COSEWIC
Assessment and Status Report

on the

Carmine Shiner
Notropis percobromus

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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Previous report(s):

COSEWIC 2006. COSEWIC assessment and update status report on the carmine shiner *Notropis percobromus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 29 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

COSEWIC 2001. COSEWIC assessment and status report on the carmine shiner *Notropis percobromus* and rosyface shiner *Notropis rubellus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. v + 17 pp.

Houston, J. 1994. COSEWIC status report on the rosyface shiner *Notropis rubellus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-17 pp.

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For additional copies contact:

COSEWIC Secretariat
c/o Canadian Wildlife Service
Environment and Climate Change Canada
Ottawa, ON
K1A 0H3

Tel.: 819-938-4125
Fax: 819-938-3984
E-mail: ec.cosepac-cosewic.ec@canada.ca
http://www.cosewic.gc.ca

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Carmine Shiner — Photo courtesy of D. Watkinson, DFO, Winnipeg.

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COSEWIC
Assessment Summary

Assessment Summary – April 2018

Common name
Carmine Shiner

Scientific name
Notropis percobromus

Status
Endangered

Reason for designation
The range of this small, colourful minnow is restricted to Manitoba. Although there is limited information on population trends since the last assessment, projected declines over the next 10 years related to the threat of habitat loss and pollution will put the species at risk of extinction in Canada.

Occurrence
Manitoba

Status history
Designated Special Concern in April 1994. Status re-examined and designated Threatened in November 2001 and in April 2006. Status re-examined and designated Endangered in April 2018.

COSEWIC
Executive Summary

Carmine Shiner
Notropis percobromus

Wildlife Species Description and Significance

Carmine Shiner (*Notropis percobromus*) is a small (<67 mm), slender, elongate minnow. Carmine Shiner is olive green dorsally, silvery on the sides, silvery white on the belly, has black pigment outlining the scale pockets dorsally, and adults have a pinkish or rosy pigment on the opercula and cheek. It is a single designatable unit found only in the Saskatchewan-Nelson River National Freshwater Biogeographic Zone.

Distribution

Carmine Shiner is distributed widely throughout highland and glaciated regions of eastern North America. In Canada, it is at the northernmost extent of its range and is only found in the Whitemouth and Winnipeg river systems in eastern Manitoba.

Habitat

Carmine Shiner is found in flowing water over primary bottom substrates of sand, gravel, cobble, boulder, and bedrock, with a possible preference for sand and aversion to silt. It prefers water temperatures around 23.6°C. Little is known of where spawning occurs, the location of nursery, rearing, feeding or food-supply areas, and the timing or extent of migrations, should they occur.

Biology

Carmine Shiner in Manitoba can live to 5 years of age. The generation time (i.e., average age of mature individuals) of fish sampled in Birch River was 2.9 years. Little is known of the species' spawning habitat; however, spawning most likely occurs in riffles in June and July when water temperatures are between 20 to 30°C. Nearly half of Carmine Shiner are mature by age 2 with the rest maturing by age 3. Carmine Shiner have 144 to 2806 eggs per female, with the number of eggs increasing with increasing fish size. Hybridization of Carmine Shiner with other species has not been described, but it is possible they hybridize with Common Shiner (*Luxilus cornutus*). Carmine Shiner occupies a mid-trophic level, with insects as its main prey item.

Population Sizes and Trends

The size of Canadian Carmine Shiner populations is currently unknown. Some assumptions can be made regarding its relative abundance from netting (seine) and environmental DNA (eDNA); however, there has been no targeted effort to obtain abundance estimates. Catch-per-unit-effort (CPUE) estimates from targeted sampling for Carmine Shiner in Birch River ranged from 0 to 97 individuals per standardized seine haul. CPUE from Birch and Whitemouth rivers were higher, on average, than sites on the Pinawa Channel and Peterson Creek. This is consistent with eDNA sampling, where Carmine Shiner DNA was detected in a greater number of samples from Birch and Whitemouth rivers than samples from Pinawa Channel and Peterson Creek.

