Journal of Insect Science, (2020) 20(5): 33; 1–9
doi: 10.1093/jisesa/ieaa125
Research

New Population of the Rare Dragonfly *Ophiogomphus howei* (Odonata: Gomphidae) in Southern Michigan, United States

Julie A. Craves,[1,3] Darrin S. O'Brien,[1] and David A. Marvin[2]

[1]2200 Centennial Lane, Ann Arbor, MI 48103, [2]604 West Lapeer, Lansing, MI 48933, and [3]Corresponding author, e-mail: jcraves@umich.edu

Disclaimer: All *Ophiogomphus howei* were collected under the Threatened and Endangered Species Permit issued by the state of Michigan to J. A. C., and all vouchers will be deposited in the University of Michigan Museum of Zoology, Insect Division (4 adults: 29 May 2019, 2 June 2019, 4 June 2019, and 13 June 2020; 6 exuviae: 2 from 1 June 2020; and 4 from 4 June 2020).

Subject Editor: Philippe Usseglio-Polatera

Received 22 July 2020; Editorial decision 29 September 2020

Abstract

Ophiogomphus howei Bromley is a rare North American dragonfly, given a global conservation rank of Vulnerable by NatureServe. This species inhabits localized stretches of a limited number of typically undisturbed, high-quality, forested rivers in two disjunct regions in North America. We describe a new population in between the known ranges from an impaired river in a largely urban watershed in southern Michigan, United States. We also report a previously overlooked specimen from a new location in Pennsylvania, United States, and provide current occurrence and conservation status of the species in North America.

Key words: Odonata, dragonfly, range expansion

Gomphidae is the second-largest dragonfly (Anisoptera) family in the world; there are 102 species in 17 genera in North America (Ware et al. 2017, Tennessen 2019). Nearly all species inhabit flowing waters, and their aquatic nymphs are highly modified to burrow into substrate, a niche exploited by only one other family of Odonata (Tennessen 2019). *Ophiogomphus* Selys is a Holarctic genus of 29 species, 20 of which are restricted to the New World (Garrison et al. 2006, Tennessen 2019, Schorr and Paulson 2020). They are small to medium-sized dragonflies that occupy clean streams or rivers, often with rocky or gravelly substrates (Paulson 2011). *Ophiogomphus howei* Bromley (Pygmy Snaketail) is the smallest *Ophiogomphus* in North America, with abdomen and hindwing lengths not exceeding 35 and 22 mm, respectively (Needham et al. 2014).

Ophiogomphus howei occurs in two disjunct geographical areas in North America (Fig. 1). A western population is located in the Great Lakes region, centered in the northern half of Wisconsin, extending into Minnesota and the western Upper Peninsula of Michigan; there is a single record in northwestern Ontario. An eastern population occurs in scattered locations from New Brunswick, Canada, to South Carolina, United States, with the westernmost records from Kentucky. *Ophiogomphus howei* has not been recorded from states between the western and eastern ranges, despite considerable survey efforts (Curry 2001, Olcott 2011, ODS 2019, Tennessen 2019).

The distribution of *O. howei* within each region is discontinuous, as this species is localized and found only along limited stretches of some river systems. Although it can be common in spots (Paulson 2007), it has been considered rare and restricted throughout its range (Tennessen 1993). This scarcity and patchy distribution has led *O. howei* to be given a global conservation rank of G3 ('Vulnerable') by NatureServe (2020), whereas the IUCN Red List categorizes the status as Least Concern using the same lines of evidence (Abbott et al. 2017). Table 1 presents the most current occurrence and conservation status of *O. howei* by state and province.

Ophiogomphus howei is listed as Threatened in the state of Michigan (Derosier et al. 2015). Prior to records described herein, it was known in Michigan only from 19 exuviae (shed exoskeletons of newly emerged nymphs) and 2 nymphs collected in 1997, and a single exuvia collected in 2014, all from the Paint River, Iron County, in the western Upper Peninsula (Lee 2007, Craves 2015, SCAN 2020). We describe a new population of *O. howei* in southern Michigan from the Grand River in Ingham and Eaton counties. This location is ~390 km from the closest western population site in Wisconsin, and about 485 km from the closest reported eastern population location in northern Kentucky.

