interspecific agonistic behavior. The Maple Flats area is the only site in Virginia where these species (both are rare in the state) are known to occur syntopically (Fig. 5); *L. intacta* is primarily a northern species and *C. verna* is basically a southern species. The range of *L. intacta* extends south to Kentucky and Tennessee, but there are no records for North Carolina (Trogdon, 1961; Resener, 1970; Huggins & Brigham, 1982; Bick, 1997; R. D. Cuyler, pers. comm.).

**Libellula auripennis* (Golden-winged Skimmer)

I recorded a minimum of 20 males of this species at Loves Run Pond, plus 3-5 more at the nearby marshy pond, on 20 June 1995. At least 10 adult males and three mated pairs were observed at Horseshoe Swamp later that same day (but none was present on 13 June 1997). Otherwise, I noted this species only infrequently in the Maple Flats pond complex (e.g., several adults at South

Pond on 18 August 1993). These are the first Virginia records from outside of the Coastal Plain (Fig. 5). Carle (1982) did not list *L. auripennis* for Quarles Pond. My observation of 30 August exceeds the previous Virginia late date of 18 August that was reported by Roble & Hobson (1996).

+Libellula axilena (Bar-winged Skimmer)

I observed at least 20 males of this species at Loves Run Pond ($n = 5$) and the nearby marshy pond ($n = 15+$) on 20 June 1995. No less than 10 adults were also present at the Horseshoe Swamp marsh on this same date; I saw a maximum of five adults during a subsequent visit on 13 July (one of these was a dying male with very tattered wings), but only one male and one female were recorded on 13 June 1997. At least 10 males were present at Oak Pond on 27 July 1995.

**Libellula cyanea* (Spangled Skimmer)

This species was fairly common in the Maple Flats pond complex (recorded at 5 ponds); it was also present at all of the other study areas.

**Libellula deplanata* (Blue Corporal)

This is a spring and early summer species that was recorded infrequently in the Maple Flats area. I found one live male captured in a spider web on 31 May. My latest record (8 July) exceeds Carle's (1982) latest date for Virginia populations (12 June) by nearly a month.

**Libellula incesta* (Slaty Skimmer)

This species was common and widespread in the Maple Flats pond complex (documented at all study sites except pond 18). It was also recorded at Loves Run Pond and Quarles Pond, but not observed by me at Green Pond.

Libellula luctuosa (Widow Skimmer)

The widow skimmer was surprisingly rare in the study area and apparently not a local breeder. I observed lone males at or near South Pond on 18 August 1993 and 27 July 1995. Lone males were also seen in a gas pipeline right-of-way near Loves Run Pond on 20 June and 27 July 1995.

**Libellula lydia* (Common Whitetail)

This species was common and widespread in the Maple Flats pond complex (documented at eight study ponds). It was also common at Green Pond.

Libellula pulchella (Twelve-spotted Skimmer)

My records for this species in the Maple Flats pond complex are limited to seven individuals (5♂, 2♀) that were observed on six different dates ranging from 10 June

to 20 September; Kurt Buhlmann collected a male at one of these ponds on 3 June 1990. I also observed a lone male at Loves Run Pond on 30 August 1996. Carle (1982) reported that the flight period extends from 29 April to 19 September in Virginia. This species may breed in the study area.

**Libellula semifasciata* (Painted Skimmer)

This species was common in the study area, being most abundant at the Horseshoe Swamp marsh. It was the most abundant skimmer in this sedge marsh on 13 June 1997, when at least 50 adults were present.

**Pachydiplax longipennis* (Blue Dasher)

The blue dasher was common at Loves Run Pond and common to abundant at various ponds in the Maple Flats complex (recorded at 9 of 11 study ponds). It was the dominant species in terms of abundance during one of my few visits to Split Level Pond.

