

Dragonfly and Damselfly Colonization and Recolonization of a Large, Semi-permanent Pennsylvania Pond

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Abstract - Odonata (dragonflies and damselflies) at Ten Acre Pond in central Pennsylvania have been monitored on a yearly, monthly, and often weekly basis for over half a century, making the Odonata fauna of the pond the most thoroughly documented of any habitat in the United States. Here we summarize the yearly and seasonal distribution of all species reported from 1955 through 2011. Of the 938 Odonata surveys at this semi-permanent pond, 60% are since 1994 when observations were last summarized. Of the 86 species observed at least once, 14 appeared since 1994. Several species that were rare or absent before 1980 have established transient populations, and a few with southern affinities have become well established. The pond's water levels often fluctuate dramatically from year to year and through the year. For populations of "resident" species, recolonization from other local populations occurs efficiently after periods of drought.

Introduction

In the past 50 years, the dragonfly and damselfly fauna of many states and smaller geographic regions have become well known with a myriad of books, publications, and state-sponsored surveys. Those in the northeastern United States include: Pennsylvania (Ahrens et al. 1968; Beatty and Beatty 1968, 1971; Beatty et al. 1969a, 1969b, 1970), Ohio (Glotchober and McShaffrey 2002, Rosche et al. 2008), New York (Donnelly 1992, White et al. 2010), New Jersey (Barlow et al. 2009), Delaware (Delmarva; White 2011), Massachusetts (Carpenter and Ellis 1991, Nikula et al. 2003), New Hampshire (Hunt 2012), Maine (Brunelle and de-Maynadier 2005), and the Eastern United States (Dunkle 2000, Lam 2004, Paulson 2011). Similarly, there are numerous reports about the fauna of specific habitats or local regions in the literature (e.g., White et al. 1968). However, there are few, if any, reports that document the faunal changes at a particular site over an extended period. By virtue of interest and fortuitous circumstances, one of us (C.N. Shiffer) has extended by more than 40 years earlier efforts by others including H.B. White (Shiffer and White 1995, White 1963) to provide a nearly continuous 57-year record of the dragonfly and damselfly populations at Ten Acre Pond in central Pennsylvania that allows us to infer a number of colonization and recolonization events.

Field-Site Description

Ten Acre Pond (40°47'N, 77°57'W; elev. 410 m [1350 ft]) is a semi-permanent pond within about 2 km of western residential areas of State College in Centre

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County, central Pennsylvania (Figs. 1, 2). It is at the edge of the Scotia Barrens, the largest area of pine and scrub oak barrens in Pennsylvania. Poor sandy soils and local climate have discouraged farming. The nearest small headwater streams are more than 1 km north, and there are no larger bodies of water within several km. Other than cultivated fields at the eastern end of the pond, the area is dominated by second-growth forest.

It is uncertain whether the pond existed before the 1880s when Andrew Carnegie bought the area and established the town of Scotia (now abandoned) to support the mining of iron ore (Conklin 1943). Smaller natural vernal ponds dot the local landscape, but it is clear that mining operations and the construction of a railroad grade considerably modified any preexisting pond that might have been present. Aerial photographs taken by the USDA in 1938 and 1957 (USDA) show that the pond was modified by mining activities during World War II. This includes a raised railroad bed that cuts across the pond and isolates a small portion on the north side. Operations extensively disturbed land surrounding the pond to the south and west, much of which has now reverted to scrub forest. At the far western corner of the pond, there are two concrete pillars near the railroad bed with two large pipes at ground level. In the winter and spring water flows out of these pipes from an unknown source and supplements local water drainage in replenishing the pond.



Figure 1. Variations in the size of Ten Acre Pond based on aerial images 14 April 1994 (6.95 ha [17.17 Acres]), 20 August 2012 (3.5 ha [8.64 Acres]), and April 2006 (2.27 ha [5.6 acres]). Contours were georeferenced and overlaid on the 2006 image. North is to the top of the figure.



Figure 2. Two views of Ten Acre Pond. Upper panel: View to the southwest from old railroad bed. Lower panel: View northeast from the southwest corner. Both photographs were taken 7 July 2013 by H.B. White.

The size of Ten Acre Pond varies from temporarily dry to nearly 8 ha (20 A) depending upon local precipitation and summer evaporation (Fig. 1). As water levels drop, portions of the pond become disconnected and may be isolated for more than a year if surface water is not replenished. It is typically a fishless pond; bass, sunfish, and catfish have been introduced at various times only to be extirpated when the pond dries up.