Threats and Limiting Factors

The overall threat impact was estimated as “Medium-Low”, with the most important threats being: dams and water management/use, specifically related to the dam at the outflow of Whitemouth Lake; drainage in the watershed for agriculture and peat mining; hydro development on the Winnipeg River system; and hydrostatic testing of pipelines. Agricultural runoff and sediment, as well as herbicides, pesticides and nutrient inputs, present in the watershed could affect this species. The exact extent of these inputs is unknown. Some small-scale habitat alterations (e.g., rip-rap, boulder removal, beach building) are present but, for the most part, limited. Invasive or introduced species, such as Rusty Crayfish and Walleye, respectively, have been introduced into the system. Their impacts were estimated as “Low”. Threats considered negligible include: livestock farming; roads and railroads; utilities and service lines; bait fishing; recreational activities; and scientific sampling.

Protection, Status and Ranks

Carmine Shiner is currently listed as Threatened under the Canadian *Species at Risk Act* (SARA). Both the species and its habitat receive protection under SARA. Critical habitat for the species has been identified under SARA through a finalized recovery strategy. The Manitoba Conservation Data Centre has assigned it a provincial rank of S2, meaning that it is rare in Manitoba and may be vulnerable to extirpation. Carmine Shiner may also be indirectly protected by the federal *Fisheries Act* where the species shares habitat with fishes of Commercial, Recreational, or Aboriginal fishery significance. The species is listed as secure globally (G5) by NatureServe.

TECHNICAL SUMMARY

Notropis percobromus

Carmine Shiner

Tête carminée

Range of occurrence in Canada (province/territory/ocean): Manitoba

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines (2011) is being used)	2.9 y
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]	NA
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	NA
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	NA
[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.	NA
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	NA a. b. c.
Are there extreme fluctuations in number of mature individuals?	Unknown

Extent and Occupancy Information

Estimated extent of occurrence (EOO	2,122 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	160 km^2 discrete 312 km² continuous
Is the population “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 population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. No b. No

Number of “locations”* (use plausible range to reflect uncertainty if appropriate) Whitemouth River watershed Winnipeg River watershed	2
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
Is there an [observed, inferred, or projected] decline in number of “locations”*?	No
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes, inferred decline in quality of habitat
Are there extreme fluctuations in number of subpopulations?	NA
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**
1	unknown
Total	

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)

i. Dams and water management
ii. Pollution

What additional limiting factors are relevant?

* See Definitions and Abbreviations on COSEWIC web site and IUCN (Feb 2014) for more information on this term

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada. Minnesota (SNR), North Dakota (S3),South Dakota (S2)	Not ranked-Imperiled
Is immigration known or possible?	No
Would immigrants be adapted to survive in Canada?	Unknown
Is there sufficient habitat for immigrants in Canada?	Unknown
Are conditions deteriorating in Canada?+	Yes, inferred
Are conditions for the source (i.e., outside) population deteriorating?+	Variable
Is the Canadian population considered to be a sink?+	No
Is rescue from outside populations likely?	No

Data Sensitive Species

Is this a data sensitive species?	No

Status History

Designated Special Concern in April 1994. Status re-examined and designated Threatened in November 2001 and in April 2006. Status re-examined and designated Endangered in April 2018.

Status and Reasons for Designation:

Status: Endangered	**Alpha-numeric codes:** B1ab(iii)+2ab(iii)

Reasons for designation:
The range of this small, colourful minnow is restricted to Manitoba. Although there is limited information on population trends since the last assessment, projected declines over the next 10 years related to the threat of habitat loss and pollution will put the species at risk of extinction in Canada.

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. Percent declines unknown.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Endangered, B1ab(iii)+2ab(iii), because the EOO, IAO, and number of locations are below the threshold, and a decline in habitat quality is projected from habitat modification (water flow regimes) and destruction, and pollution.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable. Exceeds thresholds.
Criterion D (Very Small or Restricted Population): Not applicable. Exceeds thresholds.
Criterion E (Quantitative Analysis): None available.

