COSEWIC
Assessment and Status Report

on the

Rapids Clubtail
Phanogomphus quadricolor

in Canada

ENDANGERED
2018

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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COSEWIC. 2008. COSEWIC assessment and status report on the Rapids Clubtail *Gomphus quadricolor* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 35 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

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Photo of Rapids Clubtail (male); photograph provided by Bonni Kinder with permission.

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COSEWIC
Assessment Summary

Assessment Summary – November 2018

Common name
Rapids Clubtail

Scientific name
Phanogomphus quadricolor

Status
Endangered

Reason for designation
This dragonfly has a fragmented distribution with a very small area of occupancy. Considerable search effort indicates that it is restricted to small portions of five rivers in southern Ontario. It is believed to be extirpated from one other river. Habitat decline due to a variety of factors remains a serious threat to remaining subpopulations.

Occurrence
Ontario

Status history
Designated Endangered in April 2008. Status re–examined and confirmed in November 2018.

COSEWIC
Executive Summary

Rapids Clubtail
Phanogomphus quadricolor

Wildlife Species Description and Significance

The Rapids Clubtail (*Phanogomphus quadricolor*) is a small (wing length of 25–27 mm) brownish-black clubtail dragonfly with yellowish-green stripes across the thorax and yellow spots along the abdomen. Many odonate species are considered indicators of good water quality, including stream-loving species, such as many clubtails. The Rapids Clubtail is rare and not well known by the general public; however, odonates are popular subjects of numerous field guides and nature outings.

Distribution

The Rapids Clubtail is rare throughout much of its range, found in the province of Ontario and 25 states in the US. Within Canada, this species has been recorded from six Ontario rivers. This includes the Credit River where this species is thought to be extirpated. This species is known historically from the Thames River and four extant subpopulations located on the Mississippi, Humber, Grand, and Nith Rivers.

Habitat

The Rapids Clubtail requires water for both the larval and adult stages. This species favours medium to large, clear rivers with riffles and areas of quieter pools where larvae forage in soft sediments. Larvae develop over a period of 2–4 years within the river environment. Adults emerge from the water and persist as adults for a period of approximately 4 weeks adjacent to the river where males patrol along rocky areas near riffles, while females spend the majority of their time away from the river in forested habitats, coming to breed in proximity to water.

Biology

Female Rapids Clubtails lay eggs within riffles which then drift downstream to hatch in calm pools. Larvae spend the bulk of their time hidden under soft sediments, with only the tip of the abdomen extended into the water column for respiration. Prey is captured using mouthparts that can be extended rapidly to capture small benthic invertebrates as well as small fish, and tadpoles as they grow larger. After a period of 2–4 years, larvae emerge out of the water to grassy/vegetated areas, shed their skin through a process called ecdysis,

and emerge as adults in late May and June and fly until early July in Ontario. Males patrol small sections of river, often around fast water, looking for aerial insect prey and mates. Upon locating a mate, males will grasp the female on the head with special claspers at the tip of the abdomen. Sperm which has been transferred from the tip of the abdomen to secondary genitals near the base of the abdomen is collected by the female as she raises her own abdomen to join in what is called a 'mating wheel'. Fertilized eggs are then deposited by the female by dipping the tip of her abdomen within the water after the male has departed.

Population Sizes and Trends

Population estimates of abundance or trends for the Rapids Clubtail in Ontario are not available. This species is considered extirpated from the Credit River, and was also historically known from the Thames River. The Rapids Clubtail has been identified on the Grand and Nith Rivers within the last 10 years.

Threats and Limiting Factors

The Rapids Clubtail, as with most odonate species, is a bioindicator that is typically found in relatively unpolluted environments. The apparent loss of this species at the Credit River (and possibly the Thames River) sites, where water quality has been significantly degraded, could indicate that this species is sensitive to decreased water quality related to sedimentation, increased chloride content, and agricultural runoff, although to what degree is unknown. Another considerable threat to this species is the loss of riparian forest cover which females and newly emerged males spend the majority of their time foraging within. Invasive species, particularly those with the ability to alter water quality, such as Common Carp (*Cyprinus carpio*), Zebra Mussel (*Dreissena polymorpha*), and Spiny Water Flea (*Bythotrephes longimanus*), may also threaten this species, although to what degree is uncertain. Other threats to this species may include recreational activities such as ATV use of shoreline habitats where some direct mortality may occur, as well as general disturbance of foraging, resting, and mating.

Protection, Status and Ranks

The Rapids Clubtail is designated as Endangered under Schedule 1 of the *Species at Risk Act* in Canada, and provincially in Ontario under the *Endangered Species Act*. This species has a 'sub-national rank' of S1, meaning that it is 'Critically Imperiled'. Globally the species is ranked as G3G4 and is thought to be secure. The Rapids Clubtail does not receive protection within the US, although it is a tracked species in many states, having a sub-national rank of S1-S3 (Critically Imperiled-Vulnerable).

Provincially, this species and its habitat are protected. Habitat is prescribed in a habitat regulation under the *Endangered Species Act* and includes instream environments where the species occurs and 200 m of surrounding shoreline habitat. Critical Habitat, defined by the *Species at Risk Act,* is described in the same way. The governments of Canada and Ontario have defined various proposed actions to assist in recovering this species including habitat restoration measures and inventory and monitoring, as well as education of the general public on threats to this species. The instream environment of the Rapids Clubtail is also indirectly protected under the *Fisheries Act* for fish habitat.

TECHNICAL SUMMARY

Phanogomphus quadricolor

Rapids Clubtail

Gomphe des rapides

Range: Ontario

Demographic Information

Generation time (usually average age of parents in the subpopulation; indicate if another method of estimating generation time indicated in the IUCN guidelines(2011) is being used)	2–4 years (larvae live 2–4 years, adults live approximately 1–2 months)
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Unknown.
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown.
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Unknown.
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown.
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown.
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	a. No. Water quality/habitat loss is unlikely to improve in urbanized areas where subpopulations occur. b. Yes. Decline in suitable terrestrial and aquatic habitat availability, especially water quality degradation. c. No. All threats to this species continue to persist for most populations and will for the foreseeable future.
Are there extreme fluctuations in number of mature individuals?	No.

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	7,995 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	36 km²

Is the subpopulation “severely fragmented” i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable subpopulation, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. No. b. Yes.
Number of “locations” (use plausible range to reflect uncertainty if appropriate)	4–5 extant locations (Range reflects that Thames River is historic and may or may not be extirpated, but no search effort to confirm). Plus 1 extirpated location (Credit River).
Is there an [observed, inferred, or projected] decline in extent of occurrence?	No
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	No
Is there an [observed, inferred, or projected] decline in number of subpopulations?	No. Two additional subpopulations have been discovered since 2008 (although these subpopulations may have been only recently discovered, it is possible that they remained undiscovered for some time).
Is there an [observed, inferred, or projected] decline in number of “locations”?	No. Two additional subpopulations have been discovered since 2008 (although these subpopulations may have been only recently discovered, it is possible that they remained undiscovered for some time).
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes. Inferred decline in area, extent and quality of habitat
Are there extreme fluctuations in number of subpopulations?	No.
Are there extreme fluctuations in number of “locations”?	No.
Are there extreme fluctuations in extent of occurrence?	No.
Are there extreme fluctuations in index of area of occupancy?	No.

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	**N Mature Individuals**

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations, or 10% within 100 years]?	Unknown.

Threats (direct, from highest impact to least, as per IUCN Threats Calculator)

Was a threats calculator completed for this species? Yes.

Threats for this species have been identified as:

9. Pollution (Medium–Low Impact)
1. Residential and Commercial Development (Medium–Low Impact)
6. Human Intrusions and Disturbance (Medium–Low Impact)
2. Agriculture and Aquaculture (Low Impact)
4. Transportation and Service Corridors (Low Impact)
7. Natural System Modifications (Low Impact)
3. Energy Production and Mining (Negligible Impact)
5. Biological Resource Use (Negligible Impact)

Rescue Effect (immigration from outside Canada)

Status of outside subpopulation(s) most likely to provide immigrants to Canada.	Stable in most northern U.S. states. Possibly declining in the south and southeast, but little data is available. Of the 25 states where it is known to occur, 11 have downgraded the sub-national rankings to reflect additional locations where this species has been observed. Only one state has up-graded the rarity. This is likely a result of increased search effort in the US and identification of previously undiscovered subpopulations.
Is immigration known or possible?	Unknown, but unlikely due to large gaps separating subpopulations and barriers to movement such as the Great Lakes and large impassable rivers.
Would immigrants be adapted to survive in Canada?	Likely.
Is there sufficient habitat for immigrants in Canada?	Yes. Apparently suitable riverine habitat is found throughout eastern Ontario and at several locations in southwestern Ontario, and northwestern Ontario where this species has not been recorded.
Are conditions deteriorating in Canada?[+]	Yes. Agricultural intensification and increased urbanization which result in salt, sediment, and pesticide runoff remain considerable threats to this species, which continues to decrease water quality.
Are conditions for the source (i.e., outside) subpopulation deteriorating?[+]	N/A
Is the Canadian subpopulation considered to be a sink?[+]	No.
Is rescue from outside subpopulations likely?	No.

[+] See Table 3 (Guidelines for modifying status assessment based on rescue effect)

Data Sensitive Species

Is this a data sensitive species?	No. Collection of this species is thought to be uncommon.

Status History

COSEWIC: Designated Endangered in April 2008. Status re–examined and confirmed in November 2018.

Status and Reasons for Designation:

Status:	**Alpha-numeric codes:**
Endangered	B2ab(iii)
Reasons for designation: This dragonfly has a fragmented distribution with a very small area of occupancy. Considerable search effort indicates that it is restricted to small portions of five rivers in southern Ontario. It is believed to be extirpated from one other river. Habitat decline due to a variety of factors remains a serious threat to remaining subpopulations.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable, total number of mature individuals unknown.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets criterion for Endangered, B2ab(iii), as IAO is less than 500 km² (36 km²) and it is known to exist at 4-5 or locations which continue to experience habitat quality degradation.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable, total number of mature individuals unknown.
Criterion D (Very Small or Restricted Subpopulation): Not applicable, total number of mature individuals unknown.
Criterion E (Quantitative Analysis): Not applicable, data insufficient for quantitative analysis.

PREFACE

Rapids Clubtail was first assessed by COSEWIC as Endangered in April 2008 under the scientific name *Gomphus quadricolor*. Since then, the subgenus *Phanogomphus* has been elevated to the generic level and the species is now considered *Phanogomphus quadricolor*.

Since the initial assessment by COSEWIC, the species has been identified at two new locations: the Grand River in 2009 and the Nith River in 2014. The species persists at two other locations: the Humber and Mississippi Rivers, including at a new site on the Mississippi approximately 8 km upstream of the previous extent. It has not been recorded from the Thames River since 1989, but there has been little to no search effort at the specific site since and so it may or may not still persist there. It is thought to be extirpated from the Credit River.

Most of the potentially suitable rivers in southern Ontario have been surveyed for Odonata (adults and/or exuviae) including intensive targeted surveys in 2018 for Rapids Clubtail on those rivers most lacking survey coverage. It is, therefore, unlikely that this species occurs on many more rivers than those currently known.

Most of the known locations are threatened by degradation of habitat due to agricultural intensification and increased urbanization resulting in salt, sediment, and pesticide runoff.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS (2018)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment and Climate Change Canada
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Canada

The Canadian Wildlife Service, Environment and Climate Change Canada, provides full administrative and financial support to the COSEWIC Secretariat.

COSEWIC Status Report

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Rapids Clubtail

Phanogomphus quadricolor

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Phylum: Arthropoda – arthropods
Sub-Phylum: Hexapoda – hexapods
Class: Insecta – insects
Subclass: Pterygota – winged insects
Infraclass: Palaeoptera – ancient winged insects
Order: Odonata – dragonflies and damselflies
Suborder: Anisoptera – dragonflies
Family: Gomphidae – clubtails
Genus: *Phanogomphus*
Species: *Phanogomphus quadricolor* (Ware *et al.* 2016)
Synonyms: Gomphus alleni (Howe 1922)
English common name: Rapids Clubtail
French common name: Gomphe des rapides

The Rapids Clubtail (*Phanogomphus quadricolor*) is a member of the family Gomphidae (clubtail dragonflies), which includes approximately 960 species. It was first described as a distinct species by Walsh (1963) and originally considered part of the genus *Gomphus* and the subgenus *Gomphus*. Carle (1986) placed it within a new subgenus, *Phanogomphus*. Recent molecular phylogenetic studies have elevated the subgenus *Phanogomphus* to the generic level. *Phanogomphus* currently includes the Rapids Clubtail along with 16 other gomphid species (Ware *et al.* 2016). There are no subspecies.