Since monitoring of dragonfly and damselfly populations began in 1955, several years are notable for exceptionally high water levels that took more than a year to fall to more typical levels. Hurricane Agnes in June 1972 produced almost a foot of rain (25 cm; Penn State Weather Center 2013), flooding surrounding forest, drowning many trees and shrubs, and altering pond vegetation as well for several years. Similarly, Hurricane Ivan in early September 2004 caused flooding in areas that had been dry for years. On the other hand, the pond has been almost dry during other years, notably in the early 1960s and again around 2000 and 2007. The pond's changing character from year to year supports unusually diverse and often large Odonata populations (Shiffer and White 1995).

The main pond has a clay bottom overlain by organic sediments in the deeper areas (White 1963). Patches of *Nuphar* (Spatterdock) dominate the surface where the water is deeper than about a meter. Due to fluctuating water levels, the shoreline vegetation varies from year to year with *Cephalanthus* (Buttonbush) forming a band that approximates a high-water contour. In open areas on the southeast of the pond that are flooded every decade or so, *Spiraea* dominates the vegetation (C.N. Shiffer and H.B. White, pers. observ.). A variety of aquatic habitats exist at the pond and other nearby depressions. Nearby Odonata habitats include Buttonbush Pond (40°48'11"N, 77°56'33"W), Cranberry Slough (40°47'56"N, 77°56'58"W), Ore Pit (40°48'08"N, 77°56'47"W) and Leatherleaf Swale (40°47'51"N, 77°56'56"W). In contrast to our previous publication (Shiffer and White 1995), observations of dragonflies and damselflies made at these locations are included when they provide additional seasonal or yearly information.

For most of the period of this study, the pond, though privately owned, has been publicly accessible and generally considered part of the adjacent Pennsylvania State Game Lands #176. In 2006, Helen and Hubert Haugh sold a tract of 208 ha (465 A) containing Ten Acre Pond to Patton Township with provisions to preserve the land as open space (Danahy 2006). Thus, there is reasonable hope that the pond and surroundings will remain undeveloped in the future despite the encroachment of suburban State College.

Survey Methods

There was no systematic survey protocol for this study other than to attempt to record every species seen during a visit to the pond. The duration (typically ≥ 3 h) and completeness of individual surveys varied depending on the time of year, weather conditions, and state of the pond. Having a single observer (C.N. Shiffer) who was familiar with the fauna and who knew the microhabitats where certain species could be found ensured that surveys were purposeful and increased the

likelihood that species, if present at some threshold abundance, would be observed and unusual or new occurrences would be recognized immediately. Few voucher specimens were taken in recent years. Difficult-to-identify species were examined in hand and released, and photographs were frequently taken.

As some measure of the thoroughness of these surveys, one can compare the cumulative list of species compiled by over 30 Odonata specialists who visited the pond over three days in June 2005 as part of the Northeast Regional meeting of the Dragonfly Society of the Americas (Pfeiffer 2005) to the individual censuses by C.N. Shiffer during, and immediately before and after the meeting. Of the 35 species reported by others, all but four were reported by C.N. Shiffer, who observed an additional four species not seen by others. The work by Bried et al. (2012) indicates that the approaches used here more than adequately document the faunal diversity of Odonata at the pond.

The period since 1994, which was not covered in our previous publication (Shiffer and White 1995), includes 60% of the 938 observations since 1955. This interval also emphasizes more visits early and late in the season to more closely document the appearance of species that fly during those times of the year. For example, prior to 1995, the pond had been visited only once in November, whereas there are 44 visits in November since 1994. The month of April also has been more frequently sampled since 1994. Appendix 1 summarizes how often Ten Acre Pond was visited between late March and the end of November in five-year intervals since 1955.

Observations of every species collected, seen, or photographed on all visits to Ten Acre Pond since 1955 are recorded along with other Pennsylvania Odonata records in 1490 pages of several notebooks maintained by C.N. Shiffer. The loose-leaf pages have been scanned and the files distributed on a compact disc to the Frost Museum at Penn State University, The Academy of Natural Sciences of Drexel University, the Carnegie Museum of Natural History in Pittsburgh, and the Florida State Collection of Arthropods in Gainesville, FL, where the CNS collection and the source loose-leaf notebooks are now housed.

Regular monitoring of the pond concluded on 30 June 2011. In 2011, observations were incomplete and only certain species of interest were noted.