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

PREFACE

Carmine Shiner (*Notropis percobromus*) remains a poorly monitored species in Canada; however, new biological information from Canadian populations regarding diet, life history, and physiology has reduced the dependence of this report on information from Rosyface Shiner (*N. rubellus*) and Carmine Shiner from other localities. Results of sampling efforts in areas known to be occupied by Carmine Shiner over the last 15 years suggest that all populations currently persist. Environmental DNA (eDNA) sampling efforts in areas adjacent to historical Carmine Shiner records suggest an increase in the known distribution of this species in Peterson Creek. Since the last report, Critical Habitat has been defined in the Recovery Strategy for Carmine Shiner using a Bounding-Box Approach and an Action Plan has been proposed with management actions underway. Intensified sampling effort has increased the current extent of occurrence (EOO) since the last species status report to 2,122 km^2. Similarly, the discrete and continuous index of area of occupancy (IAO) has increased to 160 km^2 and 312 km^2, respectively. The overall threat impact for Carmine Shiner was estimated as “Medium-Low”, with the most important threats being: dams and water management/use; habitat alterations; and agricultural runoff and sediment, and introduced and invasive species.

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
Canadian Wildlife Service

Environnement et Changement climatique Canada
Service canadien de la faune

Canada

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

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

The taxon was first reviewed by COSEWIC as Rosyface Shiner (*Notropis rubellus*) (Houston 1996), but the Manitoba populations are now considered to be Carmine Shiner (*N. percobromus*) (Wood *et al.* 2002; Stewart and Watkinson 2004; Page *et al.* 2013). The initial review by Houston (1996) summarized knowledge of both species without differentiating between them. Consistent with the 2006 update, this report addresses only Carmine Shiner.

Class: Actinopterygii

Order: Cypriniformes

Family: Cyprinidae

Genus: *Notropis*

Species: *Notropis percobromus* (Cope, 1871)

Common name: English: Carmine Shiner
French: Tête carminée

Carmine Shiner is a small minnow (Cyprinidae) in the genus *Notropis* (Figure 1); the second largest genus of freshwater fishes in North America (Page *et al.* 2013). Many species in this genus are difficult to distinguish from one another and, historically, phylogenetic relationships among them were largely unresolved (Dowling and Brown 1989). Allozyme studies support the existence of five to seven species that had hitherto been recognized only as “Rosyface Shiners”, including the Rosyface Shiner, Highland Shiner (*N. micropteryx*), Rocky Shiner (*N. suttkusi*), Carmine Shiner, and one to three clades that have not yet been described (Wood *et al.* 2002; Berendzen *et al.* 2008). A morphometric approach found minimal differences between the different clades (Berendzen *et al.* 2009).

Figure 1. Carmine Shiner from the Whitemouth River watershed in Manitoba (Photo courtesy of D. Watkinson, DFO, Winnipeg).

Stewart and Watkinson (2004) accepted Carmine Shiner as the identity of the Manitoba population(s) on the basis of the biogeographic information in Wood *et al.* (2002) and in conformity with Nelson *et al.* (2004). This is consistent with the biogeographic information in Berendzen *et al.* (2008). These studies show that the fish in Manitoba are Carmine Shiner, like those to the south, and not Rosyface Shiner like those in eastern Canada.

Morphological Description

Carmine Shiner is a slender, elongate minnow (Figure 1) that can be distinguished from other minnows in Manitoba by the following features:

1) the origin of the dorsal fin is located behind a line drawn vertically from the insertion of the pelvic fins;
2) absence of a fleshy keel on the abdomen and of a strongly decurved lateral line;
3) a narrowly conical snout that is equal in length, or nearly so, to their eye diameter;
4) five to seven short gill rakers on the lower limb of the first gill arch;
5) the longest gill raker being about as long as the width of its base; and
6) four slender, hooked, main row pharyngeal teeth (Stewart and Watkinson 2004).