Morphological Description

The Rapids Clubtail is a small distinctively marked dragonfly. The total body length is 42–45 mm and a wing length of 25–27 mm. The face is light green and bisected by two lateral black stripes. As with all clubtails, the eyes are widely separated and are bluish green in colour (Figure 1). The thorax is patterned with a brownish/blackish colouration with yellowish vertical stripes. A small pale spot is present at the posterior end of the dorsal pale thoracic stripe. The abdomen is slender and black with linear yellow spots on the dorsal side. Dorsal spots on the abdomen are generally absent from the final three abdominal segments (S8–S10). Small yellow lateral spots are also present at the base of the 4th to the 7th abdominal segment (S4–S7), with larger yellow spots and markings on the first three abdominal segments (S1–S3) as well as on the 8th and 9th segments (S8–S9). The legs and claspers are black (Dunkle 2000; Needham *et al.* 2000; Needham *et al.* 2014). Adults of this species can be confused with other gomphids such as Least Clubtail (*Phanogomphus exilis*), Dusky Clubtail (*Phanogomphus spicatus*), Green-faced Clubtail (*Hylogomphus viridifrons*), Mustached Clubtail (*Hylogomphus adelphus*), and Harpoon Clubtail (*Phanogomphus descriptus*); however, these species all differ from the Rapids Clubtail in terms of their colour patterns, size, and morphological characteristics of their sexual organs.

Figure 1. Male Rapids Clubtail at the Grand River, June 2013 (Photo by Bill Lamond, with permission).

The male's secondary genitalia (anterior hamules) located at the base of the abdomen are sickle-shaped and terminate in a slender hook. In females of this species, the vulvar lamina is short (generally <1/6th the length of the 9th abdominal segment) and is V-shaped almost to the base of this structure (Walker 1958).

The larvae of this species have a lanceolate shape to the abdomen typical of gomphid species (Figure 2). Lateral spines are present on the 6th to 9th abdominal segments, with vestigial dorsal hooks present on only the 9th and 10th abdominal segments (Figure 2; Walker 1932). Larvae are superficially similar to other gomphid species and require examination under a dissecting microscope to identify.

Figure 2. Rapids Clubtail exuviae (Photograph provided by Peter Burke, with permission).

Population Spatial Structure and Variability

In Canada, the spatial structure and variability of the Rapids Clubtail has not been studied, and no genetic studies have occurred on this species. However, the known subpopulation in Eastern Ontario (Mississippi River) is geographically isolated from the apparently larger subpopulation at locations throughout the Greater Toronto Area (GTA) and southwestern Ontario. Genetic barriers to movement and dispersal of this species to new habitats or between subpopulations occur as a result of gaps in suitable habitats between these patches. The Rapids Clubtail, and gomphids in general, are not known for long distance dispersal or movements, as is seen in some other odonate species (i.e., aeshnids, libellulids)(Needham *et al.* 2014).

Designatable Units

The Rapids Clubtail is assessed as a single designatable unit, within which there are no known biological or behavioural differences. No subspecies or varieties are recognized

throughout its range. The entire population in Canada occurs within Ontario and there is no information on genetic structure between sites.

The Thames, Credit, Humber, Grand, and Nith Rivers are located within the Mixedwood Plains Ecozone, while the Mississippi River site is on the border between the Boreal Shield Ecozone and the Mixedwood Plains Ecozone (Crins *et al.* 2009). The climatic and biotic conditions vary considerably between these two ecozones, with the Boreal Shield Ecozone experiencing colder conditions and shallower soils over Precambrian granite bedrock (Crins *et al.* 2009). There is no data on discreteness of these subpopulations or evolutionary significance among populations in Canada or the United States.

Special Significance

The Rapids Clubtail is an uncommon dragonfly species throughout much of its range. Dragonflies are becoming more popular within the naturalist community. Dragonflies and damselflies, in general, are utilized as indicators of water quality in a wide range of aquatic environments (Bode *et al.* 1996; D'Amico *et al.* 2004; Bhandari *et al.* 2016). Gomphids play an important role in stream ecology as predators on a wide range of benthic invertebrates, small fish, and tadpoles (Walker 1958).

There is currently no Aboriginal Traditional Knowledge available for this species.

DISTRIBUTION

Global Range

The global range of the Rapids Clubtail is from Ontario in the north, southwards through Minnesota and Maine and as far south as Alabama and northern Georgia. The western extent of the range occurs from Minnesota south to Arkansas and the eastern limit of the range extends from North Carolina to the New England States. The global range remains similar to the initial COSEWIC status report (2008), although there has been a slight range expansion within North Carolina, Virginia, and Arkansas.

Recent surveys throughout the northeastern US from Pennsylvania to Vermont have also recorded new sites for this species (Odonata Central 2017), which may indicate increased search effort as opposed to range expansion.

All known locations, including historical, are shown on Figure 3.

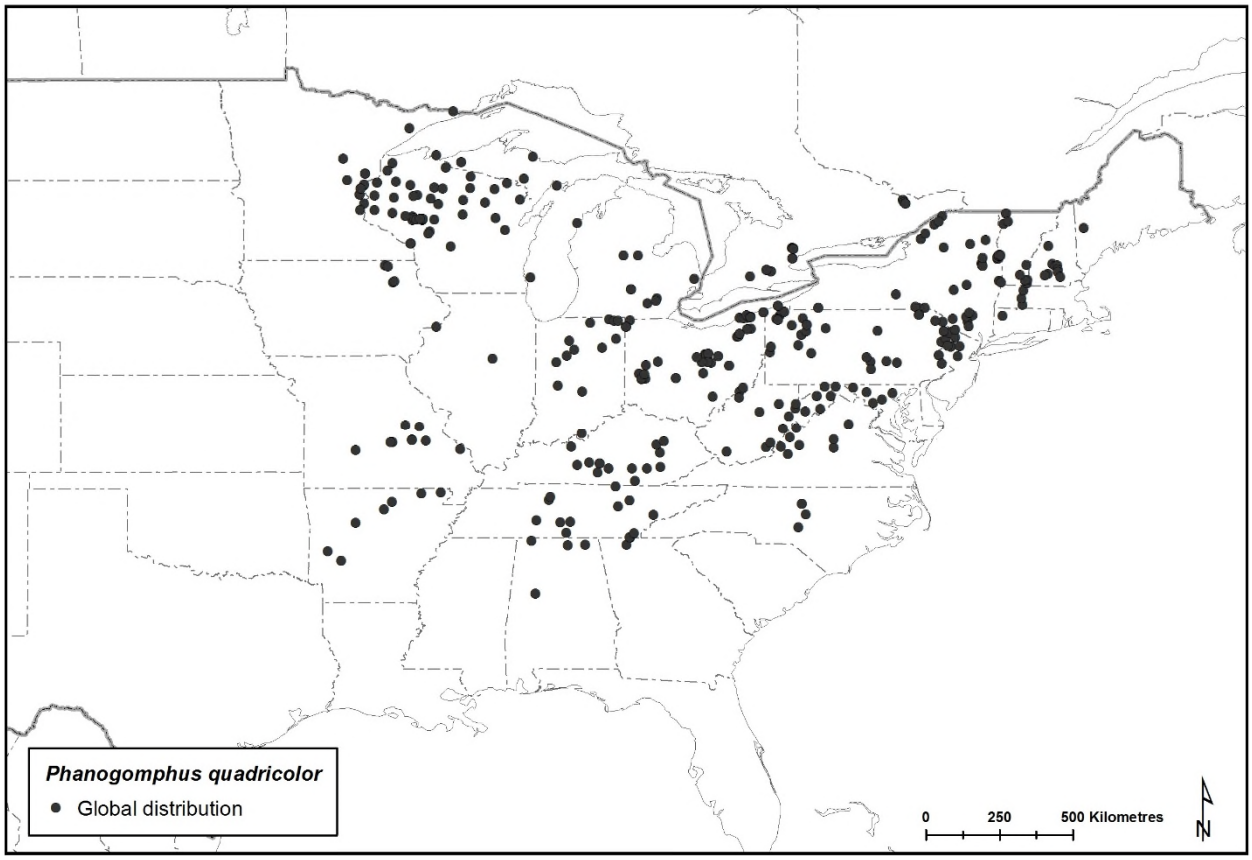

Figure 3. Global Range of Rapids Clubtail in North America.

Canadian Range

The Canadian range of the Rapids Clubtail is found within southern Ontario, where the species is known from 6 discrete locations including the Thames, Credit, Humber, Nith, Grand, and Mississippi Rivers, with each subpopulation being separated by between 30–450 km (Figure 4). The species is considered extirpated from the Credit River, and possibly extirpated from the Thames River (although there has been no recent search effort to confirm), and is currently extant at the other four rivers.

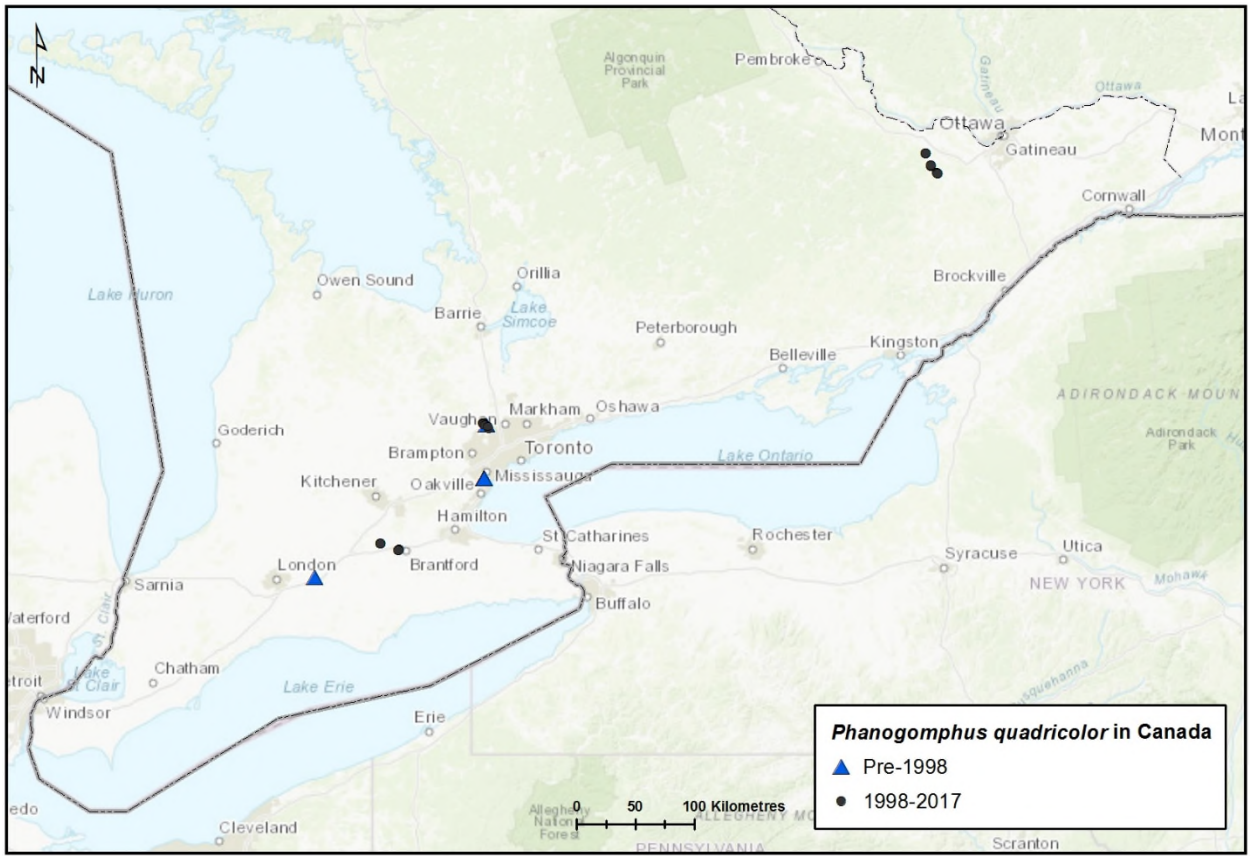

Figure 4. Range of Rapids Clubtail in Canada (pre-1998 and 1998-2017).

Extent of Occurrence and Area of Occupancy

The extent of occurrence (EOO) in Canada between 2008–2017 at extant sites is 7,995 km^2, with an index of area of occupancy (IAO) of 36 km^2 (Figure 5). EOO prior to 2008, including historical/extant sites was 7,317 km^2 with an IAO of 24 km^2 (Figure 6).