Results

Patterns of occurrence of dragonflies and damselflies at Ten Acre Pond

Since 1955 when Odonata observations were first made at Ten Acre Pond, the pond has been visited 938 times, and a total of 86 species of Odonata have been recorded¹. From the first warm days in late March or early April when migrating *Anax junius* (Common Green Darner) arrive from the south to the first hard freeze, usually in November, when *Sympetrum vicinum* (Autumn Meadowhawk) finally succumb, adult Odonata are present at Ten Acre Pond. Appendices 2–6 provide the scientific and common names (Paulson and Dunkle 2012) as well as the occurrence of all Anisoptera (dragonflies) and Zygoptera (damselflies) species found at the pond by year since 1955. The seasonal distributions for those species are displayed in Appendices 7–9, with the earliest and latest dates indicated. In all but a few cases,

the distributions reported here represent seasonal extensions compared to those previously reported.

Discussion

Odonata colonization and recolonization of Ten Acre Pond

In a typical year when water levels are not too low, more than 60 to as many as 70 species of Odonata can be observed at Ten Acre Pond. As with any habitat, some species are resident and common, others are rare, and some are strays from other sites. With yearly fluctuations in water level, the character of the pond changes in ways that favor different species. Consequently, fluctuations in population sizes and the relative abundance of different species exist in a dynamic state that from time to time requires recolonization. The process of recolonization certainly occurs after the pond dries up. Most of these events are unremarkable because they occur for species that are locally and regionally common. Virtually every “resident” species at Ten Acre Pond, including the iconic *Rhionaeschna mutata* (Spadderdock Darner), can claim more than one such event in the past fifty years. Having a record of species present for that period enables us to identify and focus on some conspicuous colonization events that apparently required dispersal from more distant locations.

Among the 86 species recorded at Ten Acre Pond, perhaps 10–15 should be considered strays. They were observed once to several times and come from habitats unlike the pond. For example, *Calopteryx maculata* (Ebony Jewelwing), a common stream species, has been observed nine times. Each time, a single individual was passing through and did not stop. Other species are more problematic because they could potentially establish populations but did not. These would include *Epiptera princeps* (Prince Baskettail) and *Gomphus borealis* (Beaverpond Clubtail). Aside from these rare encounters and sightings of migratory *Pantala flavescens* (Wandering Glider), *P. hymenaea* (Spot-winged Glider), and the early season migrant *Anax junius* (Common Green Darner), it is impossible to identify non-resident individuals. The following are examples of species we infer have colonized Ten Acre Pond from other locations in the past 50 years due to their multiyear absences. In some cases the populations have persisted, while others were ephemeral.

Archilestes grandis (Great Spreadwing). This large damselfly is found more commonly at nearby wetlands and always late in the season. For half an hour on 21 October 2001, a female was observed ovipositing in a twig of a *Quercus palustris* Münchh. (Pin Oak) tree 25–30 feet high overhanging the pond. Among Odonata, this species is known for its large range expansion into the Northeast during the last century (Cannings 1989). Interestingly, another species with a similar reputation and with populations in the area, *Enallagma basidens* (Double-striped Bluet), has never been recorded at the pond.

Coenagrion resolutum (Taiga Bluet). This widespread northern species at the southern limit of its distribution established a breeding population from 1984 to 1986 and reappeared briefly in 2001 after 16 years of absence. There are no known populations of this damselfly anywhere nearby at its preferred well-vegetated, often boggy-margined pond habitats, so its brief colonization was surprising.

Enallagma traviatum (Slender Bluet). During a period of relatively high water from 1994 to 1998, this species was a regular resident at the pond. It was seen four other years, but not in the well-sampled 2006 year, despite high water. Those observed were of the *E. t. traviatum* subspecies.

Ladona deplanata (Blue Corporal). The appearance of a population of this southeastern and Atlantic Coastal Plain species in the center of Pennsylvania was unexpected. A single male and a female were seen between 21 May and 4 June 2004, and the species was again seen in small numbers four of the following five years. These were the first records for Centre County and the second known locality for the state of Pennsylvania.

Erythrodiplox minuscula (Little Blue Dragonlet). This is another southern species previously unknown in most of Pennsylvania. Several individuals were recorded in three years (1991, 2006, and 2010), suggesting a breeding population that may have been missed by the small size of adults and the species' restriction to certain microhabitats at the pond.