The last four characters distinguish Carmine Shiner from Emerald Shiner (*N. atherinoides*), with which it is often confused. Emerald Shiner has a more blunt, rounded snout, usually only about 3/4 the length of the eye diameter; eight to twelve gill rakers on the lower limb of the first arch, the length of longest being twice the width of its base; and four stouter, and only slightly hooked, pharyngeal teeth in the main row on each side. The largest documented Carmine Shiner in Manitoba was collected in the Whitemouth River and had a fork length of 67 mm (Watkinson unpubl. data).

Outside of the breeding season, Carmine Shiner is olive green dorsally, silvery on the sides and silvery white on the belly (Stewart and Watkinson 2004). It has black pigment outlining the scale pockets dorsally, and freshly caught adult specimens often retain pinkish or rosy pigment on the opercula and cheek (Stewart and Watkinson 2004). Fins are transparent (Watkinson pers. comm. 2017).

Spawning fish of both sexes are olive dorsally and silvery with blue iridescence laterally, with carmine colour on the snout, on the upper portions of the operculum and the cheek, along all of the pectoral girdle and sides around the base of the pectoral fins, the lateral line back to the anal fin, and the bases of the fins (Watkinson pers. comm. 2017). The pinkish or rosy pigment on the opercula and cheek becomes more vivid and extensive during spawning. Full development of spawning colour in Carmine Shiner is ephemeral, and the colours also fade quickly after death and preservation. Breeding males develop fine, sandpaper-like nuptial tubercles on the head, on some predorsal scales, and on the upper surface of the pectoral fin rays.

Population Spatial Structure and Variability

There is no evidence of relevant differentiation below the species level; however, populations in the Whitemouth and Winnipeg rivers are disjunct from those in the Red River and elsewhere and were likely isolated <7,800 years ago when glacial inflows and outflows no longer persisted (Stewart and Watkinson 2004) and isostatic rebound severed drainage connections with the Whitemouth watershed and the Red Lakes watershed in Minnesota.

Designatable Units

Populations of Carmine Shiner described herein represent the only known occurrence of this taxon in Canada. There is no evidence of relevant differentiation below the species level and Carmine Shiner occupies a single National Freshwater Biogeographic Zone (NFBZ), the Saskatchewan-Nelson River NFBZ as recognized by COSEWIC. Thus, there is only a single designatable unit within this species in Canada.

Special Significance

Carmine Shiner has no direct economic importance and limited importance as a forage species, but is of scientific interest (Scott and Crossman 1973; Houston 1996; Stewart and Watkinson 2004). It does have intrinsic value as a contributor to Canada's biodiversity and as a potential colonizing species from the United States if the species range shifts northward, as predicted due to climate change (Pandit *et al.* 2017). As peripheral populations at the northwestern limit of the distribution of the species, that are geographically isolated from their nearest neighbours in Minnesota, Carmine Shiner in Manitoba may be unique and exhibit evidence of local adaptation to their habitat and genetic differentiation from other populations of the species (Stewart and Watkinson 2004). They may constitute a significant component of the genetic diversity of the species. Scientific studies of these populations might improve our understanding of the timing and routes of post-glacial re-colonization of Manitoba by fishes (Houston 1996). They may also provide evidence of genetic adaptation near the limit of a species' distribution.

DISTRIBUTION

Global Range

The genus *Notropis* is widely distributed throughout highland and glaciated regions of eastern North America (Wood *et al.* 2002; Berendzen *et al.* 2008). Carmine Shiner specifically has populations in the upper Mississippi (Rock River northward), middle Missouri River drainages, drainages of the Ozarks, and Arkansas tributaries (Figure 2; Berendzen *et al.* 2008). Carmine Shiner is no longer present in the Big Sioux River in South Dakota (Hoagstrom *et al.* 2006) or major river basins in Nebraska (Yildirim *et al.* 2012) and is considered rare in the Minnesota River (Proulx 2005). In Canada, Carmine Shiner is located in the Whitemouth River, Birch River, and Winnipeg River systems.