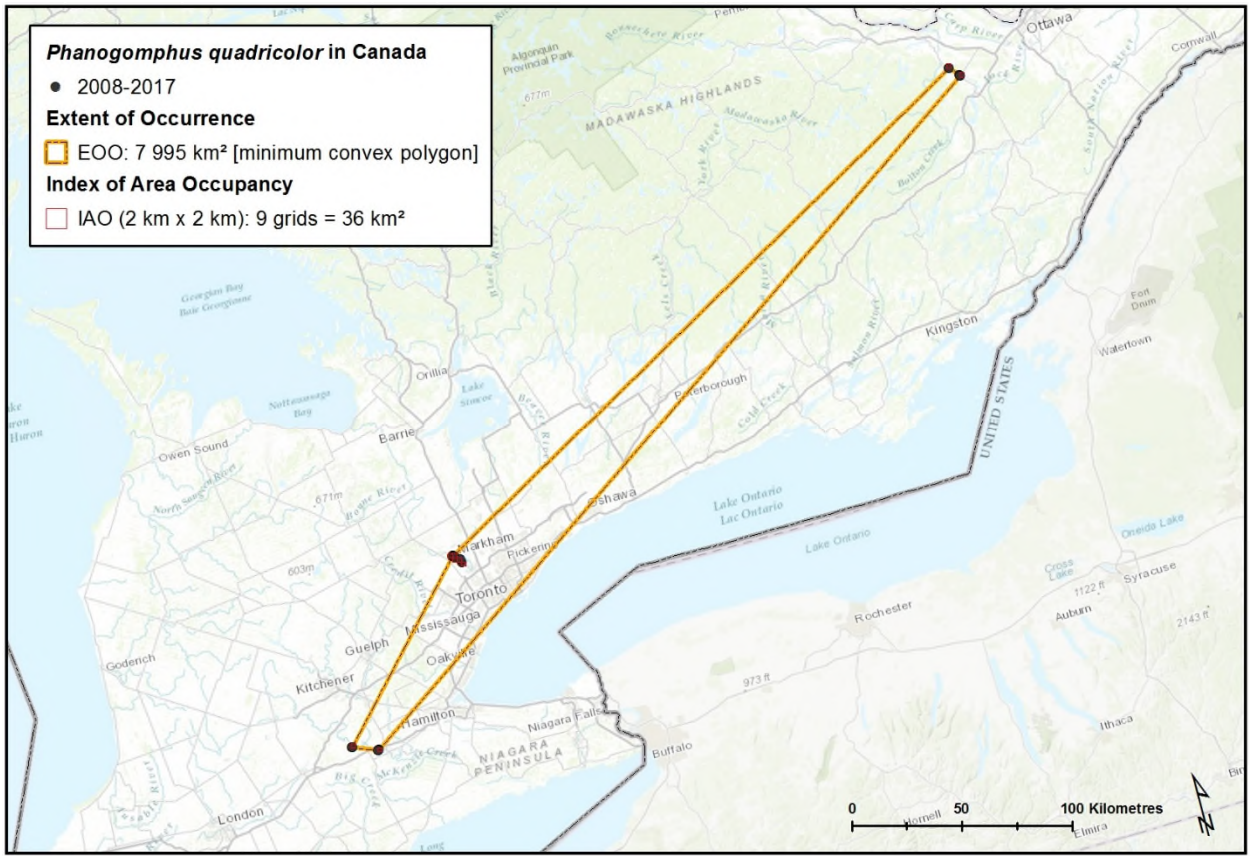

Figure 5. Extent of occurrence and index of area of occupancy (2008-2017).

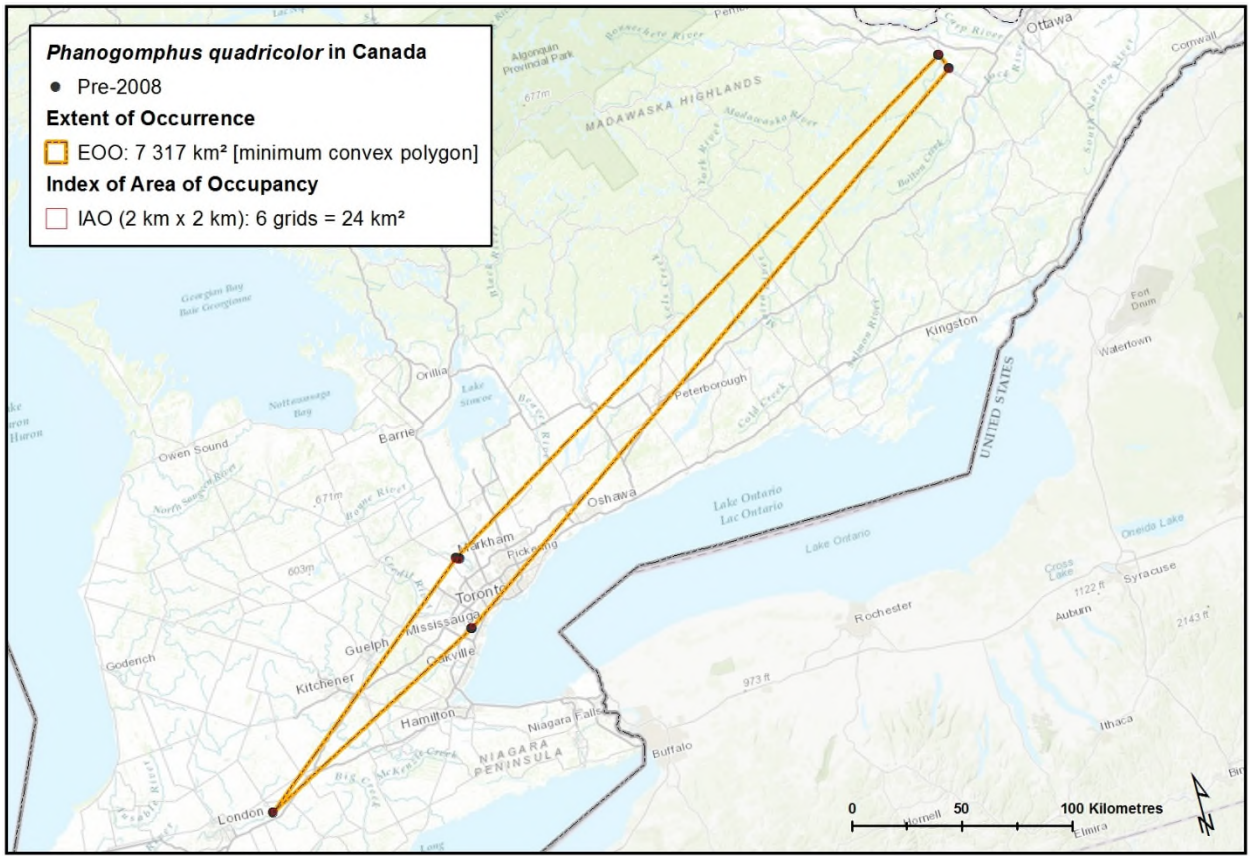

Figure 6. Extent of occurrence and index of area of occupancy (Pre-2008).

EOO is the geographical area encompassed by the shortest continuous boundary that contains all known, inferred, or projected sites of present occurrence of the Rapids Clubtail. This area is not meant to show extent of habitat, as large tracts of land are contained within these boundaries that are obviously unsuitable for this species. EOO is measured by drawing the smallest polygon which contains all sites of occurrence (COSEWIC 2017).

IAO provides an estimate of area of occupancy independent of scale, and hence, can be compared across taxa and against COSEWIC's assessment criteria. IAO is measured as the surface area of grid cells that intersect the actual area that this species occupies. This is calculated based on a grid with cell size of 2 km x 2 km.

Search Effort

Search effort in Ontario for odonate species is considered to be quite high, with most rivers within southern Ontario receiving good survey coverage. This high search effort, coupled with the ease with which the Rapids Clubtail is often observed at known breeding sites would seem to indicate that this species is very rare throughout its Canadian range (Colin Jones pers. comm. 2018a). Despite this, two new subpopulations, on the Nith and Grand Rivers, have been discovered within the past 10 years, and it is unlikely that these

represent newly colonized areas due to the geographic separation from other known subpopulations. Table 1 summarizes the targeted search effort for this species within Ontario. The Ontario Odonata Atlas maintains records of odonate species throughout Ontario. The atlas has a total of 77,264 records from across the province, with 11,041 records since 2009. Despite these extensive records, there are currently <50 records of the Rapids Clubtail (Ontario Odonata Atlas Database 2017).

Table 1. Targeted Search Effort for the Rapids Clubtail in Ontario.*

River Reach	Survey Date	Surveyors	Search Effort	Rapids Clubtail Observations
Southwestern Ontario				
Ausable River				
Hungry Hollow, ON	June 13, 2005	A. Harris, R. Foster	600 m of river searched by foot. Adult odonates recorded and exuviae collected.	None observed.
Credit River				
Erindale, ON	June 9, 2005	A. Harris, R. Foster	2.6 km of river searched by foot. Adult odonates recorded and exuviae collected.	None observed.
Grand River				
York, ON	June 14, 2005	A. Harris, R. Foster	300 m of river searched by foot. Adult odonates recorded and exuviae collected.	None observed.
Brantford, ON	May 24, 2009	B. Lamond	Short section of riffle checked near Brantford at the location of the original record for the Grand River.	1 adult male recorded.
	June 21, 2013			1 adult male recorded.
	June 15, 2014			1 adult male recorded.
	June 21, 2014			1 adult male recorded.
Humber River				
Kleinburg, ON	June 10, 2005	A. Harris, R. Foster	4.5 km of river searched by foot. Adult odonates recorded and exuviae collected.	At least 28 adult males recorded. No females observed, no exuviae collected.
Nashville Conservation Reserve	May 31, 2010	Colin Jones	Area east of Huntington Rd. searched on foot.	Several observed including at least 1 male and 1 ovipositing female.
	June 16, 2011	K. Konze		2 adult males recorded.
Humber Bridge Trail	July 1, 2011	A. Adamo	Area around Humber Bridge Trail east of Hwy 27 searched on foot.	1 adult male recorded.
Nashville Conservation Reserve	June 11, 2012	K. Konze, W. Konze	Area west of Huntington Rd. searched on foot.	1 adult male recorded.
Nashville Conservation Reserve	June 9, 2013	K. Holloway	Area near Humber Valley Heritage Trail searched	1 adult male recorded.
Kleinburg, ON	May 28, 2015	P. Burke	Area northeast of Kleinburg Station searched	6 exuviae collected.
Nashville Rd.	June 4, 2015	J. Holdsworth	Area east of Hwy 27 and south of Nashville Rd. searched on foot.	1 adult male recorded, 2 others observed (sex not recorded).
Nith River				
Township Rd. 2	June 6, 2014	N. McLeod	Area at Township Rd. 2 west of Paris searched	1 adult male recorded.
	June 7, 2014	A. Adamo		1 adult male recorded.
	June 12, 2014	P. Burke		3 adult males recorded.
	June 16, 2014	J. Holdsworth		1 adult male recorded.
		K. Tuininga		7 adult males recorded.
		N. McLeod		1 adult female recorded.
Blenheim Rd. south of Hwy 401	June 14, 2016	C. Jones, P. Burke	Area near Blenheim Rd. searched on foot.	At least 7 adult males recorded.
Wolverton	June 17, 2016	P. Burke	1.45 km of river searched on foot from Wolverton southwards.	None observed.

River Reach	Survey Date	Surveyors	Search Effort	Rapids Clubtail Observations
Blenheim Rd. south of Hwy 401	June 14, 2018	N. Miller	200 m of river surveyed on foot west of Blenheim Rd.	15 adult males Rapids Clubtail observed.
Trussler Rd.	June 14, 2018	N. Miller	150 m of river east of Trussler Rd. surveyed on foot.	None observed.
Sydenham River				
Alvinston, ON	June 11, 2005	A. Harris, R. Foster	500 m of river searched by foot. Adult odonates recorded and exuviae collected.	None observed.
Thames River				
Middle Thames River and near Banner	June 11, 2005	A. Harris, R. Foster	2.4 km of river searched by foot. Adult odonates recorded and exuviae collected.	None observed.
Eastern Ontario				
Mississippi River				
General location	June 10, 13, 2001	P. Catling, V. Brownell	Search effort not recorded.	17 and 20 adult Rapids Clubtail recorded on each respective date.
Blakeney Rapids	June 13, 2001			15 adults recorded.
Pakenham	June 21, 2002	B. Bracken, C. Lewis		1 adult male recorded.
Pakenham	June 22, 2003	D. Bree		3 adult males recorded.
Pakenham	June 25, 2004	M. Oldham, R. Oldham		1 adult female recorded.
Blakeney Rapids/Pakenham	June 26, 2005	B. Bracken, C. Lewis		3 adults recorded at Blakeney, 6 adults recorded at Pakenham.
Pakenham	July 10, 2005	P. Catling and Dragonfly Society of Americas		10 adults recorded
Almonte	May 31, 2010	C. Lewis, S. Shokay	Area search of hydroelectric dam and falls below town.	1 adult male recorded.
Almonte	June 1, 2010	Kemptville MNRF		1 adult male recorded.
Blakeney Rapids	June 10, 2014	K. Allison, R. Allison	Search effort not recorded.	3 adult males recorded.
Blakeney Rapids	June 13, 2015	K. Allison, R. Allison, P. Donaldson, D. Garcia		2-3 adult males recorded.
Almonte	June 15, 2015	P. Donaldson		1-2 adults recorded.
Almonte	June 17, 2015	P. Donaldson, G. Yarkchuk		1 adult recorded.
Almonte	June 18, 2015	P. Donaldson		1 adult recorded.
Salmon River				
Forest Mills to Kingsford, ON	June 12, 2018	N. Miller	6 km of river searched by foot. Adult odonates and exuviae collected along reach.	None observed.
Kingsford Conservation Area	June 13, 2018	N. Miller	750 m of river searched by foot from Kingsford Conservation Area southwards. Adult odonates and exuviae collected along reach.	None observed.
Tamworth, ON – Adair Road	June 14, 2018	N. Miller	200 m of river north from Adair Road surveyed during poor weather.	None observed.
Napanee River				
Yarker to Camden East, ON	June 11, 2018	N. Miller, G. Miller	8km of river searched by canoe and foot. Adult odonates and exuviae collected along reach.	None observed.
Newburgh, ON	June 13, 2018	N. Miller, Colin Jones	500 m of river searched by walking shoreline. Adult odonates and exuviae collected along reach.	None observed.
Northwestern Ontario				
Arrow River				
Arrow River Rd.	June 23, 2018	C. Jones, M. Burrell, N. Miller, K. Burrell	300 m of river searched by walking shoreline. Adult odonates and exuviae collected along reach.	None observed.