Libellula auripennis (Golden-winged Skimmer). This brightly colored southeastern species is near its northern geographical limit of distribution in central Pennsylvania. It was seen at the pond in six years before 1996 and in all but three years since 1996.

Libellula cyanea (Spangled Skimmer). After a single male of this conspicuous species was collected in 1961, it did not appear again for 20 years. Following sporadic sightings in the 1980s, it has become a resident being present all but two years since 1990. Its establishment at the pond also represents northward expansion of a species with a more southern and coastal distribution.

Libellula incesta (Slaty Skimmer). This common southeastern and Atlantic coastal species was first observed in 1994. It has established a breeding population at the pond and is now considered resident as it has been present every year since 2002.

Sympetrum obtrusum (White-faced Meadowhawk). This species with northern affinities was observed in 1960 and 1969 but not again until 1996. Thereafter, it has been seen in all but three years.

Sympetrum semicinctum (Band-winged Meadowhawk). Single observations of this species in 1960, 1980, and 1990 were followed by regular sightings almost every year since 1994.

Several other species have displayed periods of multiyear absence and recolonization at Ten Acre Pond, e.g., *Anax longipes* (Comet Darner), *Gomphus spicatus* (Dusky Clubtail), *Lestes unquiculatus* (Lyre-tipped Spreadwing), and *Enallagma ebrium* (Marsh Bluet). However, their patterns grade into those of "resident" species that are not seen in some years. Among those species highlighted for recent colonization, libellulid species with southern and coastal distributions are well represented. Other species with southern affinities that have been showing up occasionally in recent years include *Celithemis eponina* (Halloween Pennant), *Libellula axilena* (Bar-winged Skimmer), and *Libellula vibrans* (Great Blue Skimmer). Whether they will establish a regional presence and become resident will be something to look for in any future survey work.

Climate and changes in species distribution

British biologists S. Brooks, A. Parr, and P. Mill (2007) make a strong case for using dragonflies as climate-change indicators. They suggest that northward range extensions of species with southern geographical distributions are particularly sensitive evidence of a warming climate and identify several instances of recent range extensions of this type in the British Isles. This pattern was noted for additions to the Odonata fauna of Mount Desert Island, ME, in the later part of the last century when eleven of the twelve newly reported species were southern species at their northern limit of distribution (White 1989). Likewise, there are several species associated with more southern and coastal regions that have become resident at Ten Acre Pond over the past half century.

While there is good evidence that the world's climate is warming, to attribute changes in species distribution to these changes requires reliable sustained records that extend over decades and preferably centuries and from multiple locations. Unfortunately, most relevant data are temporally and geographically incomplete. A recent detailed analysis of nearly 20,000 butterfly surveys in Massachusetts by amateur lepidopterists over two decades (Breed et al. 2012) is a notable exception that provides evidence that several species of butterfly are extending their ranges northward. That study shows the value of observations by dedicated amateur naturalists.

Our records of changes in species abundance and occurrence are consistent with climate warming for several key species; however, changes in the geographic distribution of individual dragonfly and damselfly species can be due to any number of factors. Natural successional processes continue to change the character of Ten Acre Pond and its microhabitats making it more or less favorable for different species. Regional increases in farm ponds provide refuges for recolonization after a dry year. Extensive use of ground water to supply the growing city of State College nearby may have and likely will lower the water table that affects water levels in the pond. Consequently, we cannot attribute to climate change with certainty the colonization of Ten Acre Pond by several species with widespread southern distributions over the past half century. Year-to-year variation in precipitation can have far greater effects on Odonata populations than multi-year, gradual increases in average temperature. Nevertheless, the balance of long-term changes we have observed is consistent with climate warming.

Baseline data, such as we have presented here, will help sort out the signal from the noise when future surveys are done. Perhaps some of the northern species near their southern limit that have persisted will retreat. Those studies are left to others to make when they revisit these observations years from now. While we may be able to visit Ten Acre Pond occasionally in the coming years, our intensive efforts ended in June 2011.

Changes in species abundance

The data reported here only indicate the presence or absence of each species in a particular year. Consequently, a single sighting is indistinguishable from a large population, and Appendices 4 and 5 obscure examples of huge population

swings for several species, e.g., *Lestes australis* (Southern Spreadwing) and *Ischnura hastata* (Citrine Forktail). Qualitative information of relative abundance exists in the original field notes of C.N. Shiffer and deposited in the Florida State Collection of Arthropods, Gainesville, FL. All specimens collected at Ten Acre Pond by C.N. Shiffer are also in the Florida State Collection of Arthropods. Those collected by H.B. White will be deposited in the Academy of Natural Sciences of Drexel University.