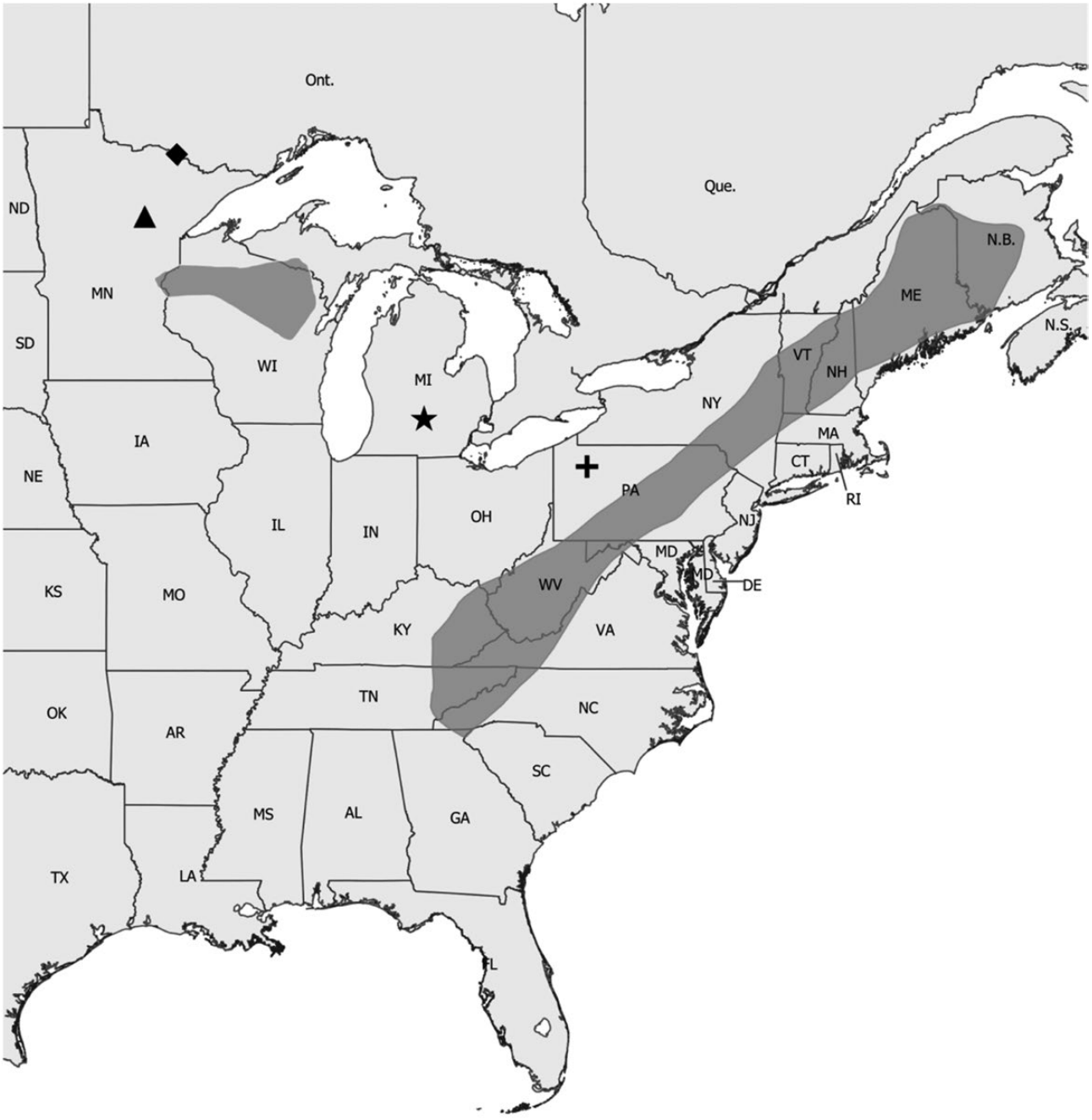

Fig. 1. Range of *Ophiogomphus howei*. Shaded areas include river systems where *O. howei* has been found, but not all states within shaded areas have records of *O. howei*; see Table 1 for summary of occurrence. Symbols represent: Diamond = single Ontario, Canada record; triangle = single Mississippi River record in Minnesota; star = population described in this paper; plus sign = new historical record described in this paper.

Observations

On 22 May 2017, DM photographed a small male gomphid at Riverbend Natural Area, Delhi Township, Ingham County, Michigan (Abbott 2006-2020a). This location is along the Grand River, ~13 km south of the state capital city of Lansing. The small size and tinting on the basal half of the hindwings, unique among gomphids, confirmed its identity as *O. howei*. A photograph of a male was taken at the same location by R. Nirschl on 1 June 2017 (Abbott 2006-2020b). Additional searches by the authors and other observers for adults or exuviae in 2017 and in 2018 at this site, as well as other nearby locations along the Grand River, were unsuccessful.

In 2019, DM observed a teneral (recently emerged) female *O. howei* at Riverbend Natural Area (hereafter referred to as RNA) on 2 June. During a search by the authors at RNA on 4 June 2019, three females were netted (one collected) and at least two other individuals (sex undetermined) were observed. All were flushed from low vegetation or were seen taking very short flights (<10 m). RNA and nearby locations were searched again on 12 June 2019, but no *O. howei* were located.

Table 1. Details of current occurrence and conservation status of *Ophiogomphus howei* by state/province

State/Province	S rank	Status	SGCN?	Notes	Sources
West					
Ontario	S1	Endangered	N/A	Only record is a single exuvia collected in 2007 in the Namakan River, Rainy River District. Subsequent searches in 2008, 2009, 2010, and 2016 were unsuccessful.	Hamill 2013, COSEWIC 2018
Minnesota	S3	Special concern	Yes	Confirmed breeding populations in the St. Croix River system in 2 counties along Wisconsin border. Records from nearby Kanabec County and a more northerly record from the Mississippi River in Itasca County are each based on single exuvia.	Haarstad 1994; Steffens and Smith 1999; MDNR 2013, 2016
Wisconsin	S4	N/A	No	Reported from 23 counties in the northern half of the state with nearly 1,500 flight season records.	WOS 2019
Michigan	S1	Threatened	Yes	Previously only known from exuviae and nymphs collected the Paint River, Iron County, in the Upper Peninsula, all but one from 1997. An undated record from Menominee County (Donnelly 2004, Abbott 2006-2020c) is unsupported by data and considered erroneous.	Lee 2007, Derosier et al. 2015, SCAN 2020
East					
New Brunswick	S2	Special concern	N/A	First recorded in 2002, now known from 6 large river systems; considered rare.	COSEWIC 2018
Maine	S2	Special concern	Yes	Known from 22 populations in 11 rivers.	Brunelle and deMaynadier 2005, MDIFW 2015
New Hampshire	S2	None	No	Known from 3 counties with most records from the Merrimack and Contoocook River systems.	Hunt 2012, NHNHB 2018
Massachusetts	SX	None	No	The type specimen was a female collected in 1922 in Massachusetts; there have been no records since.	Bromley 1924, Nikula 2002, Buchsbaum et al. 2016
New York	S1	Special concern	Yes	Most common in the upper Hudson River.	White et al. 2010, Schlesinger 2017
Pennsylvania	SH	None	Yes	Historical records are from 1921 to 1988 from Cumberland and Susquehanna counties. Additionally, we located a previously unpublished Forest County specimen from 1924 in the Cleveland Museum of Natural History (SCAN 2019); see text for details.	Calvert 1924, Kennedy and White 1979, Shiffer et al. 2014, PGC-PFBC 2015, PNHP 2020
Maryland	S1	None	Yes	First recorded in 2011 and known from the Potomac River in two counties.	MDDNR 2016, Orr 2019
Virginia	S1S2	None	Yes		VDGIF 2015, Roble 2020
Kentucky	S1S2	Endangered	No	Known from 6 counties in the eastern third of the state; no records since 1998.	KDFWR 2014, OKNP 2019
Tennessee	S3?	None	Yes	Known from two sites on the Tellico River in Monroe County; the first record from 1971 is from a site now inundated by the Tellico Dam project. State rank with question mark reflects uncertain status.	Louton 1982, Tennessen 1993, TSWAPT 2015
North Carolina	S1	Significantly Rare	No	Found only in extreme northwestern part of state in the New River system.	Ratcliffe 2018, LeGrand et al. 2020
South Carolina	Not ranked	None	No	Starting in 2008, multiple exuviae and at least one adult have been collected from both sides of the Chattooga River, which forms the border of Oconee County, South Carolina and Rabun County, Georgia.	Abbott 2006-2020d, Beaton and Dobbs 2010, Dobbs 2012
Georgia	Not ranked	None	No	See South Carolina.	

S rank from NatureServe (2020), lower numerical ranks indicate increased risk of extinction or extirpation. SX, presumed extirpated; SH, possibly extirpated. For ranking methods, see Faber-Langendoen et al. (2012); SGCN, Species of Greatest Conservation Need as indicated by each US state's latest Wildlife Action Plan (see AFWA 2019 for background on action plans).

Around this time, we were forwarded a photograph of a male gomphid that had been found moribund on 29 May 2019 on the floor inside a home in Dimondale, Eaton County, which we confirmed was *O. howei*. This residence is about 80 m from the Grand River and ~7.5 km downstream from RNA.

In 2020, DM searched RNA for adult *O. howei* without success on 31 May. JAC and DSO looked for adults and exuviae at RNA and downstream at neighboring Burchfield Park on 1 June. No adults were seen, but two exuviae of *O. howei* were found on the river bank at Burchfield. On 4 June, JAC and DSO searched the banks again from Burchfield to RNA and located four more exuviae.

On 13 June, DM observed a Skillet Clubtail, *Gomphurus ventricosus* (Walsh) (Odonata: Gomphidae) consuming a small dragonfly at RNA; the prey item was a female *O. howei*.