**Sympetrum rubicundulum* (Ruby Meadowhawk)

This late summer and fall species was common in the Maple Flats area, being most conspicuous at South, North, and Twin ponds. It was also common at Loves Run Pond. I did not record it at Green Pond (all of my surveys were in early-mid summer), but Michael S. Hayslett collected a female there on 22 August 1996 (specimen currently in DNH collection).

**Sympetrum semicinctorum* (Band-winged Meadowhawk)

Carle (1982) collected a mated pair of this species at Quarles Pond on 29 October 1978. I did not observe it at any of my study ponds, but have found it elsewhere in Augusta County at the Cowbane Prairie Natural Area Preserve along the South River southwest of Sherando.

**Sympetrum vicinum* (Yellow-legged Meadowhawk)

This late summer and fall species was common and widespread in the study area.

**Tramea carolina* (Carolina Saddlebags)

This reddish species is common in the Big Levels area. It was recorded at all study sites except pond 18.

**Tramea lacerata* (Black Saddlebags)

My few records for this species are limited to South, Twin, and Loves Run ponds. Except for two males that I noted at Twin Pond on 30 August 1996, all of my records consist of one adult per visit. However, these observations include an ovipositing female at Loves Run Pond on 18 June 1998, suggesting that this species breeds in the study area.

Table 7. Comparison of the Odonata fauna of the Shenandoah Valley sinkhole pond system and vicinity, Augusta County, Virginia, with selected other areas in Virginia and the eastern United States.

Reference	State	Locality/Habitat	Pond breeders	Shared species ^a	Overlap as % of Big Levels fauna	Percent similarity ^b
Roble & Hobson 1996	VA	Fort A. P. Hill Military Reservation, Caroline County (Coastal Plain ponds)	59	41	75.9	56.9
Roble & Stevenson 1998	VA	Grafton Ponds, York County (sinkhole pond complex)	36	27	50.0	42.9
Roble & Cuyler in press	VA/NC	Great Dismal Swamp and vicinity (various lentic habitats)	58	34	63.0	43.6
Carle 1982; Flint, unpubl. data; Roble, unpubl. data	VA	Laurel Fork Recreation Area, George Washington Nat. For., Highland Co. (montane beaver pond complex)	50	33	61.1	46.5
Donnelly 1961	VA/MD	Washington, D.C. area (various lentic habitats)	68	44	81.5	56.4
Orr 1996 + pers. comm. additions	MD	Patuxent Wildlife Research Center (various lentic habitats)	76	49	90.7	60.5
Ahrens 1968; Orr 1998	MD/WV	Cranesville Swamp (montane bog and beaver ponds)	50	34	63.0	48.6
Harwood 1974	WV	Pendleton County (various lentic habitats)	28	22	40.7	36.7
Harwood 1979	WV	Pocahontas County (various lentic habitats)	32	21	38.9	32.3
Shiffer & White 1995	PA	Ten Acre Pond, Centre County	71	42	77.8	50.6
White et al. 1968	PA	Bear Meadows Bog, Centre County	47	28	51.9	38.4
White 1989	ME	Acadia National Park and vicinity (various lentic habitats)	87	36	66.7	34.3
Gibbs & Gibbs 1954; Carpenter 1991; Nikula 1996	MA	Cape Cod, Barnstable County (Coastal Plain ponds)	84	48	88.9	53.3
Van Buskirk 1992	MI	Isle Royale National Park	43	10	18.5	11.5
Cross 1955; Kondratieff & Pyott 1987	SC	Savannah River Plant (various lentic habitats)	41 ^c	23 ^c	65.7	43.4

^a Species in common with the fauna of the Shenandoah Valley sinkhole pond (SVSP) system and vicinity; based on 54 species of pond-breeding Odonata documented at the Maple Flats pond complex, Loves Run Pond, Quarles Pond, and Green Pond, including 35 species of Anisoptera (dragonflies).

^b Percent similarity = Number of Shared Species / (Total Species from SVSP system and vicinity + Total Species at comparison site - Number of Shared Species)

^c Only includes Anisoptera.