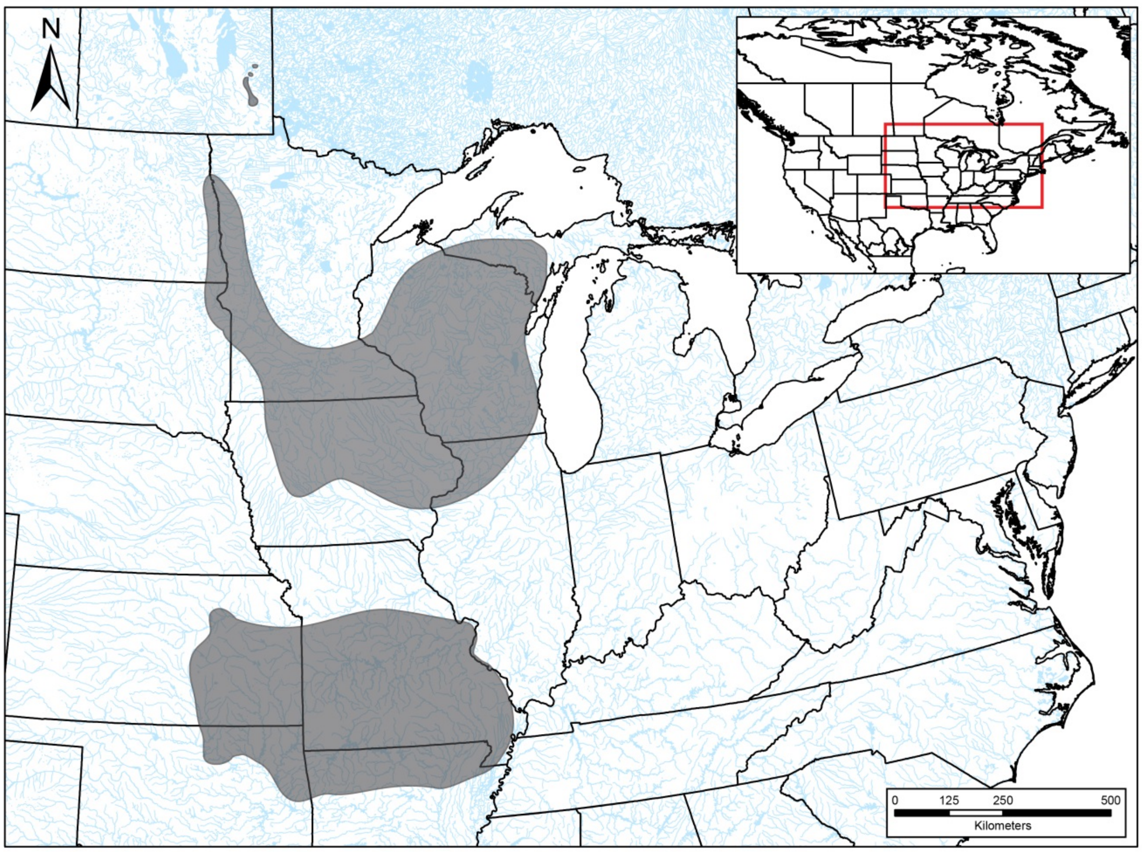

Figure 2. Approximate geographical distributions of Carmine Shiner (modified from Berendzen *et al.* 2008).

Canadian Range

In Canada, Carmine Shiner is at the northwestern limit of the species' range (Figure 2). Carmine Shiner was first reported in the Whitemouth River by Smart (1979). It was later found in the Winnipeg River at the confluence with the Whitemouth River. The species' presence in the Winnipeg River upstream of insurmountable barriers, and its apparent absence from the lower Red River and Lake Winnipeg, suggest that colonization may have been via a post-glacial connection with the headwaters of the Red Lake River in Minnesota, a dispersal track shared with the Hornyhead Chub (*Nocomis biguttatus*) and the Fluted Shell mussel (*Lasmigona costata*) (Clarke 1981). Alternatively, colonization may have been via dispersal into the Rainy River watershed from Upper Mississippi headwaters in northwestern Minnesota, a dispersal track shared by five other fish species in southern Manitoba.