Site Description

RNA, Burchfield Park, and Dimondale are within the Lansing-East Lansing Metropolitan Statistical Area, which has a population of over 550,000 (U.S. Census Bureau 2020a). The Grand River is the second-largest watershed in Michigan. In the ~130 km between the headwaters and RNA, it flows north through the urban Jackson Metropolitan Statistical Area (population ~158,000) and the small city of Eaton Rapids (population ~5,200) (U.S. Census Bureau 2020a,b). The entire main stem of the Grand River has water quality impairments, including fish consumption advisories due to mercury and polychlorinated biphenyl (PCB) levels in fish tissue, and PCBs in the water column (MDEQ 2017). Segments of the river upstream have also failed to meet dissolved oxygen and sedimentation standards (MDEGLE 2020a).

RNA and adjoining Burchfield Park are managed by Ingham County and cover an area of over 218-ha bordering 5 km of the Grand River (Kaschinske 2015). Major land cover types in the 7.24 km^2 local catchment (the drainage area for a specific stream segment) that includes RNA and Burchfield are 32.9% forest, 41.4% agriculture, and 6.7% developed (USEPA 2018). Figure 2 shows the Grand River and surrounding landscape from Eaton Rapids to Dimondale with the local catchment highlighted.

RNA consists of hiking and mountain bike trails through wooded floodplain and associated upland habitats bordering a large meander in the Grand River. Approximately 35–40 m from the river is a <2 ha old field where all the adult *O. howei* were observed, except for the Dimondale individual. In addition to heavily used trails, Burchfield has recreational amenities including canoe landings, picnic shelters, playgrounds, disc golf course, and a ball diamond. Forested areas at Burchfield have open understories, and clearings are mostly groomed or mowed. In both parks, trails are often widened and interconnected from off-trail use. The Grand River is 30- to 40-m wide, and the riverbank is highly eroded and steep in many places. The opposite bank is residential or forested, with access to the river restricted by private property.

Ophiogomphus howei exuviae were found on the riverbank adjacent to a trail that runs along the Grand River through Burchfield to RNA. All exuviae were <1 m from the water's edge on soil or horizontal forbs or duff on sections of bank with <45 degree slopes. Each spot where they were found was on the downstream side of a canoe landing or a tree that projected into the river, resulting in a disruption of the current and a slow or calm pocket of water.

The Dimondale location is in a residential area just outside Dimondale village limits, which has a population of 1,249 (US Census Bureau 2020b). Given that the *O. howei* at this location was inside a home, we exclude it from the following in-stream habitat descriptions.

The Michigan Department of Environment, Great Lakes and Energy (formerly Michigan Department of Environmental Quality) periodically surveys watersheds throughout the state, evaluating both physical habitat conditions and biological communities. A station near the RNA/Burchfield border was sampled in 2006, 2011, and 2016 (Holden 2007, 2012; Parker and Rippke 2017). This station corresponds, within a few meters, of one site where we found *O. howei* exuviae.

Depth of the river in these surveys ranged from 0.76 to 1.8 m. In 2016, substrate in the center of the river was recorded as cobble, with margins of sand and silt. Flashiness scores declined from 'Excellent' in 2006 to 'Poor' in 2011 and 2016, indicating bank scouring and erosion. Parker and Rippke (2017) took note of high eroding banks, exacerbated by foot traffic and off-trail use (Parker and Rippke 2017), as we observed. The quality of the habitat in the river was scored 'Excellent' in 2006, and 'Good' in 2011 and 2016 (Holden 2007, 2012; Parker and Rippke 2017; for substrate composition definitions, scoring methods, and metrics, see MDEQ 2008).

The station had benthic macroinvertebrate community scores of 'Excellent' in each sampling period (Holden 2007, 2012; Parker and Rippke 2017; scoring criteria in Creal et al. 1996). Macroinvertebrates in these surveys are only identified to family, and this station consistently had much higher numbers of individual Gomphidae than any other stations along the upper Grand River, including those on tributaries. In 2016, gomphids were the dominant taxa at the RNA/Burchfield station, with 43 individuals making up 16.6% of the macroinvertebrate community. Five of the other 30 stations sampled in 2016 had gomphids, but none had more than two individuals (Parker and Rippke 2017).

Discussion

Our observations of *Ophiogomphus howei* in southern Michigan represent the first adults observed or collected in the state, and a new population between the two known population ranges. The southern Michigan location is roughly 390 km from the closest Wisconsin location (Epstein et al. 2002) and 490 km from the closest Michigan site in the western Upper Peninsula.

The closest eastern population records are from northeastern Kentucky, about 485 km from the southern Michigan location, but there have been no reports of *O. howei* from the state since 1998 (KDFWR 2014). An extant population in the Potomac River, Alleghany County, in northwest Maryland (Hubick and Brighton 2012–2020, Orr 2019) is ~615 km distant from the southern Michigan site.

In the course of our research, we discovered a specimen of an adult female *O. howei* in the Cleveland Museum of Natural History (catalog no.: CMNHENT0039305; SCAN 2019) collected 19 May 1924 at Tionesta, on the Alleghany River, Forest County, Pennsylvania, that has not been included in previous lists of Pennsylvania Odonata (Shiffer 1985, Shiffer et al. 2014). There have been no records of *O. howei* in Pennsylvania since 1988 and the species is considered 'historical' in the state (PGC-PFBC 2015). Aside from a 1921 record from south-central Pennsylvania, all records have been from the Susquehanna River in extreme northeastern Pennsylvania (Shiffer et al. 2014). The Tionesta location extends the Pennsylvania range at least 200 km west, and at 440 km from our southern Michigan location would be the closest eastern site if the population were extant.

In addition to being apparently extirpated from Pennsylvania, *O. howei* has not been detected during recent statewide Odonata atlas projects in West Virginia (Olcott 2011) or Ohio (Glotzhober and McShaffrey 2002, ODS 2019). The southern Michigan population is the first to be found in the gap between the western and eastern ranges.

Fig. 2. Landscape overview that includes the portion of the Grand River in southern Michigan occupied by *Ophiogomphus howei*. The outlined area is the local catchment surrounding sites where all exuviae and most adults were found. The Village of Dimondale, where a single adult was found, is noted. The red line is the county line dividing Eaton County (west) and Ingham County (east). The river flows from south to north then west in this region.

Collectively, our observations of adult *O. howei* from 2017 to 2020 give a conservative estimated flight period in southern Michigan from 22 May to 13 June. The majority of records of *O. howei* across North America are based on exuviae, not adults (Tennessen 1993, White et al. 2010, COSEWIC 2018). Therefore, there is inadequate data from the eastern population at latitudes similar to southern Michigan for comparison of adult flight dates. Flight season in Wisconsin, where the range of *O. howei* is further north than southern Michigan but has a large adult sample size, is late May to early July, with 77% of observations occurring in June (WOS 2019).