River Reach	Survey Date	Surveyors	Search Effort	Rapids Clubtail Observations
Arrow River at Arrow Lake Dam	June 24, 2018	C. Jones, M.Burrell, N. Miller, Ken Burrell, R. Foster, D. Elder	250 m of river searched by foot from Arrow Lake dam to 250m south. Adult odonates and exuviae collected along reach.	None observed.
Pigeon River				
Pigeon River Provincial Park	June 23, 2018	C. Jones, M. Burrell, N. Miller, K. Burrell	400 m of river searched by foot. Adult odonates and exuviae collected along reach.	None observed.
Pigeon River adjacent to Hwy 593	June 25, 2018	N. Miller K. Burrell	400 m of river searched by foot. Adult odonates and exuviae collected along reach.	None observed.
Pigeon River adjacent to Hwy 593	June 25, 2018	C. Jones, M. Burrell	5km of river searched by foot. Adult odonates and exuviae collected along reach.	None observed.
Pine River				
Hwy 61	June 23, 2018	C. Jones, M. Burrell, N. Miller, K. Burrell	200 m of river searched north of Hwy 61. Adult odonates and exuviae collected along reach.	None observed.
Pine River at Lake Superior	June 25, 2018	N. Miller, K. Burrell	1.4 km of river searched by boat and on foot from Lake Superior northwards. Adult odonates and exuviae collected along reach.	None observed.
Little Whitefish River				
Hwy 593	June 23, 2018	C. Jones, M. Burrell, N. Miller, K. Burrell	250 m of river searched on foot along Little Whitefish River adjacent to Hwy 593. Adult odonates and exuviae collected along reach.	None observed.
Hwy 593 at Jackpine, ON	June 25, 2018	N. Miller, K. Burrell	1 km of river searched by boat and foot from the junction of Little Whitefish River at Hwy 593 southwards. Adult odonates and exuviae collected along reach.	None observed.
Whitefish River				
Pakka Road-south	June 24, 2018	C. Jones, M. Burrell, N. Miller, K. Burrell, R. Foster, D. Elder	500 m of river searched on foot from Pakka Road eastwards adjacent to Hwy 588. Adult odonates and exuviae collected along reach.	None observed.
Dave's Road	June 24, 2018	C. Jones, M. Burrell, N. Miller, K. Burrell, R. Foster, D. Elder	1 km of river searched on foot upstream of Dave's Road. Adult odonates and exuviae collected along reach.	None observed.
Harstone, ON	June 26, 2018	C. Jones, M. Burrell, N. Miller, K. Burrell, B. Greaves	5 km of river searched from Dave's Rd. downstream by foot. Adult odonates and exuviae collected along reach.	None observed.

*Note: this table does not include all observations of this species in Ontario, only search effort carried out with the purpose of searching specifically for Rapids Clubtail.

The subpopulation on the Credit River is considered extirpated, with no new observations in recent history despite several surveys undertaken in 2005 and 2006 when a 2.6 km stretch of river near Erindale was searched (COSEWIC 2008). The Credit River has been surveyed fairly extensively, while no records have been identified since 1939, when E.M. Walker noted the species to be common near Erindale.

The first and only record from the South Thames River occurred in 1989; however, survey coverage within this portion of the Thames River has been limited, particularly in comparison to other known sites in Ontario, and hence, this subpopulation should be considered historical rather than extirpated. The South Thames was re-surveyed in 2005, but the species was not detected. Other locations on the Thames River (North Thames and Middle Thames) have received considerably greater search effort, with no additional observations of this species to date (Colin Jones pers. comm. 2018).

The species was first identified on the Humber River from exuviae collected by E. Walker in 1939 and is now known from a stretch of the river from southwest of Kleinburg, Ontario to the Nashville Conservation Reserve to the north. The Humber River location may be the best surveyed river for this species, as it is located in close proximity to a large human population. Surveys documenting the presence of this species on the Humber River occurred on seven different survey dates from 2010–2015. In 2005, a 4.5 km stretch of the Humber River from southwest of Kleinburg, ON to Nashville Conservation Reserve in the north, was surveyed for this species, and numerous species observations were documented at various sites (COSEWIC 2008).

Positive surveys for the Rapids Clubtail at the Mississippi River subpopulation occurred on seven different survey dates between 2010–2015 (Ontario Odonata Atlas Database 2017). The Mississippi River subpopulation was discovered in 2001 at two sites approximately 8 km apart, and in 2010, additional sites on the Mississippi were identified near Almonte, Ontario, stretching the known occurrences across approximately 15 km of river.

Search effort on the Grand and Nith Rivers resulted in the discovery of two new subpopulations within the past 10 years. In 2009, the species was identified on the Grand River northwest of Brantford, Ontario (Figure 7). In 2014, the species was documented for the first time on the Nith River, west of Paris, Ontario, with an additional site being found approximately 10 km further north in 2016 (Ontario Odonata Atlas Database 2017; Figure 8). Surveys at the Nith River location resulted in this species being observed on five separate dates in June 2014, although it is unclear how often surveys with negative results have been carried out, as these often go unreported. It appears that fewer surveys were carried out at this location in 2015, with only a single positive record from May 29th. All of these observations were at the same general location on the Nith River. During 2016, more extensive surveys of the Nith River were carried out, documenting this species south of highway 401, where this species was confirmed again on a subsequent visit in 2018. Surveys were also carried out in 2016 at the previously identified sites from 2014, but the Rapids Clubtail was not located. During the surveys carried out in 2016, at least seven other locations on the Nith River as well as a single site on Whiteman's Creek and the Grand River (near Glen Morris) were also surveyed, with no Rapids Clubtail being observed (Ontario Odonate Atlas Database 2017).

Figure 7. Location of first Grand River location for Rapids Clubtail, June 15, 2014 (Photograph provided by Bill Lamond, with permission).

Figure 8. Representative habitat on the Nith River where this species was observed, June 24, 2016 (Photograph provided by Peter Burke, with permission).

Other rivers in Ontario have potential habitat for the Rapids Clubtail, including on the Sydenham and Ausable Rivers, which were surveyed relatively extensively in 2005 as well as in more recent years (COSEWIC 2008; Colin Jones pers. comm. 2018b). Additional habitat is also present in northwestern Ontario, with records of this species occurring 3 km from the Canadian border (Odonata Central 2017). During June of 2018, reaches of the rivers west of Thunder Bay including the Pigeon, Arrow, Pine, Whitefish, and Little Whitefish were surveyed by between 4–6 biologists, and the species was not detected. Similarly, potentially suitable habitat for this species was also surveyed for the same project in June 2018 on reaches of the Salmon and Napanee Rivers in southeastern Ontario with the same result.

This species has been identified from two new locations since the development of the original status report (COSEWIC 2008), and the species has had sub-national rankings downlisted in 12 of 25 U.S. states following the identification of numerous other sites (Table 3). Globally, the population is thought to be relatively stable, with </= 10% change anticipated over the short term (NatureServe 2016). It is likely that the identification of additional subpopulations of the Rapids Clubtail is more a function of increased search effort rather than a population trend.

There is currently no Aboriginal traditional knowledge relating to search effort for this species.

HABITAT

Habitat Requirements

The Rapids Clubtail requires both aquatic habitat for larval development and adult egg laying as well as terrestrial habitat adjacent to riverine areas where adults can be found foraging and mating. The Rapids Clubtail generally requires medium to large (20–50 m wide in Ontario) rivers with adjacent forest cover, some fast water including riffle habitat, and relatively unpolluted clear, clean water with a gravel or cobble bottom (Cuthrell 2000; Paulson 2012; Needham 2014). In Vermont and New Hampshire, it can also be found on slower rivers containing entirely flat water without rapids (Blust and Pfieffer 2015). In Ontario, it appears that riffle habitat is important for this species, as adult males are often observed perched on rocks from where they will carry out foraging, territorial, and mating flights and females will oviposit overtop of rapids (Walker 1958; Catling and Brownell 2000; COSEWIC 2008; Peter Burke pers. comm. 2017). Adjacent forested habitat is thought to be of particular importance to females and newly emerged males of this species, which may disperse as far as 800 m into the forest canopy prior to returning to riverine areas to breed (Larry Rosche pers. comm. 2007 as cited in COSEWIC 2008). Typical upland habitat use is more often considered to be approximately 200 m from riverine habitat, as described in the provincial Habitat Protection Summary (MNRF 2018) and the federal Recovery Strategy (Environment Canada 2016).

All of the Ontario rivers where the Rapids Clubtail occurs contain slower sections of water, which is important habitat for larvae, which are often located in small pools downstream from faster sections of water where they will burrow into soft sediments (Walker 1958; Corbet 1999). Adjacent vegetation, such as grasses and shrubs are thought to be important supporting habitat for larvae, which will crawl into dense vegetation after emergence, prior to shedding their larval skin (ecdysis) (Walker 1958).

The six Ontario rivers from which the Rapids Clubtail has been recorded vary considerably in terms of size and composition. Mean discharge rates of these rivers between the years of 1970–2016 were found to range from 2.83 m^3/sec on the Humber River to 52.37 m^3/sec on the Grand River (Government of Canada 2017a). Mean discharge rates of all rivers where this species has been recorded are shown in Table 2 along with water quality parameters. River width is also quite variable in these habitats, ranging from approximately 20 m wide at the Humber site to nearly 145 m wide on the newly discovered location on the Grand River. The other rivers are generally more similar to the Humber in size, with the Credit, Mississippi, Thames, and Nith ranging from 30–50 m in width.

Table 2. Average water quality and discharge rates for Ontario rivers between 2000-2014 (June-October) with records of Rapids Clubtail.*

	Credit River	Grand River	Humber River	Mississippi River	Nith River	Thames River
Mean Discharge Rate (m^3/sec)	8.85	52.37	2.83	26.56	10.35	5.68
Mean July Water Temperature (°C)	21.14	21.9	22.29	23.7	22.57	21.24
Dissolved Oxygen (mg/L)	11.53	10.21	11.53	9.90	10.79	12.79
Turbidity (Formazin Turbidity Unit)	No Data	20.17	85.63	1.79	29.65	16.79
Suspended Solids (mg/L)	30.04	30.98	47.27	1.63	55.71	20.87
Chloride (mg/L)	146.84	69.60	129.93	6.56	38.10	61.1
Nitrate (mg/L)	1.90	3.28	0.64	0.08	3.57	5.44
Nitrite (mg/L)	0.02	0.04	0.02	0.004	0.02	0.06
Phosphorus (mg/L)	0.05	0.08	0.08	0.02	0.10	0.11

*Monitoring stations where this data was collected include the Credit River at Erindale (<1 km from extirpated location), Grand River at Brantford (approx. 5 km from extant location), Humber River at Kleinburg (<3 km from extant locations), Mississippi River at Appleton (6 km from extant location), Nith River near Canning (<1 km from extant location), and Thames River at Ingersoll (approx. 5 km from extirpated location).