Tramea onusta (Red-mantled Saddlebags)

An adult male that was collected at Green Pond on 2 July 1991 by C. A. Pague constituted only the third documented record of *T. onusta* in Virginia (Roble et al., 1997). I did not observe this species during three early-mid summer visits to this site and doubt if it breeds in the Big Levels area. *Tramea onusta* is primarily a southern species that wanders widely in late summer. I regard it as a vagrant or accidental species in Virginia.

DISCUSSION

The dragonfly and damselfly fauna of the Shenandoah Valley sinkhole pond system is rather diverse, accounting for nearly one-third of Virginia's known Odonata fauna (Table 5). Excluding the families Calopterygidae, Gomphidae, Cordulegastridae, and Macromiidae, the members of which breed primarily or exclusively in running water, this percentage becomes even greater (45%). I regard this community of dragonflies and damselflies as one of the most diverse and interesting assemblages of lentic species known in the state. It contains a considerable number of species that are monitored as rare or uncommon taxa (Roble, 1996) by the Virginia Department of Conservation and Recreation's Division of Natural Heritage (Table 6). The proportion (= 15%) of state-rare species of Odonata that inhabit the Shenandoah Valley sinkhole pond system is virtually identical to that documented for the Fort A. P. Hill Military Reservation in Caroline County, which Roble & Hobson (1996) also regarded as a significant lentic Odonata fauna. The vascular flora of sinkhole ponds and seepage wetlands in the study area contains a comparable proportion of state-rare species (34 of 274 species, or 12%) (Fleming & Van Alstine, 1999), whereas only one state-rare amphibian has been documented at sinkhole ponds in this region (Mitchell & Buhlmann, 1999).

The composition of the Odonata fauna of the Shenandoah Valley sinkhole pond system is compared with other sites in Virginia and the eastern United States in Table 7. The Shenandoah Valley fauna is considerably more diverse than the recently documented (Roble & Stevenson, 1998) fauna of the Grafton Ponds sinkhole complex (York County) on Virginia's Lower Peninsula and is comparable in diversity to the Coastal Plain pond fauna of Fort A. P. Hill (Caroline County) and the montane beaver pond fauna of the Laurel Fork Recreation Area (Highland County). Although the latter site is nearer to the Shenandoah Valley study area, Fort A. P. Hill shares a considerably greater (76% vs. 61%) proportion of the fauna. The areas exhibiting the greatest species overlap with the Shenandoah Valley sinkhole pond system are the Patuxent Wildlife Research Center in eastern

Maryland and Cape Cod, Massachusetts (Table 7). During a nine-year survey of the former site, Orr (1996; pers. comm.) documented 54 of the 60 species present in the Shenandoah Valley study area, including 20 of 21 damselflies. Only the following species were not recorded at his study site: *Enallagma doubledayi*, *Aeshna constricta*, *A. tuberculifera*, *Boyeria grafiana*, *Cordulia shurtleffi*, and *Leucorrhinia intacta*. The fauna of Cape Cod includes 52 of the 60 species documented in the Shenandoah Valley study area.

The geographic affinities of the Odonata fauna of the Shenandoah Valley sinkhole pond system are summarized in Table 8. As expected, my analysis reveals a preponderance (67%) of species that are widespread in eastern North America or the entire continent. Most of the remaining species are evenly divided between those with predominantly northern or southern distributions. As noted previously in the species accounts, the discovery of apparently isolated populations of *Celithemis martha* and *Nehalennia integricollis*, both of which have predominantly Coastal Plain distributions, was unexpected. Curiously, the former species is at the extreme southwestern limit of its range at Maple Flats, whereas the latter species is known primarily from the southeastern United States (compare Figs. 4 and 8).

Table 8. Geographic affinities of the Odonata fauna of the Shenandoah Valley sinkhole pond system and vicinity.