Presence of adult *O. howei* over several years and the recent discovery of exuviae indicate that there is a breeding population at RNA/Burchfield. Exuviae are considered conclusive evidence that odonates have completed development close to the location where they are found (Tennessen 1993, Raebel et al. 2010, Bried et al. 2012, DuBois 2015, DuBois and Smith 2016). *Ophigomphus howei* nymphs are reported to emerge on mud banks or low vegetation,

close to the water's edge, concentrated where current slows abruptly such as below structures along erosional banks (Kennedy and White 1979, COSEWIC 2018), which coincides with our collections along the Grand River. Emergence sites may not always reflect the exact in-stream location where nymphs developed if they drifted downstream prior to emergence. *Ophiogomphus* nymphs are burrowers, which might make them less susceptible to drift (Hardersen and Toni 2019), although there is some evidence that *O. howei* nymphs come out of the substrate and drift with the current, probably late at night and prior to emergence (DuBois and Pratt 2017). Little is known about the frequency and distance involved, but limited data suggest there is not substantial downstream displacement of *O. howei* via drift (summarized in Gibbs et al. 2004).

Estimating abundance or population size at this southern Michigan site is hampered by difficulty in detection and limited survey effort. Adult *O. howei* are rarely seen even where they are known to occur (White et al. 2010, Paulson 2011, COSEWIC 2018), as they are presumed to spend most of their lives in the forest canopy (Kennedy and White 1979, Shiffer 1985, COSEWIC 2018). They have a flight period of ~6 wk that is often concentrated over ~10 d (Brunelle and deMaynadier 2005, White et al. 2010, Hunt 2012, WOS 2019). Prior to our efforts there were few records for collections or surveys of adult odonates from the RNA area during the appropriate time frame (Michigan Odonata Survey, unpublished data).

To our knowledge, we are the only people that have made an effort to survey for exuviae. Frequent searches are recommended for accurate detection of exuviae (Aliberti Lubertazzi and Ginsburg 2009, Raebel et al. 2010, Bried et al. 2012). The bulk of *O. howei* nymphs emerge over 4–6 d (Gibbs et al. 2004), providing an abbreviated window for surveys. Odonate exuviae do not persist long in the environment. A primary cause of exuviae loss is heavy rainfall and wind (Bried et al. 2012, DuBois 2015). We were unable to perform systematic surveys for *O. howei* adults or exuviae, and several of our planned searches for exuviae were prevented by weather events. Further, river morphology and more gently sloping, less-eroded banks suggest that emergence locations, and therefore exuviae deposition, may be more numerous on the opposite bank of the river from RNA and Burchfield, where we had no access due to private property.

That *O. howei* should be found in the Grand River in southern Michigan at all is surprising, given that some landscape and water quality characteristics reported to be important habitat indicators for this species are markedly different from most sites where *O. howei* has been found.

Habitat requirements are typically reported as medium to large, 'fast-flowing', 'high-quality' rivers. Landscapes are noted as being 'forested' and relatively 'undisturbed' with 'minimal' agriculture. Surveys of rivers that meet these criteria in states and provinces where *O. howei* has been found (Nikula 2002, White et al. 2010, Hamill 2013, COSEWIC 2018) or where it is presumed they could occur (Wagner and Thomas 1999, Klymko 2010, Olcott 2011, ODS 2019, Pfeiffer et al. 2019, Savard 2019) have often failed to locate any individuals. This localized and patchy distribution and the apparently narrow habitat requirements has led *Ophiogomphus howei* to be designated as a habitat specialist (Kennedy and White 1979, White et al. 2010, COSEWIC 2018).

A comparison of the southern Michigan site with the Paint River site in Michigan's Upper Peninsula where nearly all *O. howei* exuviae have been collected (Lee 2007) and a site on Wisconsin's St. Croix River with a large *O. howei* population (DuBois and Pratt 2017), utilizing local catchment data from the U.S. Environmental Protection Agency's WATERS GeoViewer application (USEPA 2018) reveals some notable contrasts. The RNA/Burchfield local catchment occupied by *O. howei* has a lower estimated mean annual flow velocity (0.95 ft/s) compared with 1.27 ft/s the Paint River site or 1.83 ft/s at the St. Croix River site. The RNA/Burchfield location is also less forested (32.9%) with more agriculture (41.4%) than the Paint River (76.2% forest, no agriculture) or St. Croix River sites (53.5% forest, 27.9% agriculture). The degree of potential agricultural influence on the river is reflected in the level of crop inputs. For example, the level of pesticide usage in the RNA/Burchfield catchment (77.3 kg/km^2) and synthetic nitrogen fertilizer application (17.8 kg/ha/yr) is far higher than reported for the Paint River location (negligible for both) or the St. Croix River site (4.5 kg/km^2 and 7.2 kg/ha/yr, respectively). Further, nutrient levels for the upper Grand River watershed (encompassing the RNA/Burchfield sites and upstream to the headwaters) are high relative to other rivers in southern Michigan (MDEQ 2017), with agrochemicals being the primary source of nitrogen and phosphorus (Luscz et al. 2015). High nutrient levels can contribute to depressed dissolved oxygen levels in waterways. Kennedy and White (1979) described dissolved oxygen levels where *O. howei* nymphs were found in the New River, North Carolina, as 'always near the saturation point'. Average July temperature for the Grand River at the upstream end of RNA is ~25°C, at which the saturation point would be expected to be >8.0 mg/liter (Hanshue and Harrington 2017). Dissolved oxygen measurements averaged 6.3 mg/liter at this location from 2010 to 2014 (HRC 2017). The state standard minimum level in warm waters is 5.0 mg/liter, and portions of the Grand River upstream from RNA have a history of failing to meet this standard (MDEGLE 2020b). More comprehensive and comparable data are not available for this water quality metric.

The extent of developed land in the RNA/Burchfield local catchment (6.7%) is roughly similar to the Paint River (2.8%) and St. Croix River (6.4%) catchments. However, <13 km upstream from RNA, the Grand River passes through Eaton Rapids, an urban area with catchments that are 69.6% developed. Another ~66 km upriver is the city of Jackson, with a local catchment that is 83.7% developed. The density of road crossings upstream from RNA is triple the density present upstream from the Paint Creek or St. Croix locations. Impervious surfaces and road runoff are major causes of stream sedimentation and pollutants in waterways (Tetra Tech 2006). Conditions upstream influence the habitat, water quality, and environmental conditions experienced by aquatic invertebrates further downstream (Strayer 2006, Collins and McIntyre 2017). Pollution, including that from pesticides and other agricultural runoff, is listed as a threat to *O. howei* that needs further investigation due to a lack of data (Hunt et al. 2010, Environment Canada 2013, COSEWIC 2018). While urbanization tends to affect Odonata diversity negatively (reviewed in Villalobos- Jiménez et al. 2016), studies suggest there are many mechanisms contributing to 'urban stream syndrome' (Paul and Meyer 2001, Walsh et al. 2005) and their impacts on Odonata may be very species-specific (Villalobos-Jiménez et al. 2016, Prescott and Eason 2018, Tippler et al. 2018). We compared the southern Michigan site with only two other locations for which we could pinpoint specific stream reaches and local catchments. These sites are representative of typical *O. howei* site descriptions, but careful comparisons of a range of specific habitat metrics over many sites would help clarify which qualities are most critical to *O. howei* reproductive success.