Table 3. Province or State Sub-national Rankings for Rapids Clubtail.*

Province/State	2008 Ranking	Current Ranking
Ontario	S1	S1
Alabama	S3S4	S1
Arkansas	SNR	SNR
Connecticut	S1	S1
Georgia	S1	S1
Illinois	SNR	SX
Indiana	S2	S2
Iowa	S1	S1
Kentucky	S2S3	S2S3
Maine	S1	S1
Maryland	S1	S2
Massachusetts	S1	S1
Michigan	S2S3	S2S3
Minnesota	SNR	SNR
Missouri	SNR	SNR
New Hampshire	SNR	S1
New Jersey	S2	S3
New York	S1S2	S3
North Carolina	S1S2	S1?
Ohio	SNR	S3
Pennsylvania	S1S2	S2S3
Tennessee	S3S4	S3S4
Vermont	SNR	S2
Virginia	S1	S2S3
West Virginia	S2S3	S3
Wisconsin	S4	S4

*All sub-national rankings are from NatureServe 2016, except where rankings are out of date, in which case the more recent rankings from various state Natural Heritage Information Centres have been shown.

Water quality is variable between rivers where the Rapids Clubtail is present (Table 2; MOECC 2016). Chloride levels remain very high within the Credit River where this species is extirpated, but are also relatively high within the Humber River where this species is extant. Water quality parameters indicative of agricultural runoff (e.g., nitrate, nitrite, and phosphorus, etc.) were found to be highest within the Thames River where this species is also considered extirpated. Agricultural activities within the Thames River catchment are extensive and likely contribute to these elevated levels. It is currently unclear to what degree these water quality parameters influence the physiology of developing eggs and larvae within the riverine environment, particularly when extant sites such as the Nith River have similar levels of agricultural runoff as extant sites such as the Thames (Table 2).

In addition, where agricultural runoff is present, there are invariably levels of pesticides within nearby watercourses which may go undetected as this is not often recorded at water monitoring stations. Pesticides are discussed further in the *Threats and Limiting Factors* section below.

Water temperature across all rivers was relatively similar, ranging from 21.6 °C in the Thames to 23.3 °C in the Mississippi (mean July temperatures). Other parameters including turbidity and suspended solids are also provided in Table 2; however, it is unclear to what degree these influence the persistence of this species throughout its range.

Habitat Trends

Rapids Clubtail subpopulations are found in some of the most intensely used agricultural and urban areas within Ontario. Deforestation and development of the lands adjacent to the rivers used by this species has occurred extensively since the early 1800s and has likely significantly impacted the water quality within these rivers as well as the associated riparian habitats (Riley and Mohr 1994). Agricultural activities within southern Ontario are considered to have peaked in the early to mid-1900s. Across southern Ontario, the percentage of agricultural lands declined from 68% in 1966 to 54% in 1986. This trend was also mirrored within the GTA, at both the extirpated site on the Credit and the extant sites on the Humber River which have seen a decline of 64% to 40% over the same 20-year period (Riley and Mohr 1994). However, intensification of agricultural activities and urban sprawl adjacent to the six rivers that the Rapids Clubtail has been recorded from continue to cause increasing pressure on these areas, with the risk of reducing habitat quality.

Forest cover in the South Thames River watershed has remained relatively low at 11% within the past decade, as measured between 2001 and 2012 (UTRCA 2001 and 2012). Riparian forest cover in the location of the historically known population west of Ingersoll is relatively high and unfragmented along the Thames River corridor and ranges from 60–600 m in width on either side of the river. This has remained relatively unchanged over the past 10 years (Google Earth 2017).

Similarly, forest cover has remained consistent at approximately 17% in the Humber River watershed between the years of 2000–2013 (Humber Watershed Alliance 2000; TRCA 2013). The TRCA is currently targeting 30% forest cover as a goal necessary to sustain the biological integrity of forest ecosystems in the Humber watershed due to the intense pressure of human development on this area. Riparian forest cover along the Humber River is relatively high in the location of the Rapids Clubtail observations north of Kleinburg to Nashville Conservation Reserve, ranging from between 50–500 m in width, and has remained relatively unchanged within the past 10 years (Google Earth 2017). South of Kleinburg, forest cover is less continuous and more fragmented, and in some locations is non-existent or fragmented with agricultural land up to the edge of the Humber River (Google Earth 2017).

The Credit River watershed continues to increase forest cover, which reached an all-time low of 16.3% in 1954 and has consistently increased to 21% in 2013 (CVCA 2013). The riparian zone within the Credit River watershed has a higher amount of forest cover at 37%, but this is still considered inadequate, as this indicates that most streams and rivers do not have supporting forest cover (CVCA 2013). Adjacent to the extirpated location at this site, riparian forest cover is high and is approximately 150 m on either side of the river.

Riparian forest cover quickly decreases to the north of highway 403 and to the south where a golf course is found adjacent to the Credit River. This pattern has remained unchanged in the past 10 years (Google Earth 2017).

The Grand River watershed forest cover has also substantially increased over the past century through natural regeneration and tree planting, and currently has approximately 19% forest cover (GRCA 2004). Riparian forest cover near the extant subpopulation on the Grand River is highly variable and fragmented, up to 250 m wide on the north side, to approximately 30 m wide on the south side of the river (Google Earth 2017). This pattern of forest cover along the Grand River has remained largely unchanged within the past 10 years (Google Earth 2017).

Forest cover has not been calculated for Blandford-Blenheim Township, containing the Nith River subpopulation of the Rapids Clubtail; however, it is likely similar to the nearby Grand River, as it is located less than 10 km away. At the known locations on the Nith River, riparian forest cover is also highly variable, ranging from <50 m to > 500 m wide near Canning, ON. On average, riparian forest cover along the Nith River is <150 m on either side and is fragmented by agricultural lands, and has remained largely unchanged within the past 10 years (Google Earth 2017).

The Mississippi River subpopulation of the Rapids Clubtail is located within Lanark County, which has an estimated 83% forest cover (Lanark County 2010). However, although riparian forest cover adjacent to the river is extensive, it is relatively narrow and is bordered by agricultural lands. In the locations of the extant subpopulations, the width of riparian vegetation ranges from 0–300 m, as agriculture and urban areas are located immediately adjacent to the river in some cases. This pattern of forest cover has remained relatively unchanged in the past 10 years (Google Earth 2017).

Water quality continues to be a limiting factor for this species, as the Credit River, where this species is considered extirpated, and the Thames River where it is considered historical and possibly extirpated were found to have high levels of chlorides (Credit River) and nitrates, nitrites and phosphorus (Thames River), consistent with considerably reduced water quality (Table 2). However, water quality is also reduced at locations where this species is extant, such as on the Nith River which has higher levels of phosphorus and nitrates than on the Credit River, and similar to levels found on the Thames River. Hence, it is unclear to what degree water quality is limiting the range of this species in Ontario.

All of the six rivers where the Rapids Clubtail has been recorded from have water levels that are regulated by dams. Dams have the potential to degrade habitat for the Rapids Clubtail by reducing the amount of riffle habitat, increasing water temperature, and decreasing the availability of sediments on the river bed for larval development. Dams on these rivers are unlikely to be removed, as they have been put in place for recreational purposes, flood control and for hydroelectricity.

Discharge rates on all 4 of the rivers with extant subpopulations of the Rapids Clubtail have remained relatively constant since monitoring began in the early 1900s, with slight

increases seen at all of the rivers except for the Mississippi. It is likely that these slight increases in discharge are the result of increased urbanization and agricultural practices that have resulted in the clearing of vegetation/increases in impermeable surfaces and corresponding increases in stormwater runoff to these rivers. The potential implications of altered riverine discharge rates on the Rapids Clubtail is unclear, but these changes have the potential to impact the availability and distribution of suitable aquatic habitat in terms of prey availability, larval habitat within pools, and the distribution of riffles utilized by adults for ovipositing and breeding. Average discharge rates are shown in Figure 9.

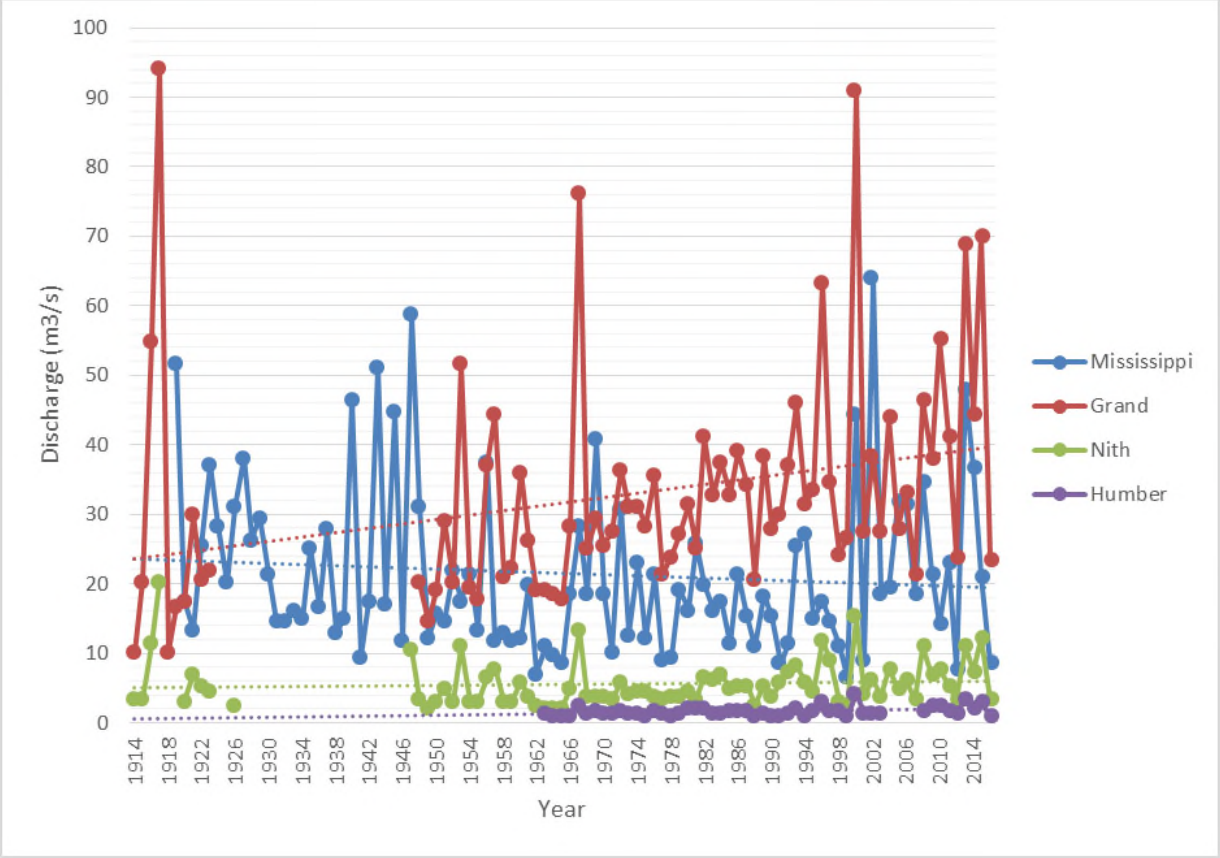

Figure 9. Average discharge rates (m^3/s) during June/July at Ontario rivers containing extant subpopulations of Rapids Clubtail between the years of 1914-2016. Monitoring stations are the Mississippi River–Appleton, Grand River–Brantford, Nith River–Canning, Humber River–Elder Mills.

BIOLOGY

Given the relative obscurity of the Rapids Clubtail, little species-specific research on the biological life cycle of this species has been carried out. Where available, information from similar species within the genus *Phanogomphus* or within the family Gomphidae has been utilized to fill in gaps in knowledge for this species.

Life Cycle and Reproduction

The life cycle of all gomphid species is 2–4 years, followed by a terrestrial stage up to four weeks in duration (Walker 1958; Dunkle 2000).

The lifecycle of the Rapids Clubtail begins with oviposition of eggs by the female directly into the rapid water of a riverine habitat, after which the eggs drift a short distance downstream, settling into the soft sediment of a quiet pool (Walker 1958). Little is known about the length of the egg stage of the life cycle, although it is likely to be similar to that of other related species which require from five days to one month to hatch (Walker 1953; Corbet 1999). Egg development time may vary slightly depending on water temperature, as increased water temperature is known to result in faster development in gomphid species (Hawking and New 2008).

After larvae hatch, they will burrow into the soft substrate, breathing through internal gills located within the abdomen. Gomphid species have a snorkel-like apparatus at the tip of the abdomen that extends beyond the sediment and delivers water to the internal gills, allowing the species to remain concealed (Walker 1958; Dunkle 2000; Paulson 2012). Feeding during the larval stage, as with other river gomphids, begins with extremely small prey, such as protozoans, progressing to larger macroinvertebrates, small fish, and tadpoles at larger instars (Needham *et al.* 2000; Needham *et al.* 2014). Prey is captured through the use of a prehensile labium which can be rapidly deployed to seize small prey. In gomphid species in Europe, larval development spans up to four years, requiring numerous instars to reach maturity (Walker 1953).