The second author (H.B. White) visited Ten Acre Pond on three days in early July 2013 and noted the scarcity of damselflies among the 32 species observed. Only one of the five damselfly species seen was common (*Enallagma aspersum*, Azure Bluet) and only a few individuals of one spreadwing species were seen (*Lestes eurinus*, Amber-winged Spreadwing). An additional four species of spreadwings were observed at nearby wetlands. This result is in striking contrast to his observations between 1961 and 1965 when a variety of damselfly species were present in significant numbers. While this may be an anomalous year, it replicates observations of a number of people that damselfly species abundance and diversity during the summer is declining in portions of the eastern US (Hill 2011; Paulson 2004, 2007; White 2002). The populations of dragonflies (Anisoptera) do not appear to be similarly affected.

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Endnotes

- ¹*Enallagma boreale* (Boreal Bluet), a northern species reported in our previous publications, was represented by a single record from in 1955, the first year of surveying Ten Acre Pond, seems anomalous and may represent a misidentified *E. annexum* (Northern Bluet). The specimen has not been located, and we have removed it from the species list for the pond.

Appendix 1. Number of dates on which Odonata observations were made at Ten Acre Pond by monthly quarter in five year intervals between 1955 and 2011.

	1955– 1959	1960– 1964	1965– 1969	1970– 1974	1975– 1979	1980– 1984	1985– 1989	1990– 1994	1995– 1999	2000– 2004	2005– 2009	2010– 2011	Total
March IV		1								2			3
April I		1						1	3	1	1		7
April II		1							2	1	4	2	10
April III					1					1	4	1	9
April IV		1	2	2	2		1		2	1	8	1	19
May I		2	1	2	3		2	1	4		5	1	18
May II		3	1	2			2	2	3		8		23
May III		1	2	5	3	2	5	6	3	7	9	1	42
May IV		5	4	5		6	11	7	4	4	10	2	59
June I	1	11	2	5	2	3	7	6	11	11	12	3	73
June II		2			2	6	6	4	5	11	9	3	48
June III	3	8	1	1	3	2	8	1	4	11	4	1	47
June IV	8	5		1	2	4	6	3	2	11	3	3	48
July I	2	3	4	4	1	3	5	10	6	12	7	1	53
July II	3	1	2	1	1	4	4	4	3	10	6		42
July III	3	2	2	1	1		3	3	5	7	4	1	32
July IV		3	2	1			4	2	9	6	6		33
August I	1	2		1	1	1		2	5	13	4	1	31
August II		2	1	2		1	3	1	4	7	6		27
August III	1	1	1	1		2	1	2	3	13	7	1	33
August IV		2		1	1	1	2	2	7	6	3	1	26
Sept I	1	3		1		1	5	5	8	10	10	1	45
Sept II		3	2	2			3	1	5	10	6		32
Sept III		3					2	2	5	9	7		28
Sept IV		1	1		1		2	2	6	6	4		23
Oct I		2		1			2	1	3	12	4		25
Oct II		2					1		3	10	2	1	19
Oct III	1	1					1	1	2	10	2		17
Oct IV		1							8	10	2		21
Nov I				1					2	15	4		22
Nov II									1	4	6		11
Nov III										8	1		9
Nov IV									1	2			3
Total	24	73	28	39	23	36	83	69	129	241	168	25	938

Appendix 2. Anisoptera species found at Ten Acre Pond, 1955–2011.