It is unknown if the degraded landscape and water quality at the southern Michigan location is suppressing the *O. howei* population, accounting for the low number of individuals recorded so far. However, the Grand River has a long history of impaired water

quality (Parker and Rippke 2017); the section between Eaton Rapids and Dimondale that includes RNA and Burchfield has had fish consumption advisories dating back to at least 1998 for mercury and/or PCBs (USEPA 2016). Considering that members of the genus *Ophiogomphus* tend to stay close to their in-stream habitats, with dispersal distances estimated to be no greater than ~10 km (Collins and McIntyre 2017, COSEWIC 2018), it seems likely this population has been present for some time. These circumstances suggest that *O. howei* may be less specialized, or more adaptable, than previously believed. Given the very low encounter rates of adults even where intensive surveys have been conducted (e.g., 11/114 records in Maine and New Brunswick, COSEWIC 2018), we are optimistic that the observations of at least 10 adults reported here from a limited number of surveys over several years could indicate a robust population at the southern Michigan site.

No genetic studies have been done with *O. howei* comparing the eastern and western populations (COSEWIC 2018) despite variation in the morphology of nymphs in the southernmost portion of the eastern range from individuals in the western population (Beaton and Dobbs 2010, Tennessen 2019). Given that diminished capacity for dispersal may lead to low gene flow and consequently higher genetic differentiation between populations in lotic species (Hof et al. 2006, Marten et al. 2006), this type of investigation could reveal diversity in the genetic makeup of this species across North America.

Due to their more limited habitat availability and geographical range sizes, lower dispersal capabilities, and often narrower ecological requirements, lotic Odonata species are at higher risk of local or regional extirpation or extinction, with riverine Gomphidae often identified as particularly vulnerable (Clausnitzer et al. 2009, White et al. 2015, Collins and McIntyre 2017, Rocha-Ortega et al. 2020). Identifying habitat requirements, sensitivity to environmental change, and accurate knowledge of temporal and distributional data are all key to effective conservation actions (Cardoso et al. 2011).

Acknowledgments

We thank Aaron Parker and Gary Kohlhepp of the Michigan Department of Environment, Great Lakes and Energy for access to water and biomonitoring data and samples; Hailey Majewski and Gavin Svenson of the Cleveland Museum of Natural History for specimen verification; Shelby Fulton of the Office of Kentucky Nature Preserves for data verification; Jo Stakely of the Monroe County Tennessee Archives for historical maps; Doug McWhirter for years of surveys in Ingham and Eaton counties, and notifying us of his discovery of *Ophiogomphus howei* in his living room; and Giff Beaton, Nick Donnelly, Chris Hill, Ellis Laudermilk, Kurt Mead, Mark O'Brien, Brainard Palmer-Ball, Jr., and Ken Tennessen for insights and assistance. The University of Michigan-Dearborn provided access to academic publications.

Author contribution

JAC assisted with field work, accessed academic resources, and wrote the paper; DSO performed field work and assisted with paper; DAM performed field work and photography.

Conflict of Interest

The authors have no conflicts of interest to declare.

References Cited

Abbott, J. C. 2006-2020a. *Ophiogomphus howei*, OC# 463103. Odonata Central: An online resource for the distribution and identification of Odonata. https://www.odonatacentral.org/index.php/SubmissionAction.get/submission_id/463103. Accessed 7 March 2020.

Abbott,J.C.2006-2020b.*Ophiogomphushowei*,OC#463346.OdonataCentral: An online resource for the distribution and identification of Odonata. https://www.odonatacentral.org/index.php/SubmissionAction.get/submission_id/463346. Accessed 7 March 2020.

Abbott,J.C.2006-2020c.*Ophiogomphushowei*,OC#463346.OdonataCentral: An online resource for the distribution and identification of Odonata. https://www.odonatacentral.org/index.php/SubmissionAction.get/submission_id/234935. Accessed 7 March 2020.

Abbott, J. C. 2006-2020d. *Ophiogomphus howei*, OC# 463346. OdonataCentral: An online resource for the distribution and identification of Odonata. https://www.odonatacentral.org/index.php/SubmissionAction.get/submission_id/374870. Accessed 7 March 2020.

Abbott, J. C., T. Donnelly and D. R. Paulson. 2017. *Ophiogomphus howei*. The IUCN Red List of Threatened Species 2017: e.T15366A65817976. https://dx.doi.org/10.2305/IUCN.UK.2017-3.RLTS.T15366A65817976.en. Accessed 27 August 2020.

(AFWA) Association of Fish and Wildlife Agencies. 2019. State Wildlife Action Plans - Blueprints for Conserving Our Nation's Fish & Wildlife. https://www.fishwildlife.org/afwa-informs/state-wildlife-action-plans. Accessed 18 June 2020.

Aliberti Lubertazzi, M. A., and H. S. Ginsberg. 2009. Persistence of dragonfly exuviae on vegetation and rock substrates. Northeast. Nat. 16: 141–147.

Beaton, G., and M. Dobbs. 2010. 2008–2009 summary of Odonate research in Georgia. Argia 22(1): 15–17.

Bried, J. T., F. D'Amico, and M. J. Samways. 2012. A critique of the dragonfly delusion hypothesis: why sampling exuviae does not avoid bias. Insect Conserv. Diver. 5: 398–402.

Bromley, S. W. 1924. A new *Ophiogomphus* (Aeschnidae: Odonata) from Massachusetts. Entomol. News. 35(10): 343–344.

Brunelle, P-M., and P. deMaynadier. 2005. Maine Damselfly and Dragonfly Survey Final Report. Technical Report to Maine Department Inland Fisheries and Wildlife, Bangor, ME, 34pp.

Buchsbaum, R., C. W. Leahy, and T. Allison. 2016. Distribution and abundance of Odonata species across Massachusetts: results of a long-term monitoring program. Northeast. Nat. 23: 501–524.

Calvert, P. P.1924. The supposed male of *Ophiogomphus howei* Bromley (Odon:Aeschnidae). Entomol. News. 35(10): 345–374.

Cardoso, P., T. L. Erwin, P. A. V. Borges, and T. R. New. 2011. The seven impediments in invertebrate conservation and how to overcome them. Biol. Conserv. 144: 2647–2655.

Clausnitzer, V., V. J. Kalkman, M. Ram, B. Collen, J. E. M. Baillie, M. Bedjanic, W. R. T. Darwall, K. B. Dijkstra, R. Dow, J. Hawking, H. Karube, et al. **2009**. Odonata enter the biodiversity crisis debate: the first global assessment of an insect group. Biol. Conserv. 142: 1864–1869.

Collins, S. D., and N. E. McIntyre. 2017. Extreme loss of diversity of riverine dragonflies in the northeastern US is predicted in the face of climate change. Bull. Am. Odonatol. 12: 7–19.

(COSEWIC) Committee on the Status of Endangered Wildlife in Canada. 2018. COSEWIC assessment and status report on the Pygmy Snaketail *Ophiogomphus howei* in Canada. Canadian Wildlife Service, Ottawa, Canada, vii + 46 pp.