Prior to the final instar moult, the larvae crawl out of the water to adjacent vegetation to undergo ecdysis, the final transformation to a flying adult. They are generally located within a few metres of the high waterline, often in grassy areas (Peter Burke pers. comm. 2017). This is the most vulnerable stage of the dragonfly's life cycle, with approximately 5% of gomphids failing to emerge due to environmental conditions and predation (Jakob and Suhling 2010). The Rapids Clubtail, as with other gomphids often engages in mass emergence, whereby many individuals emerge at the same time to undergo ecdysis.

In Ontario, emergence into the adult form typically occurs in June, with records as early as the end of May (Ontario Odonata Atlas Database 2017). It is also likely that observations slightly underestimate the emergence dates, as adults usually disperse into forest habitat for a period of approximately one week in order to feed and harden their exoskeletons prior to males returning to the rivers, where they will establish territories, awaiting the arrival of females (Walker 1953). Males patrolling sections of river encounter females, and prior to copulation transfer sperm from the abdominal tip to the secondary genitalia at the base of the abdomen. Upon capture of females, the male will attach his abdominal claspers to the head of the female, at which point the female will raise her abdomen to join with the male secondary genitalia, and sperm transfer occurs. Females carry out oviposition without being attended by males (Walker 1953). As many as 5000 eggs may be produced by a single female of a gomphid species (Walker 1953).

Adults hunt during daylight hours on sunny days, feeding on a wide range of flying insect species, in particular Diptera, Ephemeroptera, Lepidoptera, and Trichoptera (Walker 1953). In turn, adults are preyed upon by a range of aerial predators, particularly various bird species and other dragonflies, in addition to other species such as frogs, spiders and other insects (Walker 1953; Dunkle 2000). In Ontario, the adult stage is rarely observed beyond early July (Ontario Odonata Atlas Database 2017).

Physiology and Adaptability

Very little information is known about the physiology of the Rapids Clubtail and the adaptability of this species to environmental changes and fluctuations. Gomphids in general are widely considered bioindicators of healthy aquatic environments, as they are often absent in polluted environments (Schmidt 1983). Corbet (1999) notes that Biological Oxygen Demand (BOD) of >10 mg/L is not typically tolerated by this species (Water Survey 2007; Ontario Ministry of the Environment 2007). Even the rivers where this species has been extirpated have mean BOD values considerably lower than this value, with the Thames River having the highest, at 2.7 mg/L. It is currently unclear how a moderately elevated BOD over a long time scale would affect this or other gomphid species within river communities.

Pesticides likely affect the health and survivorship of the Rapids Clubtail during its nymphal life stages. Elevated chloride levels and parameters indicative of agricultural runoff (nitrate, nitrite, phosphorus) may also negatively affect the development of gomphid eggs and larvae, although studies have not been carried out to examine this in detail. As the Rapids Clubtail is currently found within river systems containing a wide range of water quality parameters related to salinity, sediment load, and turbidity, it is unknown to what degree these factors affect the physiological condition of this or similar species. These threats are discussed in more detail in the Threats and Limiting Factors section below.

The Rapids Clubtail is thought to generally prefer cool water riverine environments (Cuthrell 2000). Mean July water temperature across all rivers was relatively similar, ranging from 21.6 °C in the Thames to 23.3 °C in the Mississippi (MOECC 2016). Egg development time may vary slightly depending on water temperature, as increased water temperature is known to result in faster development in gomphid species (Hawking and New 2008).

Adults of this species require warm, sunny conditions to forage and patrol territories. During cool or overcast conditions, this species is typically less active. Daytime mean temperatures during June at the locations where adults have been observed ranged from approximately 21 °C–25 °C during the day, with evening lows between 11 °C and 14 °C (Environment Canada 2017).

Dispersal and Migration

The Rapids Clubtail is not migratory. Subpopulations typically remain resident and within close proximity to their riverine habitat for the duration of their life (Dunkle 2000). Females and newly emerged males are known to disperse between 200–800 m into forest habitat before returning to the river to breed (Larry Rosche pers. comm. 2007; MNRF 2018; Environment Canada 2016; Walker 1953). The habit of foraging close to the surface of the water rather than above the forest canopy as in some other dragonfly species means that they are likely less susceptible to wind directed dispersal than other species. Passive dispersal likely occurs predominantly following oviposition of eggs or nymphs within the water column, which may drift for considerable distances before settling on the river bottom.

Known subpopulations within Ontario are geographically isolated from one another by approximately 30–450 km. Separation from subpopulations within the US is equally large, and separated via the Great Lakes and St. Lawrence River, which likely represent sizable barriers to dispersal. Unless other subpopulations are discovered between the locations currently identified, dispersal between them is unlikely to occur, and each of the four rivers (Humber, Mississippi, Grand, and Nith) should be considered separate, extant subpopulations.

Interspecific Interactions

The Rapids Clubtail does not have any known symbiotic or parasitic relationship with other species.

The Rapids Clubtail is a predatory insect at both its adult and nymphal life stages. There is little information specifically on the Rapids Clubtail prey preferences although based on information from other gomphids, prey items include protozoans, midges, oligochaetes, other benthic invertebrates and small fish and tadpoles as they mature to larger instars (Walker 1953; Mahato and Johnson 1991). Adults likely feed on a wide range of aerial insects, particularly species found close to the water such as various fly species, mayflies, moths, and caddisflies (Walker 1953).

Predators of the larval stage of most stream gomphids likely include a wide range of fish species, particularly those that focus on benthic prey such as sculpins, madtom, and darters (Phillips and Kilambi 1996). During the adult flying stage, predators likely include numerous different aerial insectivores such flycatchers (Tyrannidae spp.), swallows (Hirundidae spp.), American Kestrel (*Falco sparverius*), Merlin (*Falco columbarius*) as well as various frog species, all of which are known to feed on odonates.

The Rapids Clubtail often occurs with other stream and river odonates such as Rusty Snaketail (*Ophiogomphus rupinsulensis*) and Ebony Jewelwing (*Calopteryx maculata*). The Rapids Clubtail may compete with these, and other odonates, for food both as larvae and adults, although this is likely offset somewhat through interspecific differences in foraging niches.

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Sampling effort and methods to derive subpopulation size at known sites or for the Canadian population as a whole have not been completed. Most information is from search effort and limited to one or two days of information on the abundance (e.g., number) of specimens observed at the site. Sampling effort has typically been by wandering transects throughout shoreline terrestrial habitat that otherwise appears suitable for the species during the adult flight period. Aquatic surveys for the nymphal life stages has occurred regularly but sporadically throughout Ontario.

Abundance

Subpopulation or Canadian population estimates are not possible given the lack of population studies undertaken for the species. In general, estimating population sizes for odonates with accuracy is very difficult (Corbett 1999).

During the initial COSEWIC Status Report for this species in 2008, a crude estimate of abundance was estimated based on the number of adults observed during several more extensive surveys on the Humber and Mississippi Rivers. A similar exercise has not been undertaken for the years of 2008–2017 for this report, as it is unlikely to reflect an accurate representation of abundance due to a lack of systematic surveys during these years.

Surveys at the Grand River site have only identified the presence of a single male. As many as seven males have been identified at the Nith River at two sites. Since 2008, high counts of adults along the Humber River have ranged from one to three individuals, with six exuviae also being collected east of Kleinburg on May 28, 2015 (P. Burke). The highest tally of adults on the Mississippi River was recorded in 2002 with 25 males being observed across the Pakenham and Blakeney Rapids. Between 2008–2017, high counts of the Rapids Clubtail males have been 3 at Blakeney and 2 at the new site in near Almonte, ON. No observations have been recorded at Pakenham since 2005 (Ontario Odonata Atlas Database 2017).

The global population of the Rapids Clubtail is estimated at between 2,500–10,000 individuals and is listed as vulnerable globally, although this is a very rough approximation of abundance for this species (NatureServe 2016).

Fluctuations and Trends

There is currently no data on fluctuations or trends for the Rapids Clubtail. Search effort since the initial COSEWIC status report has primarily recorded the species when observed and not null search effort.

Rescue Effect

The Rapids Clubtail is not considered to be a long distance dispersing species, and has never been identified a great distance from water in Ontario (Ontario Odonata Atlas Database 2017). The distance the Rapids Clubtail disperses during its adult life stage and aquatic nymphal stage is unknown.

In Ontario, most of the subpopulations are widely separated from one another with little apparent opportunity for 'rescue effect' of extirpated subpopulations. The exception to this may be the Nith River and Grand River subpopulations which are located relatively close together, with a linear distance of approximately 10 km between the closest sites. The Nith River flows into the Grand River providing a relatively contiguous corridor of suitable habitat between Paris and Brantford. However, the Grand River/Nith subpopulations and the Humber River subpopulation are geographically isolated from one another (separated by 100 km), and rescue is also unlikely to occur from the nearest US subpopulations in Ohio and New York that are >150 km away and separated by Lake Erie/Lake Ontario and the Niagara River. The Mississippi River subpopulation in Eastern Ontario is >300 km from the nearest Canadian subpopulation and is also separated from the nearest US subpopulation approximately 80 km away. The St. Lawrence River may also act as a substantial barrier to gene sharing and rescue between these subpopulations.

The Canadian subpopulations of the Rapids Clubtail on the Grand, Nith, Humber, and Mississippi Rivers in Ontario should be considered geographically distinct subpopulations with little chance for genetic transfer between them unless additional subpopulations are identified.

THREATS AND LIMITING FACTORS

The threats classification for the Rapids Clubtail in Canada is based on the IUCN-CMP (World Conservation Union–Conservation Measures Partnership) unified threats classification system (see Salafsky *et al.* 2008; Master *et al.* 2012). Threats to the Rapids Clubtail have been assessed based on available literature and input from specialists and those with local knowledge of this species. The following main categories of potential threats to this species have been identified in order of greatest to lowest impact.

Threat 1. Residential and Commercial Development (Medium–Low Impact)

1.1 Housing & Urban Areas (Medium–Low Impact)

The greatest threat from housing and urban areas, is likely the loss and degradation of riparian forest that provides habitat for adults and likely also acts to filter urban runoff. As mentioned within the *Habitat Trends* section, riparian forest cover at most of the river locations where the Rapids Clubtail has been recorded from is relatively sparse in many of the watersheds, ranging from 11–83%. Decreased forest cover has the impact of not only reducing suitable habitat for females and young males, but it also may result in

amplification of the stressor of decreased water quality. Riparian buffers are known to attenuate sediment and nutrient loading (Woodard and Rock 1995) and are also effective in reducing the concentrations of pesticides reaching water bodies (Sheldon *et al.* 2005). As such, maintaining suitable woodland buffers around known the Rapids Clubtail habitat is critical for the persistence of this species.

The Humber population may be particularly susceptible to impacts from housing and urban areas as development within the Greater Toronto Area (GTA) continues to encroach on natural habitats surrounding the locations from where the Rapids Clubtail is known, much of which is located on private land. The northern extent of the Humber River subpopulation north of Kelinburg receives some protection from urban encroachment within the Nashville Conservation Reserve. The Nith and Grand River populations are currently experiencing less pressure from urban development, although residential development is still high in some of these areas (e.g., adjacent to Grand River observations near Brantford). The Mississippi River population is not expected to be significantly impacted by urbanization in the near future.

1.2 Commercial & Industrial Areas (Low Impact)

Similarly, commercial and industrial areas have the potential to remove and degrade riparian habitat for the Rapids Clubtail, resulting in similar impacts as described above. No commercial or industrial facilities are present adjacent to known locations of the Rapids Clubtail although such facilities are present along other reaches of these rivers that provide habitat for this species.

1.3 Tourism & Recreation Areas (Negligible Impact)

Tourism and recreation activities along riverine areas have the potential to impact this species indirectly by disturbing adult Rapids Clubtails during breeding, resting and foraging behaviours as well as causing direct mortality to nymphs (as described below). None of the areas where the Rapids Clubtail is extant are known to be important tourist areas and they are unlikely to become such in the future. Any impacts from tourism would likely be negligible for this species.

Threat 6. Human Intrusions & Disturbance (Medium–Low Impact)

6.1 Recreational Activities (Medium–Low Impact)

Recreational activities such as boating and all-terrain vehicle (ATV) use adjacent to the Rapids Clubtail subpopulations have been noted as having the potential to crush emerging nymphs that are in the process of eclosing. ATV trails were noted within the Critical Habitat of this species, along the edges of several of the rivers where this species is known from (refer to Section on *Legal Protection and Status* for definition of Critical Habitat). This may also cause disturbance of adults that are foraging, seeking mates or engaging in ecdysis (Peter Burke pers. comm. 2017). As this species often engages in mass emergence on a few suitable dates, ATV use in areas in close proximity to the water

during late May to early June has the potential to greatly reduce or eliminate an entire cohort of the Rapids Clubtail at a given location (Colin Jones pers. comm. 2018b). A photograph depicting the damage caused by such activities at the Nith River is shown in Figure 10.