Distribution	Maple Flats ponds		Shen. Valley study ponds	Percent
	All species	Breeders		
Continental	9	9	9	15.0
Eastern	28	23	31	51.7
Northern	7	7	8	13.3
Southern	7	6	8	13.3
Midwestern	1	1	1	1.7
Appalachian	1	0	1	1.7
Coastal Plain	2	2	2	3.3
Endemic	0	0	0	0
Total	55	48	60	100

Fleming & Van Alstine (1999) performed a similar geographic analysis for the vascular flora that has been documented at sinkhole ponds and seepage wetlands in the Big Levels - Maple Flats area. They determined that the majority of these species were widely distributed, which agrees with the results for Odonata. Plant species with more restricted ranges were dominated by northern species, followed by southeastern taxa and Coastal Plain species. The latter group accounted for 7.3% of all plants in the Big Levels - Maple Flats wetlands and 10.9% of those at sinkhole ponds (Fleming & Van Alstine, 1999).

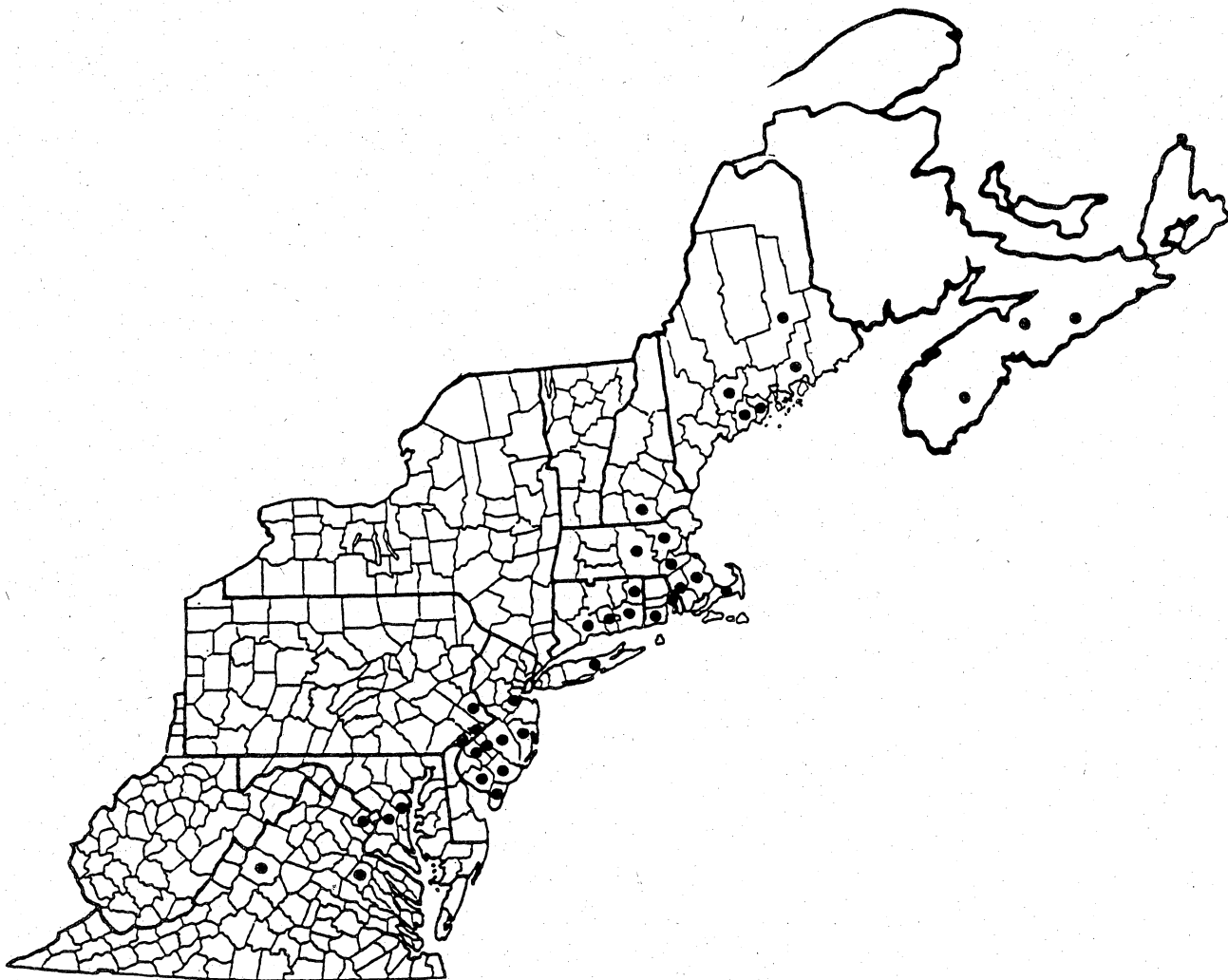


Fig. 8. Geographic distribution (by county) of Martha's pennant (*Celithemis martha*). See Appendix for data sources.

By comparison, only two of the 55 species (3.6%; increases to 4.2% if non-breeders are excluded) of Odonata that I recorded at the Maple Flats ponds have primarily Coastal Plain distributions. The Maple Flats flora also includes one species that is endemic to the Shenandoah Valley (and another that is endemic to Virginia), whereas there are no endemic species of Odonata in Virginia.

Craig (1969) conducted a palynological study of Spring Pond (reported as Hack Pond) and concluded that an oak-hickory forest replaced the preceding spruce-dominated (boreal) forest about 10,000 B.P. during glacial retreat. Harvill (1992) postulated that elements of the Coastal Plain flora that occur in the Shenandoah Valley migrated inland after the decline of the boreal forest but while the climate of the region was still oceanic. He further believed that as the climate of the region