Craves, J. A. 2015. Michigan DNR species status assessment worksheet: Ophiogomphus howei (Pygmy Snaketail). Unpublished report to Technical Advisory Committee (Insects) for Endangered and Threatened Species in Michigan. Michigan Dept. Natural Resources, Wildlife Div., Lansing, 7 pp.

Creal, W., S. Hanshue, K. Kosek, M. Oemke, and M. Walterhouse. 1996. Update of GLEAS Procedure 51 Metric Scoring and Interpretation. Revised May 1998. MDEQ Report #MI/DEQ/SWQ-96/068, Lansing, MI, 27 pp.

Curry, J. R. 2001. Dragonflies of Indiana. Indiana Academy of Science, Indianapolis, IN.

Derosier, A. L., S. K. Hanshue, K. E. Wehrly, J. K. Farkas, and M. J. Nichols. 2015. Michigan's wildlife action plan. Michigan Department of Natural Resources, Lansing, MI. http://www.michigan.gov/dnrwildlifeactionplan. Accessed 15 August 2019.

Dobbs, M. 2012. In pursuit of a pygmy. Argia. 24(2): 3–4.

Donnelly, T. W. 2004. Distribution of North American Odonata. Part I: Aeshnidae, Petaluridae, Gomphidae, Cordulegastridae. Bull. Am. Odonatol. 7: 61–90.

DuBois, R. B. 2015. Detection probabilities and sampling rates for *Anisoptera exuviae* along river banks: influences of bank vegetation types, prior precipitation, and exuviae size. Int. J. Odonatol. 18: 205–215.

DuBois, R. B., and D. Pratt. 2017. Species and life stages of Odonata nymphs sampled with large drift nets in two Wisconsin rivers. Great Lakes Entomol. 50: 11–16.

DuBois, R. B., and W. Smith. 2016. Pre-emergent movements and survival of F-0 larvae of *Ophiogomphus rupinsulensis* (Odonata: Gomphidae) in a northern Wisconsin river. Int. J. Odonatol. 19: 83–93.

Environment Canada. 2013. Management plan for the pygmy snaketail (Ophiogomphus howei) in Canada. Species at risk act management plan series. Environment Canada, Ottawa, Canada. iii + 13 pp.

Epstein, E., W. Smith, C. Anderson, E. Spencer, J. Lyons, and D. Feldkirchner. 2002. Wolf river basin biotic inventory and analysis. Publ. ER-802–2002. Wisconsin Deparment of Natural Resources, Bureau of Endangered Resources, Madison, WI, 364 pp.,

Faber-Langendoen, D., J. Nichols, L. Master, K. Snow, A. Tomaino, R. Bittman, G. Hammerson, B. Heidel, L. Ramsay, A. Teucher, and B. Young. 2012. NatureServe conservation status assessments: methodology for assigning ranks. NatureServe, Arlington, VA. 52 pp.

Garrison, R. W., N. von Ellenrieder, and J. A. Louton. 2006. Dragonfly genera of the New World. John Hopkins Univ. Press, Baltimore, MD.

Gibbs, K. E., B. Bradeen, and D. Borland. 2004. Spatial and temporal segregation among six species of coexisting *Ophiogomphus* (Odonata: Gomphidae) in the Aroostook River, Maine. Northeast. Nat. 11: 295–312.

Glotzhober, R. C., and D. McShaffrey. 2002. Dragonflies and damselflies of Ohio. Ohio Biological Survey, Columbus, OH.

Haarstad, J. 1994. The dragonflies of selected eastern Minnesota Rivers. Report to Minnesota Department of Natural Resources, Division of Ecological Services. St Paul, MN, 83 pp.

Hamill, S. E. 2013. Recovery Strategy for the Pygmy Snaketail (*Ophiogomphus howei*) in Ontario. Ontario Recovery Strategy Series. Prepared for the Ontario Ministry of Natural Resources, Peterborough, Ontario, Canada, v + 14 pp.

Hanshue, S. K., and A. H. Harrington. 2017. Grand River assessment. Michigan Department of Natural History Report 20. Lansing, MI, 555 pp.

Hardersen, S., and I. Toni. 2019. Proposal for a time-based standard sampling method for the monitoring of *Gomphus flavipes* (Charpentier, 1825) and *Ophiogomphus cecilia* (Fourcroy, 1785) (Odonata: Gomphidae). Fragmenta Entomol. 51:55–62.

Hof, C., M. Brändle, and R. Brandl. 2006. Lentic odonates have larger and more northern ranges than lotic species. J. Biogeogr. 33: 63–70.

Holden, S. 2007. A biological survey of the upper Grand River watershed, Jackson, Ingham, Eaton, Clinton, and Ionia counties, Michigan, June-August 2006. Staff report MI/DEQ/WB-07/072. Michigan Department of Environmental Quality, Water Resources Division, Lansing, MI, 42 pp.

Holden, S. 2012. A biological survey of the upper Grand River watershed, Jackson, Ingham, Eaton, Clinton, and Ionia counties, Michigan, July-September 2011. Staff report MI/DEQ/WRD-12/024. Michigan Department of Environmental Quality, Water Resources Division, Lansing, MI, 24 pp.

(HRC) Hubbell, Roth & Clark, Inc. 2017. Storm water management plan, Delhi Charter Township. Report prepared for Delhi Charter Township [Ingham County, MI], October 30, 2017. Hubbell, Roth & Clark, Inc., Bloomfield Township, MI, 40 pp.

Hubick, W. J., and J. D. Brighton. 2012–2020. Maryland Biodiversity Project. Pygmy Snaketail Quad Map. https://www.marylandbiodiversity.com/viewSpeciesQuadMap.php?species=657. Accessed 8 March 2020.

Hunt, P. D. 2012. The New Hampshire Dragonfly Survey: A Final Report. Report to the NH Fish and Game Department. Audubon Society of NH, Concord, NH, 54 pp.

Hunt, P. D., M. Blust, and F. Morrison. 2010. Lotic Odonata of the Connecticut River in New Hampshire and Vermont. Northeast. Nat. 17: 175–188.

Kaschinske, B. 2015. Five year recreational plan, 2015–2020. City of Lansing Parks and Recreation Department, Lansing, MI, 101 pp.

(KDFWR) Kentucky Dept. Fish and Wildlife Resources. 2014. Species Information County observation(s) for State Threatened and Endangered Species. Pygmy Snaketail, *Ophiogomphus howei*. http://app.fw.ky.gov/speciesinfo/speciesListCounty.asp?strScientificName=Ophiogomphus+howei&strGroup=4. Accessed 2 February 2020.

Kennedy, J. H., and H. B. White II. 1979. Description of the nymph of *Ophiogomphus howei* (Odonata:Gomphidae). P. Entomol. Soc. Wash. 81: 64–69.

Klymko, J. 2010. Odonate surveys on the Tusket, Medway, and Lahave Rivers. Report to Nova Scotia Species at Risk Conservation Fund. Atlantic Canada Conservation Data Centre, Sackville, NB, 12 pp.

Lee, Y. 2007. Special animal abstract for *Ophiogomphus howei* (pygmy snaketail). Michigan Natural Features Inventory, Lansing, MI, 4 pp.