Dragonfly common names	Anisoptera species
Canada Darner	<i>Aeshna canadensis</i> Walker
Lance-tipped Darner	<i>Aeshna constricta</i> Say
Black-tipped Darner	<i>Aeshna tuberculifera</i> Walker
Shadow Darner	<i>Aeshna umbrosa</i> Walker
Green-striped Darner	<i>Aeshna verticalis</i> Hagen
Common Green Darner	<i>Anax junius</i> (Drury)
Comet Darner	<i>Anax longipes</i> Hagen
Swamp Darner	<i>Epiaeschna heros</i> (Fabricius)
Spatdock Darner	<i>Rhionaeschna mutata</i> (Hagen)
Unicorn Clubtail	<i>Arigomphus villosipes</i> (Selys)
Black-shouldered Spinylegs	<i>Dromogomphus spinosus</i> Selys
Beaverpond Clubtail	<i>Gomphus borealis</i> Needham
Lancet Clubtail	<i>Gomphus exilis</i> Selys
Dusky Clubtail	<i>Gomphus spicatus</i> Hagen in Selys
Dragonhunter	<i>Hagenius brevistylus</i> Selys
American Emerald	<i>Cordulia shurtleffii</i> Scudder
Racket-tailed Emerald	<i>Dorocordulia libera</i> (Selys)
Beaver Pond Baskettail	<i>Epithea canis</i> (McLachlan)
Common Baskettail	<i>Epithea cynosura</i> (Say)
Prince Baskettail	<i>Epithea princeps</i> Hagen
Ski-tipped Emerald	<i>Somatochlora elongata</i> (Scudder)
Mocha Emerald	<i>Somatochlora linearis</i> (Hagen)
Calico Pennant	<i>Celithemis elisa</i> (Hagen)
Halloween Pennant	<i>Celithemis eponina</i> (Drury)
Eastern Pondhawk	<i>Erythemis simplicicollis</i> (Say)
Little Blue Dragonlet	<i>Erythrodiplax minuscula</i> (Rambur)
Blue Corporal	<i>Ladona deplanata</i> (Rambur)
Chalk-fronted Corporal	<i>Ladona julia</i> (Uhler)
Frosted Whiteface	<i>Leucorrhinia frigida</i> Hagen
Crimson-ringed Whiteface	<i>Leucorrhinia glacialis</i> Hagen
Hudsonian Whiteface	<i>Leucorrhinia hudsonica</i> (Selys)
Dot-tailed Whiteface	<i>Leucorrhinia intacta</i> (Hagen)
Red-waisted Whiteface	<i>Leucorrhinia proxima</i> Calvert
Golden-winged Skimmer	<i>Libellula auripennis</i> Burmeister
Bar-winged Skimmer	<i>Libellula axilena</i> Westwood
Spangled Skimmer	<i>Libellula cyanea</i> Fabricius
Slaty Skimmer	<i>Libellula incesta</i> Hagen
Widow Skimmer	<i>Libellula luctuosa</i> Burmeister
Twelve-spotted Skimmer	<i>Libellula pulchella</i> Drury
Four-spotted Skimmer	<i>Libellula quadrimaculata</i> L.
Painted Skimmer	<i>Libellula semifasciata</i> Burmeister
Great Blue Skimmer	<i>Libellula vibrans</i> Fabricius
Blue Dasher	<i>Pachydiplax longipennis</i> (Burmeister)
Wandering Glider	<i>Pantala flavescens</i> (Fabricius)
Spot-winged Glider	<i>Pantala hymenaea</i> (Say)
Eastern Amberwing	<i>Perithemis tenera</i> (Say)
White-tailed Skimmer	<i>Plathemis lydia</i> (Drury)
Blue-faced Meadowhawk	<i>Sympetrum ambiguum</i> (Rambur)
Jane's Meadowhawk	<i>Sympetrum janeae</i> Carle
Ruby Meadowhawk	<i>Sympetrum rubicundulum</i> (Say)

Dragonfly common names	Anisoptera species
White-faced Meadowhawk	<i>Sympetrum obtrusum</i> (Hagen)
Band-winged Meadowhawk	<i>Sympetrum semicinctum</i> (Say)
Autumn Meadowhawk	<i>Sympetrum vicinum</i> (Hagen)
Carolina Saddlebags	<i>Tramea carolina</i> (L.)
Black Saddlebags	<i>Tramea lacerata</i> Hagen

Appendix 3. Zygoptera species found at Ten Acre Pond, 1955–2011.