became more continental, most populations of these (moisture-sensitive) plant species were extirpated, leaving only a few relict populations in particularly suitable habitats.

Shapiro (1971) reported that a number of butterfly species exhibit disjunctions in their ranges between Atlantic Coastal Plain and Great Lakes populations, a well-known phenomenon in plants. To my knowledge, none of the butterfly species with strong breaks in their ranges (e.g., black dash, *Euphyes conspicuus*) has been recorded in the Shenandoah Valley of Virginia. Prior to my study, the tiger salamander (*Ambystoma tigrinum*) was the only animal that was confirmed to occur in the Shenandoah Valley sinkhole pond system as a disjunct population from the Coastal Plain region of Virginia (Buhlmann & Hoffman, 1990).

If Harvill's (1992) dispersal hypothesis is correct, perhaps *Celithemis martha* and *Nehalennia integricollis* reached the Maple Flats sinkhole pond complex by a similar route and now represent relict populations. The only site where the former species was documented during this study is Spring Pond, which is the most unique habitat in the Maple Flats area (Rawlinson & Carr, 1937; Fleming & Van Alstine, 1999). Fleming & Van Alstine (1999) stated that the dominant plant community of Spring Pond may represent a Coastal Plain disjunct. The most comparable wetland known to me in Virginia is a large, boggy, golden club-dominated pond on the Fort A. P. Hill Military Reservation, where *C. martha* also occurs (site 29 in Roble & Hobson, 1996). This species was documented at five other boggy ponds on that military base as well as one small, boggy pond located elsewhere in the county; *N. integricollis* was recorded at five sites on the base. These sites are approximately 150 km east of the Maple Flats ponds, but represent the nearest confirmed populations of both species to date (Roble, 1994; Roble & Hobson, 1996).