LeGrand, H. E., Jr., J. Petranka, M. A. Shields, and T. E. Howard, Jr. 2020. The dragonflies and damselflies of North Carolina, eleventh approximation. 206 pp. http://www.dpr.ncparks.gov/odes/a/accounts.php. Accessed 4 April 2020.

Louton, J. A. 1982. Lotic dragonfly (Anispotera: Odonata) nymphs of the southeastern United States: identification, distribution and historical biogeography. Ph.D dissertation, University of Tennessee, Knoxville, TN, 357 pp.

Luscz, E. C., A. D. Kendall, and D. W. Hyndman. 2015. High resolution spatially explicit nutrient source models for the Lower Peninsula of Michigan. J. Great Lakes Res. 41: 618–629.

Marten, A., M. Brändle, and R. Brandl. 2006. Habitat type predicts genetic population differentiation in freshwater invertebrates. Mol. Ecol. 15: 2643–2651.

(MDDNR) Maryland Department of Natural Resources. 2016. Maryland State Wildlife Action Plan 2015–2025. Annapolis, Maryland. https://dnr.maryland.gov/wildlife/Pages/plants_wildlife/SWAP_Submission.aspx. Accessed 8 March 2020.

(MDEGLE) Michigan Department of Environment, Great Lakes, and Energy. 2020a. Total Maximum Daily Loads (TDMLs). https://www.michigan.gov/egle/0,9429,7-135-3313_3681_3686_3728-12464--,00.html. Accessed 27 August 2020.

(MDEGLE) Michigan Department of Environment, Great Lakes, and Energy. 2020b. Michigan Water Quality Standards. https://www.michigan.gov/egle/0,9429,7-135-3313_3681_3686_3728-350340--,00.html. Accessed 27 August 2020.

(MDEQ) Michigan Department of Environmental Quality. 2008. Qualitative biological and habitat survey protocols for wadeable streams and rivers. SWAS Procedure WRS-SWAS-051. Lansing, MI, 53 pp.

(MDEQ) Michigan Department of Environmental Quality, Surface Water Assessment Section. 2017. Upper Grand River Watershed Survey (2016). Watershed Summary Fact Sheets. https://www.michigan.gov/documents/deq/wrd-monitoring-fact-sheet-upper-grand-watershed_606148_7.pdf. Accessed 18 August 2019.

(MDIFW) Maine Department of Inland Fisheries and Wildlife. 2015. Maine's wildlife action plan. Element 1: Species of Greatest Conservation Need. Maine Department of Inland Fisheries and Wildlife, Augusta, ME, 77 pp.

(MDNR) Minnesota Department of Natural Resources. 2013. Minnesota's List of Endangered, Threatened, and Special Concern Species. Effective August 19, 2013. St. Paul, MN, 18 pp. https://files.dnr.state.mn.us/natural_resources/ets/endlist.pdf. Accessed 8 March 2020.

(MDNR) Minnesota Department of Natural Resources. 2016. Minnesota's Wildlife Action Plan 2015–2025. Division of Ecological and Water Resources, Minnesota Department of Natural Resources, St. Paul, MN, 240 pp. https://www.dnr.state.mn.us/mnwap/index.html. Accessed 8 March 2020.

NatureServe. 2020. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, VA. http://explorer.natureserve.org. Accessed 29 June 2020.

Needham, J. G., M. J. Westfall, Jr., and M. L. May. 2014. Dragonflies of North America, 3rd ed. Scientific Publishers, Gainesville, FL.

(NHNHB) New Hampshire Natural Heritage Bureau. 2018. Rare animal list for New Hampshire, including species listed as threatened or endangered under the NH Endangered Species Conservation Act of 1979. March 2018. New Hampshire Fish and Game Department, Concord, NH, 12 pp.

Nikula, B. 2002. Massachusetts species of interest. Ode News. 9(1): 5–9.

(ODS) Ohio Dragonfly Survey. 2019. Maps: distributions across Ohio. Version December 2019. https://u.osu.edu/ohioodonatasurvey/species-distributions-across-ohio/. Accessed 15 July 2020.

(OKNP) Office of Kentucky Nature Preserves. 2019. Endangered, Threatened and Special Concern Plants, Animals, and Natural Communities of Kentucky. July 2019. Frankfort, KY, 24 pp. https://eec.ky.gov/Nature-Preserves/biodiversity/Documents/Rare_species_of_Kentucky.pdf. Accessed 2 February 2020.

Olcott, S. 2011. Final Report for The West Virginia Dragonfly and Damselfly Atlas. West Virginia Division of Natural Resources Wildlife Resources Section, South Charleston, WV. 180 pp.

Orr, R. 2019. The Dragonflies and Damselflies of Maryland and the District of Columbia. Updated September 9, 2019. Mid-Atlantic Invertebrate Field Studies, Columbia, MD. http://www.marylandinsects.com/MDDCOdonateRecords.html. Accessed 8 March 2020.

Parker, A., and M. Rippke. 2017. Biological and water chemistry surveys of selected stations in the upper Grand River and Red Cedar watersheds in Eaton, Ingham, Jackson, and Livingston counties, Michigan, July-September 2016. Staff report MI/DEQ/WRD-17/017. Michigan Department of Environmental Quality, Water Resources Division, Lansing, MI, 63 pp.

Paul, M. J., and J. L. Meyer. 2001. Streams in the urban landscape. Annu. Rev. Ecol. Syst. 32: 333–365.

Paulson, D. 2007. Pygmy Snaketail (*Ophiogomphus howei*) not shy about mating. Argia 19(2): 14–15.

Paulson, D. 2011. Dragonflies and damselflies of the East. Princeton University Press, Princeton, NJ.

Pfeiffer, B., M. Blust, and K. McFarland. 2019. Vermont Odonata Atlas. Vermont's most wanted odonates. Pygmy Snaketail. Vermont Center for Ecostudies – Vermont Atlas of Life. https://val.vtecostudies.org/projects/vermont-damselfly-and-dragonfly-atlas/pygmy-snaketail. Accessed 15 July 2020.

(PGC-PFBC) Pennsylvania Game Commission and Pennsylvania Fish and Boat Commission. 2015. Pennsylvania Wildlife Action Plan, 2015–2025. https://www.pgc.pa.gov/Wildlife/WildlifeActionPlan/Pages/default.aspx. Accessed 1 March 2020.

(PNHP) Pennsylvania Natural Heritage Program. 2020. Species and Natural Features List. Insects, Spiders, and Crustaceans in Pennsylvania. List updated June 2020. http://www.naturalheritage.state.pa.us/SpeciesFeatures.aspx. Accessed 1 March 2020.

Prescott, V. A., and P. K. Eason. 2018. Lentic and lotic odonate communities and the factors that influence them in urban versus rural landscapes. Urban Ecosyst. 21: 737–750.