Figure 10. ATV use at the Nith River Rapids Clubtail location during 2016 (Photograph provided by Colin Jones, with permission).

Threat 9. Pollution (Medium–Low Impact)

Degradation of water quality as a result of human activities has the potential to be a significant threat to the Rapids Clubtail, although the extent of impact on this species remains somewhat uncertain due to a lack of understanding of the degree of pollution at specific subpopulations and the physiological response of this species to such contaminants. However, given the known response of such contaminants on prey species and other similar odonates, some impacts can be expected to occur.

9.1 Household Sewage and Urban Waste Water (Medium–Low Impact)

The extirpated subpopulations of the Rapids Clubtail on the Credit and Thames Rivers were both located in areas of intense urban development, which has clearly resulted in degraded water quality (Table 2) and reduced riparian forest cover (See *Habitat Trends;* UTRCA 2012; CVCA 2013). Currently, three out of four of the extant locations for this species are located within heavily developed portions of southern Ontario where pressures such as those described above will continue to be intense in the coming years. Only the Mississippi River location remains relatively naturalized with good water quality, low amounts of agricultural/stormwater runoff, and high riparian forest cover (MVCA 2013).

Increased salinity of rivers used by the Rapids Clubtail is likely the most substantial threat from urban runoff. Increases in the salinity of freshwater habitats such as rivers and streams as a result of urban development is known to have significant negative impacts on the survival of aquatic macroinvertebrates including odonates (Castillo *et al.* 2018). The impacts of increased salinity are widespread throughout Ontario, with significant increases being observed between 1975–2009 at 96% of monitoring stations (Todd and Kaltenecker 2012). Odonates such as the Rapids Clubtail feed on a wide variety of benthic invertebrates including those from the orders of Ephemeroptera and Trichoptera, which were found to be most sensitive to increases in salinity. In addition, this study found that macroinvertebrates in cold climates are even more sensitive to the effects of salinity than those in warmer environments indicating that Ontario aquatic food webs that support aquatic predators such as odonates could be at a greater risk from salinity than species in warmer climates (Castillo *et al.* 2018). Hence, odonates such as the Rapids Clubtail may be impacted by increased salinity through both the direct negative impacts on individuals as well as indirectly through the reduction in abundance of important larval food sources. All subpopulations of the Rapids Clubtail within Ontario are likely impacted to some degree by increased salinity as each of the rivers where this species is found is located adjacent to urban centres. As expected, chloride levels were found to be highest at rivers with major urban centres, with the Credit and Humber having greatly elevated levels (147 mg/L and 130 mg/L respectively) in comparison with the other locations. This indicates that of the extant subpopulations, the Humber River subpopulation is most at risk of impacts as a result of salts. The Mississippi River had the lowest chloride levels at approximately 7 mg/L, likely as a result of a less urbanized catchment for this river (Table 2).

9.2 Industrial & Military Effluents (Negligible)

Industrial activities are present adjacent to each of the rivers containing the Rapids Clubtail, with the exception of the Mississippi River, but none of these facilities are located within the immediate vicinity of any of these subpopulations. Industrial activities upstream of known locations on the Nith are limited to a transportation company headquarters near Piper Street. Various large industrial warehouses and distribution centres are present upstream of the Grand River location, although all of these are likely to have relatively little impact as all are located >500m from the river edge. No industrial activities are located adjacent to the Humber River within or upstream of known locations for the species. The Kleinburg Wastewater Treatment facility is located upstream of known locations for this

species and does discharge treated water to the river, which may have an impact on this species, although to what degree is unknown.

9.3 Agricultural & Forestry Effluents (Medium–Low Impact)

Agricultural lands are located adjacent to all of the rivers where the Rapids Clubtail has been recorded from. The primary concern from agricultural lands is from the use fertilizers, insecticides and sediment, which have the potential to run off into adjacent watercourses. The use of insecticides such as neonicotinoids for agricultural pest control is of particular concern to the Rapids Clubtail as these chemicals have a high runoff and leaching potential and are often present in aquatic environments adjacent to agricultural lands (Bonmatin *et al.* 2015). Numerous studies have confirmed that these chemicals have widespread negative impacts on non-target invertebrates (Pisa *et al.* 2015). Aquatic invertebrates such as odonates are particularly susceptible to pesticides as they cannot easily move to uncontaminated areas (Pisa *et al.* 2015). A study on the impacts of imidacloprid (a popular neonicotinoid) and fipronil on odonates showed that survival of *Sympetrum* larvae decreased nearly 64% after exposure to imidacloprid in the water and 18% for fipronil (Jinguji *et al.* 2013). Furthermore, macroinvertebrate abundance has been shown to consistently decline along a gradient of increasing imidacloprid concentrations (Van Dijk *et al.* 2013). This means that larval food sources for the Rapids Clubtail are also likely impacted by the presence of these chemicals in the water as macroinvertebrates such as mayfly, mosquito and *Chironomus* midges were found to be sensitive to these chemicals (Beketov and Liess 2008; Stoughton *et al.* 2008). In Ontario, all of the subpopulations are located adjacent to at least some agricultural activities, many of which likely use some form of insecticide for pest control. Neonicotinoids are used extensively throughout the province, with nearly 100% of corn seeds and 60% of soybean seeds being treated with these chemicals (Government of Ontario, 2017). In July 2015, the provincial government implemented measures to reduce the use of neonicotinoids with the goal of reducing the treatment of corn and soybean seeds by 80% by 2017 (Government of Ontario, 2017). However, the use of these chemicals on other crops and other detrimental insecticides is likely to persist.

The effects of insecticides on aquatic invertebrate populations are compounded as these chemicals are known to interact with other known stressors, such as sedimentation, to have a multiplicative effect on decreasing abundance of these species within the environment (Chara-Serna and Richardson 2017). Although widespread data is not currently available for insecticide levels within the rivers where the Rapids Clubtail has been recorded from, all of these rivers are located within close proximity to agricultural areas that likely use some form of insecticide. The Humber River population of the Rapids Clubtail may be particularly impacted by increased turbidity as a result of sedimentation. The monitoring station on the Humber River near the population of the Rapids Clubtail was found to have a level of 86 Formazin Turbidity Unit, nearly 3 times higher than the next highest site (MOECC 2016). Turbidity levels of river monitoring stations in close proximity to known populations of the Rapids Clubtail are shown in Table 2.

It is unclear to what degree fertilizer runoff containing nitrates/nitrates and phosphorus affects benthic invertebrates such as the Rapids Clubtail larvae. Some studies have found that in watercourses adjacent to agricultural land where levels of such chemicals are high, benthic invertebrate abundance can be reduced by as much as 3-fold (Quinn *et al.* 2010). Levels of nitrates/nitrites and phosphorus were found to be highest within the Thames River where this species is considered extirpated and also high within the Nith and Grand Rivers where the Rapids Clubtail is extant. All of these rivers have heavy agricultural use on adjacent lands. The Mississippi River had the lowest concentrations of these compounds, while the Credit and Humber, which are more highly urbanized had medium levels, higher than the Mississippi but generally lower than (or in some cases equal to) the other three rivers (Table 2).

Threat 2. Agriculture and Aquaculture (Low Impact)

2.1 Annual & Perennial non-timber Crops (Low Impact)

Conversion of land to agriculture is a slight ongoing threat to this species due to the potential for removal and degradation of adjacent riparian forests necessary for the adult life stage of this species. Much of the land surrounding the Humber, Nith, Grand River and even the Mississippi River sites is already heavily agricultural and impacts to the species as a result of direct habitat removal from agriculture have likely peaked. As mentioned, the Rapids Clubtail relies heavily on adjacent riparian forest cover where females tend to spend considerable time foraging and resting prior to returning to the rivers to breed.

2.3 Livestock Farming & Ranching (Negligible Impact)

Livestock farming is not present within close proximity (5 km) of known the Rapids Clubtail subpopulations. A small livestock farming operation is present near the Blakeney Rapids (Mississippi River) site on the west side of the river. It is unlikely that livestock farming and ranching is having a significant direct impact on the Rapids Clubtail in terms of habitat loss or degradation. However, where livestock are present adjacent to watercourses, there is the potential of habitat degradation of the instream environment (water quality) as well as through trampling and grazing of riparian vegetation that is used by this species to rest and undergo ecdysis.

Threat 4. Transportation and Service Corridors (Low Impact)

4.1 Roads & Railroads (Low Impact)

Roads bisect all of the rivers where the Rapids Clubtail is found, and a small amount of adult road mortality adjacent to the rivers is anticipated as has been seen with other odonate species. The extent of this impact on the Rapids Clubtail remains uncertain at this time; however, it is estimated to be low due to this species' tendency to remain close to the river for much of its life cycle. Construction of new roads adjacent to riparian areas as well as the construction of new bridges across rivers where the Rapids Clubtail is present has the potential to remove or degrade riparian habitats, through the direct removal of forested habitat required by adults or indirectly through increased sedimentation of aquatic habitat for larvae.

4.2 Utility & Service Lines (Low Impact)

Utility and service lines have the potential to remove small amounts of habitat adjacent to rivers used by the Rapids Clubtail through vegetation removal necessary to accommodate these features. However, the presence of the lines themselves does not constitute a threat.

Threat 7. Natural System Modifications (Low Impact)

7.2 Dams & Water Management/Use (Low Impact)

Dams that cause impoundment of water have the potential to alter riffle habitat utilized by this species, and is considered a threat to the persistence of this species throughout its range (NatureServe 2016). The Mississippi River subpopulation may be particularly influenced by dams, as there are currently 30 dams present along the entire length of the river, including 5 for hydroelectric generation (MVCA 2017). The area of greatest concern is located within the town of Almonte, ON where an existing dam was upgraded in 2016 to a hydroelectric dam which included the construction of a new weir, intake canal and tailrace. This area coincides with a known location for the Rapids Clubtail, and habitat for this species, in particular the downstream areas used by larvae, was likely impacted, although to what extent is unknown. It is currently unknown where larval habitat for this species is located within the Mississippi River, as the river bottom consists of a very uniform and rocky substrate with few sediment laden pools (Colin Jones pers. comm. 2017). Alteration of riffle habitat where this species forages and engages in egg-laying and mating behaviour is likely to have a substantial impact on the distribution of this species on a given river. In addition, sediments important for the larval stage are held back upstream of dams resulting in a hardening of the river bed below the dam, and a reduction in suitable habitat downstream (Colin Jones pers. comm. 2018b). Dams are present on each of the other rivers where this species has been recorded from, although none are located in such close proximity to known Rapids Clubtail subpopulations as on the Mississippi River. It is not anticipated that additional dams will be placed within the rivers inhabited by the Rapids Clubtail within the foreseeable future, and as such, the impacts from dams on this species have likely already been experienced in Ontario.

Another possible threat to the Rapids Clubtail may be the reduction of baseflows within a river as a result of water-taking activities of adjacent land uses such as agriculture. Particularly during the growing season, agricultural areas may draw water directly from the river or from groundwater sources that directly contribute to the base flow of the river. This could result in a reduction in river depth and an alteration of river hydrology. The effect of this may be particularly amplified around riffles and rapids where water depth is already low (John Richardson pers. comm. 2018). However, based on an assessment of flow data from monitoring stations near Rapids Clubtail subpopulations during June and early July when males would be actively patrolling riffles, flow rates have increased slightly at each of the extant rivers except for the Mississippi which has declined slightly (Figure 9).

Threat 3. Energy Production & Mining (Negligible Impact)

3.2 Mining and Quarrying (Negligible Impact)

Mining and quarrying are unlikely to result in impacts to this species and these activities are not generally carried out in close proximity to adjacent watercourses. There are not any known mining or quarry operations in close proximity to extant Rapids Clubtail subpopulations.

A new oil and gas line is currently under construction along the Humber River in close proximity to a known location for this species. These activities have the potential to impact habitat in the immediate vicinity in terms of riparian tree/vegetation removal for project infrastructure. Construction activities for this work also have the potential of degrading the aquatic habitat for larvae by causing increased sedimentation and possibly reducing prey populations for this species. However, this impact is considered to be isolated to a small portion of one river and is considered to be a negligible impact.

Threat 5. Biological Resource Use (Negligible Impact)

5.1 Hunting & Collecting Terrestrial Animals (Negligible Impact)

The Rapids Clubtail is not hunted and is unlikely to be a substantial target of insect collectors. Some incidental mortality caused by capture is known to have occurred for this species and will likely continue into the foreseeable future. Such impacts are anticipated to be negligible and unlikely to affect the population.