Houston (1996) reported the distribution of Carmine Shiner only from the Whitemouth River and its tributary, the Birch River. Sampling in the early 2000s (Figure 3) extended that range with additional specimens collected from the Whitemouth River, from its tributary the Birch River, and from the Winnipeg River immediately below Whitemouth Falls (Stewart and Watkinson 2004). Specimens were also collected from the Winnipeg River in the Pinawa Channel immediately below the Old Pinawa Dam, from the Bird River at the first set of rapids upstream from Lac du Bonnet (Winnipeg River mainstem lake) and at the mouth of Peterson Creek, a Bird River tributary. Surveys conducted since 2002 have expanded its known distribution to include the Birch River from its confluence with the Boggy River downstream to the Whitemouth River, Bird River near the first set of falls upstream of Lac du Bonnet and the Lee River just downstream of the Old Pinawa Dam (Stewart and Watkinson 2004; Watkinson unpubl. data) (Figure 3) Surveys conducted since 2006 have expanded the known distribution in the Birch River.

The restricted distribution of Carmine Shiner in Manitoba, and the warmwater adaptation of all species of the *N. rubellus* complex, suggest that Carmine Shiner is a relatively recent colonizer (Houston 1996) that reached the Hudson Bay Drainage from the Upper Mississippi watershed lake after glacial recession and the drainage of glacial Lake Agassiz. It is present in the headwaters of the Red River in northwestern North Dakota (Koel 1997) and may have also reached Rainy River headwaters adjacent to the Upper Mississippi watershed, as there is an early report of the species from Lake of the Woods (Evermann and Goldsborough 1907); however, it is uncertain whether the identification was accurate. The absence of records of *N. rubellus* complex fish from the upper Mississippi watershed in northern Minnesota suggests that the species may not occur upstream of the Whitemouth and Winnipeg rivers in the Hudson Bay Drainage. The nearest known Carmine Shiner population to the Whitemouth River watershed in Manitoba is found in the Lost River tributary of the Red Lakes River watershed (Red River drainage) in northwestern Minnesota.