More intensive sampling of the Odonata fauna of the Shenandoah Valley sinkhole pond system may reveal the presence of additional species that were not documented during this study. Notable absences include the unicorn clubtail (*Arigomphus villosipes*), wandering glider (*Pantala flavescens*), and eastern amberwing (*Perithemis tenera*). Additional surveys of Quarles and Spring ponds are particularly warranted, as is sampling of other ponds in the Maple Flats (e.g., Deep Pond) and Loves Run pond complexes that were not included in the present study. Nearby ponds outside of the forest service boundary, such as Hattons Pond and the five ponds in the Sherando Pond complex (*sensu* Buhlmann et al., 1999), have not been surveyed for Odonata. Apparently, no historical collections of Odonata (or other aquatic insects) are available from a site known as Mountain Lake, Shenandoah Acres, the largest sinkhole pond in the Big Levels region. This was a botanically significant site (Carr, 1938, 1940), but it was destroyed sometime during the past half century and currently functions as a recreational swimming pond for a private campground. The only invertebrate records known to me from this site are of two state-rare skippers, one of which was mentioned in Clark & Clark (1951). These authors listed a 5 July 1937 record of the two-spotted skipper (*Euphyes bimacula*), which constituted the first Virginia record of this species (female specimen in USNM). A specimen of the mottled duskywing (*Erynnis martialis*) that was collected near this sinkhole pond on the same date is also in the USNM.

There is an urgent need to survey many other sinkhole ponds in the Shenandoah Valley of Augusta, Rockingham, and southern Page counties for rare and unusual aquatic

insects, as well as amphibians. Many of these ponds, most of which are privately owned, have been visited by botanists (e.g., Longbottom & Van Alstine, 1995; Van Alstine, 1996), but very few have been surveyed by zoologists. It will be interesting to learn if other groups of aquatic insects (e.g., Coleoptera, Heteroptera) are represented in the Shenandoah Valley by Coastal Plain disjuncts, boreal relicts, or rare species.

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APPENDIX

Data sources (by state) consulted to prepare the county distribution maps of *Nehalennia integricollis* (Fig. 4) and *Celithemis martha* (Fig. 8). Museum abbreviations are: FSCA/IORI = Florida State Collection of Arthropods and International Odonata Research Institute, Gainesville, Florida; MCZ = Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts; USNM = National Museum of Natural History, Smithsonian Institution, Washington, D.C.; YPM = Peabody Museum of Natural History, Yale University, New Haven, Connecticut.

Alabama: Tennesen et al. (1995)

Connecticut: Wagner & Thomas (in press); D. L. Wagner, pers. comm.

Delaware: no records (H. B. White, pers. comm.)

Florida: Dunkle (1992)

Georgia: Calvert (1913); Root (1924); Williamson (1934); FSCA/IORI; S. W. Dunkle, pers. comm. (unpublished data); W. F. Mauffray, pers. comm. (unpublished data)

Louisiana: Mauffray (1997)

Maine: Borror (1944, 1951); White (1989); Williamson (1922); P.-M. Brunelle, pers. comm.

Maryland: Donnelly (1961); Fisher (1940); Orr (1996); Williamson (1922); USNM; R. L. Orr, pers. comm.

Massachusetts: Carpenter (1991); Howe (1920; reported as *Celithemis ornata*); White (1979); Williamson (1922); MCZ; USNM; YPM

Mississippi: Lago et al. (1979); FSCA/IORI; S. W. Dunkle, pers. comm. (unpublished data); W. F. Mauffray, pers. comm. (unpublished data)

New Hampshire: White & Morse (1973); P.-M. Brunelle, pers. comm.

New Jersey: May & Carle (1996)

New York: Donnelly (1992)

North Carolina: R. D. Cuyler, pers. comm. (unpublished data); FSCA/IORI

Nova Scotia: Brunelle (1997); Cook (1950); Walker & Corbet (1975); P.-M. Brunelle, pers. comm. (unpublished data)

Oklahoma: Bick & Bick (1957); USNM

Pennsylvania: Beatty & Beatty (1971); C. N. Shiffer, pers. comm.

Rhode Island: Carpenter (1998); Nikula (1998); V. A. Carpenter, pers. comm. (unpublished data)

South Carolina: White et al. (1983)

Texas: Johnson (1972)

Virginia: Carle (1982); Gloyd (1951); Matta (1978); Roble (1994); Roble & Hobson (1996)

State distributions (general): Bick (1997); Needham & Westfall (1955); Westfall & May (1996)