Damselfly common names	Zygoptera species
Ebony Jewelwing	<i>Calopteryx maculata</i> (Beauvois)
Great Spreadwing	<i>Archilestes grandis</i> (Rambur)
Spotted Spreadwing	<i>Lestes congener</i> Hagen
Southern Spreadwing	<i>Lestes australis</i> Walker
Common Spreadwing	<i>Lestes disjunctus</i> Selys
Emerald Spreadwing	<i>Lestes dryas</i> Kirby
Amber-winged Spreadwing	<i>Lestes eurinus</i> Say
Sweetflag Spreadwing	<i>Lestes forcipatus</i> Rambur
Elegant Spreadwing	<i>Lestes inaequalis</i> Walsh
Slender Spreadwing	<i>Lestes rectangularis</i> Say
Lyre-tipped Spreadwing	<i>Lestes unguiculatus</i> Hagen
Swamp Spreadwing	<i>Lestes vigilax</i> Hagen in Selys
Sphagnum Sprite	<i>Nehalennia gracilis</i> Morse
Sedge Sprite	<i>Nehalennia irene</i> (Hagen)
Aurora Bluet	<i>Chromagrion conditum</i> (Selys)
Taiga Bluet	<i>Coenagrion resolutum</i> (Selys)
Powdered Dancer	<i>Argia moesta</i> (Hagen)
Dusky Dancer	<i>Argia translata</i> Hagen in Selys
Northern Bluet	<i>Enallagma annexum</i> (Charpentier)
Azure Bluet	<i>Enallagma aspersum</i> (Hagen)
Familiar Bluet	<i>Enallagma civile</i> (Hagen)
Marsh Bluet	<i>Enallagma ebrium</i> (Hagen)
Stream Bluet	<i>Enallagma exsulans</i> (Hagen)
Skimming Bluet	<i>Enallagma geminatum</i> Kellicott
Hagen's Bluet	<i>Enallagma hageni</i> (Walsh)
Orange Bluet	<i>Enallagma signatum</i> (Hagen)
Slender Bluet	<i>Enallagma traviatum</i> Selys
Vesper Bluet	<i>Enallagma vesperum</i> Calvert
Citrine Forktail	<i>Ischnura hastata</i> (Say)
Fragile Forktail	<i>Ischnura posita</i> (Hagen)
Eastern Forktail	<i>Ischnura verticalis</i> (Say)

Appendix 4. Yearly Distribution of Anisoptera at Ten Acre Pond from 1955 to 2011. Data for 1955 through 1962 taken from White (1963). Data for 1963 through 1994 taken with corrections from Shiffer and White (1995). See Appendix 1 for full species name, authority and common name. TY = total number of years observed.

Species	1950s					1960s					1970s					1980s					1990s					2000s					2010s																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8

Appendix 6. Summary of total number of Odonata species observed by year in Ten Acre Pond.

Year	Anisoptera	Zygoptera	All Odonata
1955	19	11	30
1956	3	4	7
1957	9	7	16
1958	1	0	1
1959	19	9	28
1960	34	20	54
1961	26	17	43
1962	22	15	37
1963	21	10	31
1964	18	12	30
1965	9	3	12
1966	0	0	0
1967	0	0	0
1968	25	8	33
1969	13	11	24
1970	28	15	43
1971	20	15	35
1972	22	15	37
1973	16	15	31
1974	8	9	17
1975	30	13	43
1976	23	18	41
1977	18	7	25
1978	4	1	5
1979	16	9	25
1980	11	3	14
1981	24	14	48
1982	26	13	39
1983	19	13	32
1984	28	17	45
1985	26	16	42
1986	32	19	51
1987	28	17	45
1988	22	9	31
1989	34	23	57
1990	32	16	48
1991	33	19	52
1992	24	14	38
1993	21	12	33
1994	30	19	49
1995	29	16	45
1996	36	21	57
1997	39	21	60
1998	35	20	55
1999	28	15	43
2000	37	18	55
2001	35	18	53
2002	43	21	64
2003	41	23	64
2004	46	24	70
2005	45	19	64
2006	30	18	48
2007	38	19	57
2008	39	21	60
2009	31	18	49
2010	35	18	53
2011	6	1	7
Total	55	31	86

Anisoptera species	March				April				May				June				July				August				Sept.				Oct.				Nov.				# of quarters observed	Early-late dates
	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4									
<i>Libellula auripennis</i>																																		14	5/25–9/1			
<i>L. axilena</i>																																		9	6/1–8/11			
<i>L. cyanea</i>																																		15	5/22–9/6			
<i>L. incesta</i>																																		16	6/8–10/5			
<i>L. luctuosa</i>																																		18	5/31–10/2			
<i>L. pulchella</i>																																		21	5/11–10/14			
<i>L. quadrimaculata</i>																																		12	5/15–8/16			
<i>L. semifasciata</i>																																		14	5/5–8/10			
<i>L. vibrans</i>																																		10	5/31–8/11			
<i>Pachydiplax longipennis</i>																																		20	5/9–10/3			
<i>Pantala flavescens</i>																																		17	5/9–9/29			
<i>P. hymenaea</i>																																		17	5/18–9/27			
<i>Perithemis tenera</i>																																		16	6/1–9/29			
<i>Plathemis lydia</i>																																		22	4/30–10/5			
<i>Sympetrum ambiguum</i>																																		1	10/7			
<i>S. janeae</i>																																		22	5/30–11/3			
<i>S. rubicundulum</i>																																		13	7/23–10/19			
<i>S. obtrusum</i>																																		11	8/3–10/21			
<i>S. semicinctum</i>																																		13	7/12–10/13			
<i>S. vicinum</i>																																		20	7/2–11/26			
<i>Tramea carolina</i>																																		22	4/19–10/7			
<i>T. lacerata</i>																																		22	4/19–10/18			