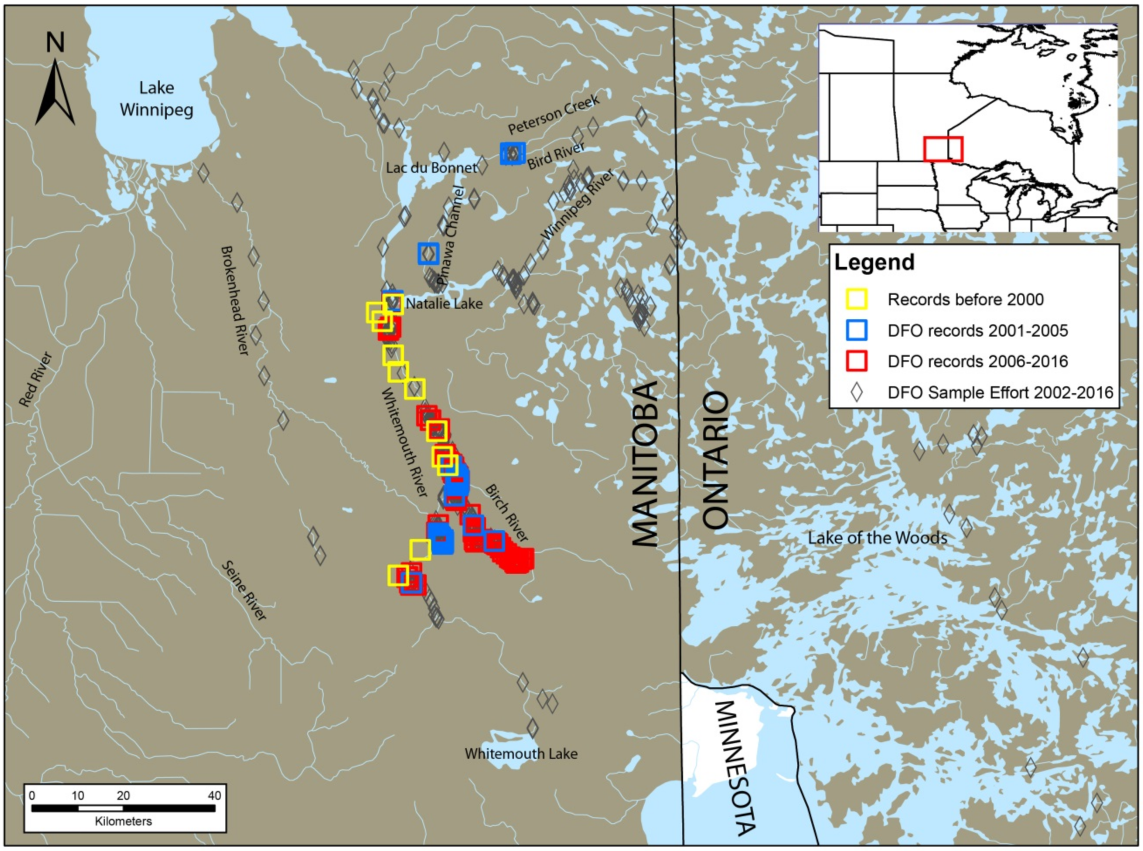

Figure 3. The distribution of fish collection sites and sites where Carmine Shiner was captured in the Whitemouth and Winnipeg river watersheds within Manitoba and northwestern Ontario. Yellow squares represent records collected before 2000. The majority of this sampling was conducted with a boat electroshocker (blue squares), 2001 – 2005, and seine netting, 2006 – 2016 (red squares). Black open diamonds represent sites that were sampled but no Carmine Shiner were detected.

Environmental DNA (eDNA)

In 2014–2016, Carmine Shiner-specific eDNA assays were developed and tested (Docker unpubl. data; see *Search Effort*) and used to screen water samples collected from 51 separate sites in 28 waterbodies (Figure 4, Appendix 1). Carmine Shiner eDNA was detected in the Birch and Whitemouth rivers and in the Pinawa Channel just downstream of the Old Pinawa Dam (Figure 4); all of these sites are within the known range of Carmine Shiner in Manitoba. Carmine Shiner eDNA was also detected in one PCR replicate in Peterson Creek at PR 315 near its confluence with the Bird River (Appendix 1). Although Carmine Shiner occurrence in Peterson Creek has yet to be confirmed with either repeated detections of eDNA or collection of one or more voucher specimens, if confirmed, this would represent a very slight upstream range extension, as Carmine Shiner were previously known to occur only at the mouth of this creek, approximately 300 m downstream.