5.3 Logging & Wood Harvesting (Negligible Impact)

Logging and wood harvesting outside of what is necessary to facilitate development is not a major industry adjacent to the Nith, Grand or Humber Rivers, which have low forest cover. Logging within the Lanark forests where forest cover is very high (>80%) does occur. Most forested habitat, besides that immediately adjacent to the Mississippi River has already been cleared for agriculture, and it is unlikely that the remainder will be subject to extensive logging or wood harvesting.

Threat 8. Invasive & Other Problematic Species & Genes (Unknown Impact)

8.1 Invasive Non-native/Alien Species (Unknown Impact)

Invasive aquatic species are present within all of the rivers that the Rapids Clubtail has been recorded from, and have the potential to alter the ecology and habitats present. Common Carp (*Cyprinus carpio*), Rudd (*Scardinius erythophthalmus*), Zebra Mussel (*Dreissena polymorpha*), Spiny Water Flea (*Bythotrephes longimanus*), Rusty Crayfish (*Orconectus rusticus*), and other invasive species are present within these watercourses and have the potential to impact the ecological conditions present by altering the biotic communities and degrading water quality through predation of nymphs, increasing turbidity,

concentrating toxins, altering nutrient patterns within foodwebs (Government of Canada 2017b; TRCA 2008; MVCA 2013; EDD Mapping 2017). Zebra Mussels have been observed on the exuviae of the Rapids Clubtail and may present some difficulties for this species during ecdysis or during the larval stage (Colin Jones pers. comm. 2018b). At present, it is largely unknown what impact invasive species may have on the Rapids Clubtail.

Number of Locations

Defining locations of the Rapids Clubtail depends on the types and degree of impacts from the varying threats described above. As each of the 4 extant subpopulations has slightly varying threats, adjacent land uses, and ownership, they may each respond differently to these threats. As such, each of these subpopulations is considered a location. The only exception to this could be the Nith and Grand populations, which are located within close proximity to one another; however, differences in land use and ownership adjacent to these sites mean that they will each respond differently to threats and should be considered separate locations.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

The Rapids Clubtail receives protection under Schedule 1 of the *Species at Risk Act* (SARA) since it was designated as Endangered in April 2008. Critical Habitat has been identified for the Rapids Clubtail within the federal Recovery Strategy for this species (Environment Canada 2016). The Rapids Clubtail was also added to the Ontario Species at Risk list on September 10, 2009. The provincial definition of Regulated Habitat, as per the Ontario Regulation 242/08 of the *Endangered Species Act*, has been adopted within the federal Recovery Strategy as the Critical Habitat definition. This definition of Critical Habitat/Regulated Habitat includes the riverine areas known to contain the Rapids Clubtail within Lanark, Middlesex, Oxford, Peel, and York counties and includes:

> *"1. Any part of a river, stream or other body of water, up to the high water mark, that is being used by a rapids clubtail or on which a rapids clubtail directly depends in order to carry on its life processes.*
>
> *2. Any part of a river, stream or other body of water, up to the high water mark, that was used by a rapids clubtail at any time during the previous 5 years and that provides suitable conditions for a rapids clubtail to carry on its life processes.*
>
> *3. An area of deciduous or mixed forest or of deciduous or mixed treed swamp that is adjacent to an area identified in paragraph 1 or 2 and within 200 metres of the relevant high water mark. O. Reg. 122/12, s. 4."*

Regulated Habitat protection is not currently applied to the locations on the Grand and Nith Rivers as these subpopulations were unknown at the time of the publishing of O.Reg. 242/08; however, these sites would receive General Habitat protection. The federal Recovery Strategy (Environment Canada 2016) includes these new locations under their definition of Critical Habitat defined as:

> *"the part of a river, stream or other body of water being used by the Rapids Clubtail will include the upstream set of rapids downstream to the end of the first downstream pool."*

Rapids Clubtail is not on the U.S. Endangered Species List.

Non-Legal Status and Ranks

The Rapids Clubtail has a sub-national rank of S1 or 'Critically Imperiled' in Ontario. The current sub-national ranks for this species in every state and province where this species is known to occur is shown in Table 3 along with the previous status rank at the time of the original COSEWIC Status Report (2008). Sub-national rankings have been revised in 12 states, with all of these changes representing a downgrading in terms of rarity. Only in North Carolina was the rarity upgraded from S1S2 to S1? (NatureServe 2016). The national ranking for this species in Canada is N1 (2012) and N3N4 in the U.S (1998). The global status of this species is G3G4, with a 'rounded' global status of G3 or 'Vulnerable' (NatureServe 2016). It is important to note that the NatureServe N-Rank and G-Rank have not been updated recently.

The Rapids Clubtail is not covered by the IUCN Red List or CITES.

Habitat Protection and Ownership

Most of the lands surrounding the locations from which the Rapids Clubtail has been recorded from are owned by private landowners, conservation authorities, and municipalities. Of the extirpated sites, the Thames River subpopulation is surrounded by private land while the Credit River subpopulation is adjoined by a municipal park and the University of Toronto, Mississauga. The Mississippi River site is mostly privately owned with small municipal parks and some crown land ownership. Many of the Humber River locations are contained within the Nashville Conservation Reserve owned by the TRCA, with some private land ownership further south. The Grand River location is located adjacent to the Brant Conservation Area owned by the Grand River Conservation Authority (GRCA), Brantford Golf and Country Club, and other private lands. The Nith River subpopulation is located adjacent to private land.

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BIOGRAPHICAL SUMMARY OF REPORT WRITERS

Nathan Miller, M.Sc., has over 10 years of experience carrying out insect surveys and studies on a wide range of insect taxa including odonates. As an Algonquin Park naturalist working for the Ontario Ministry of Natural Resources and Forestry from 2005–2008, Nathan regularly carried out surveys for numerous provincially rare odonates including Broad-tailed Shadowdragon (*Neurocordulia michaeli*), Cyrano Darner (*Nasiaeschana pentacantha*), Somatochlora emeralds and many others. As an environmental consultant working for Natural Resource Solutions Inc. (NRSI), Nathan has managed many projects requiring odonate surveys including area searches/netting of adult dragonflies and damselflies, habitat assessments for odonate Species of Conservation Concern, collection/identification of exuviae of a wide range of odonates and evaluations of impacts of development on sensitive odonate species. Nathan's research on insect species has been funded by the American Conservation Foundation, Global Forest Pure Science and the Explorer's Club among others and his research has been published in several prestigious scientific journals such as Biology Letters (Royal Society) and Behavioral Ecology

Ken Burrell, M.E.S., currently works as a consulting biologist at Natural Resource Solutions Inc. Ken has undertaken numerous odonate and other insect surveys for a wide range of projects and has authored many technical articles on a diverse range of taxa. Ken authored the Ontario survey protocol for the Henslow's Sparrow (*Ammodramus henslowii*) for the Ministry of Natural Resources and Forestry and prepared the assessment and status report for the Harris's Sparrow (*Zonotrichia querula*) for COSEWIC.

Table 4. Results for the Rapids Clubtail, *Phanogomphus quadricolor*, threats assessment in Canada.

Scientific Name	Rapids Clubtail (*Phanogomphus quadricolor*)
Date	11/01/2018
Assessor(s):	Nathan Miller and Ken Burrell (authors), Paul Grant (co-chair and moderator), Jenny Heron (co-chair), Colin Jones (Ontario jurisdictional member and SSC member), John Klymko, John Richardson, Jessica Linton and Sara Semmler (SSC members), Ken Tuininga (ECCC), Angèle Cyr (COSEWIC Secretariat).

			Level 1 Threat Impact Counts	
	Threat Impact		**high range**	**low range**
	A	Very High	0	0
	B	High	0	0
	C	Medium	3	0
	D	Low	3	6
	Calculated Overall Threat Impact:		High	Medium

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	Residential & commercial development	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	
1.1	Housing & urban areas	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	Threats from housing and urban areas pose a threat to Rapids Clubtail primarily in terms of reduction and degradation of riparian forest habitat. **(See Threats)**
1.2	Commercial & industrial areas	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	Commercial and industrial areas will also contribute to degradation of riparian habitats **(See Threats)**
1.3	Tourism & recreation areas		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Any impacts from tourism would likely be negligible **(See Threats)**
2	Agriculture & aquaculture	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	
2.1	Annual & perennial non-timber crops	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	Conversion of land to agriculture is a low threat impact to this species **(See Threats)**
2.2	Wood & pulp plantations		Not a Threat	Negligible (<1%)	Neutral or Potential Benefit	High (Continuing)	Rapids Clubtail rely on riparian forest habitat for the adult stage of their life cycle. Planting of trees in these areas is not considered an impact, although this species generally seems to prefer natural deciduous or mixed-deciduous habitats. This is not anticipated to impact large portions of the Ontario range which are currently occupied by existing agriculture, urban areas or existing forest. A large managed plantation is present north of the Nith River site and tree management activities have the potential to disturb foraging activities in the vicinity of these areas.
2.3	Livestock farming & ranching		Negligible	Small (1-10%)	Negligible (<1%)	Unknown	Livestock farming is considered a low impact threat **(See Threats)**
3	Energy production & mining		Negligible	Small (1-10%)	Negligible (<1%)	Low (Possibly in the long term, >10 yrs)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
3.1	Oil and Gas Drilling		Negligible	Small (1-10%)	Unknown	Moderate (Possibly in the short term <10 years)	There is a single oil and gas line being constructed across the Humber River that has the potential to impact habitat by removing riparian vegetation and temporarily decreasing aquatic habitat quality (increased sedimentation).
3.2	Mining & quarrying		Negligible	Small (1-10%)	Negligible (<1%)	Low (Possibly in the long term, >10 yrs)	Mining and quarrying are unlikely to result in a larger than negligible impact **(See Threats)**
4	Transportation & service corridors	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	
4.1	Roads & railroads	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	Roads bisect all of the rivers and result in road mortality **(See Threats)**
4.2	Utility & service lines	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	Utility and service lines have the potential to remove small amounts of habitat adjacent to rivers **(See Threats)**
5	Biological resource use		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	
5.1	Hunting & collecting terrestrial animals		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	Rapids Clubtail is not a substantial target of insect collectors. **(See Threats)**
5.3	Logging & wood harvesting		Negligible	Restricted (11-30%)	Negligible (<1%)	High (Continuing)	Logging and wood harvesting is considered a negligible impact to this species **(See Threats)**
6	Human intrusions & disturbance	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	
6.1	Recreational activities	CD	Medium - Low	Restricted (11-30%)	Moderate - Slight (1-30%)	High (Continuing)	Recreational boating occurs on all of the rivers where Rapids Clubtail is found. **(See Threats)**
7	Natural system modifications	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	
7.1	Fire & fire suppression		Unknown	Restricted (11-30%)	Unknown	High (Continuing)	Forest fires are unlikely to occur at any of the Humber, Nith or Grand River populations due to the small amount of forest habitat and aggressive fire prevention measures in place in these municipalities. Forest fire potential is slightly higher near the Mississippi River area, although still unlikely due to nearby residential communities. Impacts as a result of fire are unknown for this species.
7.2	Dams & water management/use	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	Dams are present on all of the rivers where Rapids Clubtail are present. **(See Threats)**
8	Invasive & other problematic species & genes		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	
8.1	Invasive non-native/alien species		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	A wide range of invasive species are present in all of the rivers occupied by this species but the level of impact is unknown **(See Threats)**.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8.2	Problematic native species		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	A wide range of native species feed on adult odonates such as Rapids Clubtail, including many aerial insectivores such as tyrant flycatchers, small falcons, other larger dragonflies, and frogs. Larvae are susceptible to predation by benthic fish species and likely other larger odonate exuviae. The severity of these impacts on this species is currently unknown.
9	Pollution		Moderate – Low	Pervasive (71-100%)	Moderate – Slight (1-30%)	High (Continuing)	
9.1	Household sewage & urban waste water		Medium - Low	Pervasive (71-100%)	Moderate-Slight (1-30%)	High (Continuing)	This threat effects Rapids Clubtail, although there is uncertainty with regards to the degree of impact **(See Threats)**.
9.2	Industrial & military effluents		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	Discharge treated water to the river which may have an impact on this species, although very few industrial/military facilities in proximity to this species **(See Threats)**.
9.3	Agricultural & forestry effluents		Unknown	Pervasive - Large (31-100%)	Moderate-Slight (1-30%)	High (Continuing)	Agricultural effluents are likely to continue to negatively impact the Nith, Grand and Humber Rivers by degrading water quality, but there is uncertainty with regards to the degree of impact **(See Threats)**.
11	Climate change & severe weather		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	It is currently unknown what impact climate change will have on this species. Warmer temperatures are known to decrease development time in some gomphid species, but it is unknown what impact this accelerated development time may have on Rapids Clubtail (Hawking and New 2008).
11.1	Habitat shifting & alteration		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	
11.2	Droughts		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	
11.3	Temperature extremes		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	
11.4	Storms & flooding		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	