Appendix 8. Seasonal distribution of Zygoptera at Ten Acre Pond from 1955 to 2011. Rows in the table group species by family. Quarters of the month: 1st to 8th (1), 9th to 15th (2), 16th to 23rd (3), and 24th to end of month (4).

Anisoptera species	March				April				May				June				July				August				Sept.				Oct.				Nov.				# of quarters observed	Early-late dates
	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4					
<i>Calopteryx maculata</i>											X		X	X	X		X																	6	6/8–8/9			
<i>Archilestes grandis</i>																																		5	9/19–11/8			
<i>Lestes congener</i>																																		22	6/10–11/19			
<i>L. australis</i>						X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	21	4/27–9/27				
<i>L. disjunctus</i>																																	1	8/28				
<i>L. dryas</i>											X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	12	5/19–8/14					
<i>L. eurinus</i>											X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	13	5/14–8/19					
<i>L. forcipatus</i>											X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	18	5/31–10/13					
<i>L. inaequalis</i>											X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	12	5/17–8/25					
<i>L. rectangularis</i>											X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	21	5/26–11/3					
<i>L. unguiculatus</i>											X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14	6/6–10/3					
<i>L. vigilax</i>											X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	15	5/31–9/11					
<i>Argia moesta</i>																																	1	8/24				
<i>A. translata</i>																																	1	10/12				
<i>Chromagrion conditum</i>																																	10	5/7–7/16				
<i>Coenagrion resolutum</i>																																	5	5/11–6/21				
<i>Enallagma annexum</i> ¹																																	11	4/27–7/15				
<i>E. aspersum</i>																																	19	5/13–10/7				
<i>E. civile</i>																																	24	5/22–11/9				
<i>E. ebrium</i>																																	8	5/25–7/18				
<i>E. exulans</i>																																	1	7/29				
<i>E. geminatum</i>																																	20	5/22–10/9				
<i>E. hageni</i>																																	15	5/17–9/7				
<i>E. signatum</i>																																	19	5/23–10/9				
<i>E. triviatum</i>																																	8	7/1–8/24				
<i>E. vesperum</i>																																	5	5/30–9/15				
<i>Ischnura hastata</i>																																	26	4/27–11/4				
<i>I. posita</i>																																	22	5/5–11/8				
<i>I. verticalis</i>																																	26	4/17–10/31				
<i>Nehalennia gracilis</i>																																	3	6/27–7/15				
<i>N. irene</i>																																	14	5/17–8/25				

¹Listed as *Enallagma cyathigerum* previously (Shiffer and White 1995, White 1963).

Appendix 9. Summary of seasonal distribution of Odonata at Ten Acre Pond from 1955 to 2011. Quarters of the month: 1st to 8th (1), 9th to 15th (2), 16th to 23rd (3), and 24th to end of month (4).

Month	Quarter	Anisoptera	Zygoptera	All Odonata
March	4	1	0	
April	1	1	0	1
	2	1	0	1
	3	4	1	5
	4	5	4	9
May	1	10	6	16
	2	18	8	26
	3	27	16	43
	4	33	19	52
June	1	36	22	58
	2	37	22	59
	3	37	24	61
	4	38	22	60
July	1	40	24	64
	2	40	23	63
	3	41	22	63
	4	38	20	58
August	1	41	20	61
	2	35	19	64
	3	31	17	48
	4	29	20	49
September	1	28	13	41
	2	25	14	39
	3	23	11	34
	4	20	12	32
October	1	19	11	30
	2	12	11	23
	3	8	5	13
	4	5	5	10
November	1	4	5	9
	2	2	2	4
	3	1	0	1
	4	1	0	1
Total		55	31	86