Raebel, E. M., Merckx, T., Riordan, P., Macdonald, D. W. and D. J. Thompson. 2010. The dragonfly delusion: why it is essential to sample exuviae to avoid biased surveys. J. Insect Conserv. 14: 523–533

Ratcliffe, J. 2018. Natural Heritage Program list of rare animal species of North Carolina. North Carolina Natural Heritage Program, North Carolina Department Natural and Cultural Resources, Raleigh, NC. https://files.nc.gov/dncr-nhp/documents/2018_Animal_List_FINAL_2019-07-11.pdf. Accessed 8 March 2020.

Roble, S. M. 2020. Natural Heritage Resources of Virginia: Rare Animals. Natural Heritage Rare Species Lists (2020-Summer). Virginia Department of Conservation and Recreation, Division of Natural Heritage, Richmond, VA, 83 pp.

Rocha-Ortega, M., P. Rodríguez, J. Bried, J. Abbott, and A. Córdoba-Aguilar. 2020. Why do bugs perish? Range size and local vulnerability traits as surrogates of Odonata extinction risk. Proc. Biol. Sci. 287: 20192645.

Savard, M. 2019. Entomofaune du Québec: Liste des 151 espèces de libellules (Odonates) inventoriées au Québec. http://entomofaune.qc.ca/entomofaune/odonates/Liste_especes.html. Accessed 4 April 2020.

SCAN. 2019. Biodiversity occurrence data from Cleveland Museum of Natural History Invertebrate Zoology Collection: *Ophiogomphus howei* detailed collection record. https://scan-bugs.org/portal/collections/individual/index.php?occid=25902292&clid=0. Accessed 1 March 2020.

SCAN. 2020. Biodiversity occurrence data from all collections: *Ophiogomphus howei*, Michigan records. https://scan-bugs.org/portal/collections/list.php?taxa=Ophiogomphus%20howei&thes=1&type=1&state=michigan&page=1. Accessed 1 March 2020.

Schlesinger, M. D. 2017. New York Natural Heritage Program Rare Animal Status List, October 2017. Albany, NY, 31 pp. https://www.dec.ny.gov/docs/wildlife_pdf/rareanimal2017.pdf. Accessed 17 July 2020.

Shiffer, C. 1985. Howe's snake darner *Ophiogomphus howei* (Bromley), pp. 97–99 in H. H. Genoways and F. J. Brenner (eds). Species of special concern in Pennsylvania. Special Publication No. 11. Carnegie Museum of Natural History, Pittsburgh, Pennsylvania.

Shiffer, C. N., H. White, and A. Deans. 2014. Pennsylvania Odonata Records. figshare. https://figshare.com/articles/Pennsylvania_Odonata_Records/1056508/5. Accessed 1 March 2020.

Schorr, M., and D. Paulson. 2020. World Odonata List. Revision 21 February 2020. Slater Museum of Natural History, University of Puget Sound, Tacoma, WA. https://www.pugetsound.edu/academics/academic-resources/slater-museum/biodiversity-resources/dragonflies/world-odonata-list2/. Accessed 4 April 2020.

Steffens, W. P., and W. A. Smith. 1999. Status survey for special concern and endangered dragonflies of Minnesota: population status, inventory and monitoring recommendations. Report to Minnesota Department of Natural Resources, Natural Heritage and Nongame Research Program, St. Paul, MN, 56 pp.

Strayer, D. L. 2006. Challenges for freshwater invertebrate conservation. J. N. Am. Benthol. Soc. 25: 271–287.

Tennessen, K. J. 1993. New distribution records for *Ophiogomphus howei* (Odonata: Gomphidae). Great Lakes Entomol. 26: 245–249.

Tennessen, K. J. 2019. Dragonfly nymphs of North America. Springer Nature, Cham, Switzerland.

Tetra Tech. 2006. Upper Grand River watershed management plan addendum. June 2006 update to Upper Grand River watershed management plan. 165 pp. http://www.uppergrandriver.org/files/Watershed%20Management%20Plan%20Update.pdf. Accessed 18 August 2019.

Tippler, C., I. A. Wright, P. J. Davies, and C. R. Evans. 2018. Are Odonata nymph adversely affected by impaired water quality in urban streams. Austral Ecol. 43: 890–902.

(TSWAPT) Tennessee State Wildlife Action Plan Team. 2015. Tennessee State Wildlife Action Plan 2015. Tennessee Wildlife Resources Agency, Nashville, TN. https://www.tn.gov/twra/wildlife/action-plan/tennessee-wildlife-action-plan.html. Accessed 16 January 2020.

U.S. Census Bureau. 2020a. Metropolitan and Micropolitan Statistical Areas Population Totals and Components of Change: 2010–2019. https://www.census.gov/data/tables/time-series/demo/popest/2010s-total-metro-and-micro-statistical-areas.html. Accessed 29 June 2020.

U.S. Census Bureau. 2020b. Explore Census Data. https://data.census.gov. Accessed 29 June 2020.

(USEPA) U.S. Environmental Protection Agency. 2016. 303(d) Impaired Waterbody History Report for MI040500040702-01. https://ofmpub.epa.gov/waters10/attains_wb_history.control?p_listed_water_id=MI040500040702-01&p_cycle=2016. Accessed 29 June 2020.

(USEPA) U.S. Environmental Protection Agency. 2018. WATERS (Watershed Assessment, Tracking & Environmental Results System) GeoViewer, watershed level reports utilizing StreamCat data. Web application. https://www.epa.gov/waterdata/waters-geoviewer. Accessed 29 June 2020.

(VDGIF) Virginia Department of Game and Inland Fisheries. 2015. Virginia's 2015 Wildlife Action Plan. Henrico, VA. http://bewildvirginia.org/wildlife-action-plan/. Accessed 4 April 2020.

Villalobos-Jiménez, G., A. M. Dunn, and C. Hassall. 2016. Dragonflies and damselflies (Odonata) in urban ecosystems: a review. Eur. J. Entomol. 113: 217–232.

Wagner, D. L., and M. C. Thomas. 1999. The Odonata fauna of Connecticut. J. Amer. Odonatol. 3: 59–85.

Walsh, C. J., A. H. Roy, J. W. Feminella, P. D. Cottingham, P. M. Groffman, and R. P. Morgan II. 2005. The urban stream syndrome: current knowledge and the search for a cure. J. N. Am. Benthol. Soc. 24: 706–723.

Ware, J. L., E. Pilgrim, M. L. May, T. W. Donnelly, and K. Tennessen. 2017. Phylogenetic relationships of North American Gomphidae and their close relatives. Syst. Entomol. 42: 347–358.

White, E. L., J. D. Corser, and M. D. Schlesinger. 2010. The New York dragonfly and damselfly survey 2005–2009: Distribution and status of the odonates of New York. New York Natural Heritage Program, Albany, NY, 424 pp.

White, E. L., P. D. Hunt, M. D. Schlesinger, J. D. Corser, and P. G. deMaynadier. 2015. A conservation status assessment of Odonata for the northeastern United States. New York Natural Heritage Program, Albany, NY, 50 pp.

(WOS) Wisconsin Odonata Survey. 2019. *Ophiogomphus howei*, Pygmy Snaketail. wiatri.net/inventory/odonata/SpeciesAccounts/SpeciesDetail.cfm?TaxaID=100. Accessed 29 June 2020.