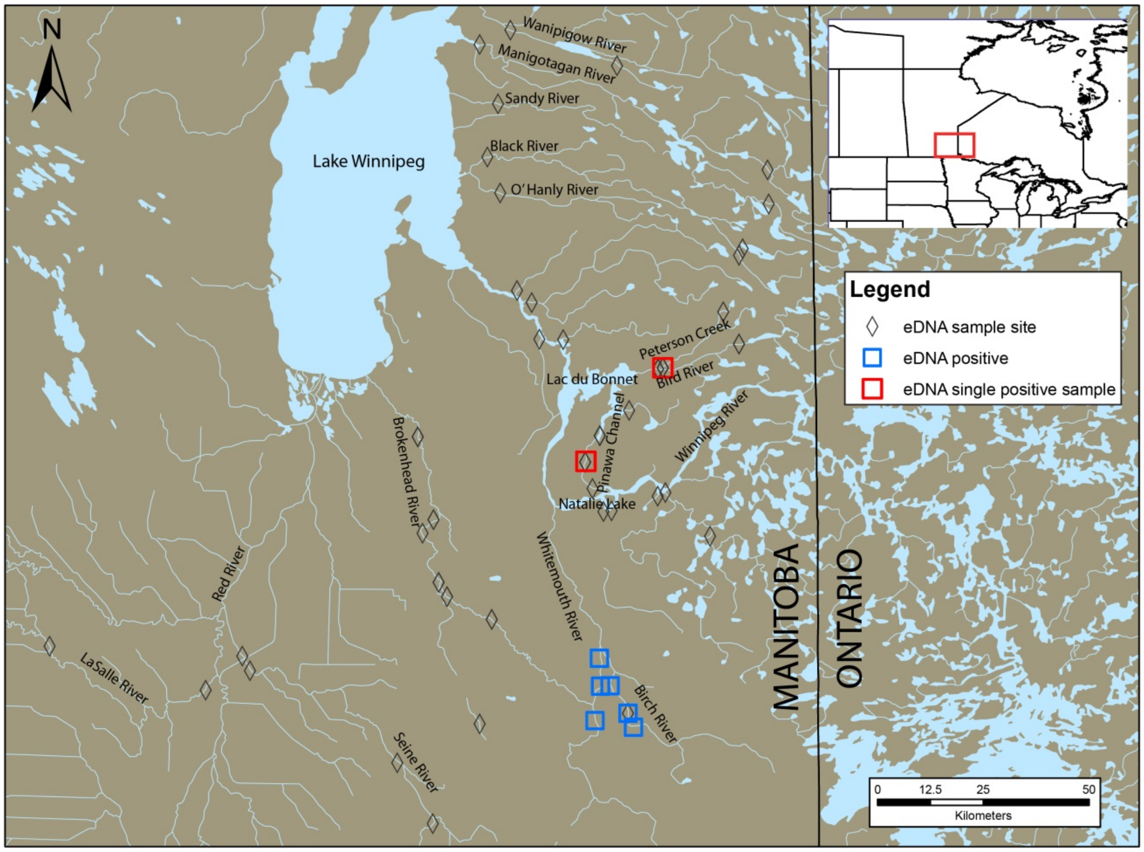

Figure 4. Sites where Carmine Shiner eDNA was detected by at least one endpoint PCR or qPCR assay along with sites where Carmine Shiner eDNA was not detected by any endpoint PCR or qPCR assays in 2014–2016. Red squares indicate sites where Carmine Shiner eDNA was detected in only one PCR replicate from one water sample; blue squares indicate sites where Carmine Shiner eDNA was detected in multiple PCR replicates from multiple water samples, and black open diamonds indicate where sampling occurred but no Carmine Shiner eDNA was detected.

Carmine Shiner eDNA was not detected at any other sites sampled (Figure 4, Appendix 1). These included waterbodies where Carmine Shiner populations might be present but undetected (e.g., Brokenhead River and Hazel Creek, tributaries of the Winnipeg River and tributaries of the east side of Lake Winnipeg) and areas where Carmine Shiner are unlikely to occur (La Salle, Rat, Red, and Seine rivers). However, the eDNA assays also failed to detect Carmine Shiner in the Bird River, where it is known to occur, despite multiple sets of samples taken at two sites. However, these samples were collected in early August; samples collected in the fall when flow rates are lower might detect the species. Thus, present methods appear adequate for detecting Carmine Shiner eDNA where the species is thought to occur in high abundance (e.g., Birch and Whitemouth rivers), but limits of detection at sites with relatively low abundance are not known. This makes it difficult to be certain whether a lack of detection at a site indicates the true absence of Carmine Shiner or a false negative result (i.e., where the organism is present at presumably low abundance but not detected). Further refinements to the eDNA assays (to increase sensitivity) and the sampling methods (e.g., fall sampling and increasing the effective volume of stream water sampled; see *Search Effort*) are currently being tested (Docker unpubl. data).

Extent of Occurrence and Area of Occupancy

The extent of occurrence of Carmine Shiner in Canada is estimated at 2,122 km² for known collection sites (Figure 5). The discrete and continuous index of area of occupancy for Carmine Shiner in Canada are estimated at 160 km² and 312 km², respectively (Figure 5). These area estimates are for the surface of the waterbodies and are rough approximations because there has been very little directed sampling for these fish and, to be conservative, exclude the Peterson Creek occurrence inferred from eDNA analysis. An increase from the previous report (extent of occurrence and area of occupancy were previously calculated as 120.66 km² and 3.44 km² respectively) is representative of intensified sampling effort and differences in how the measures were calculated. The area of occupancy is large enough to support the minimum viable population (MVP) necessary for an extinction risk of 3% in 100 years (Young and Koops 2013).

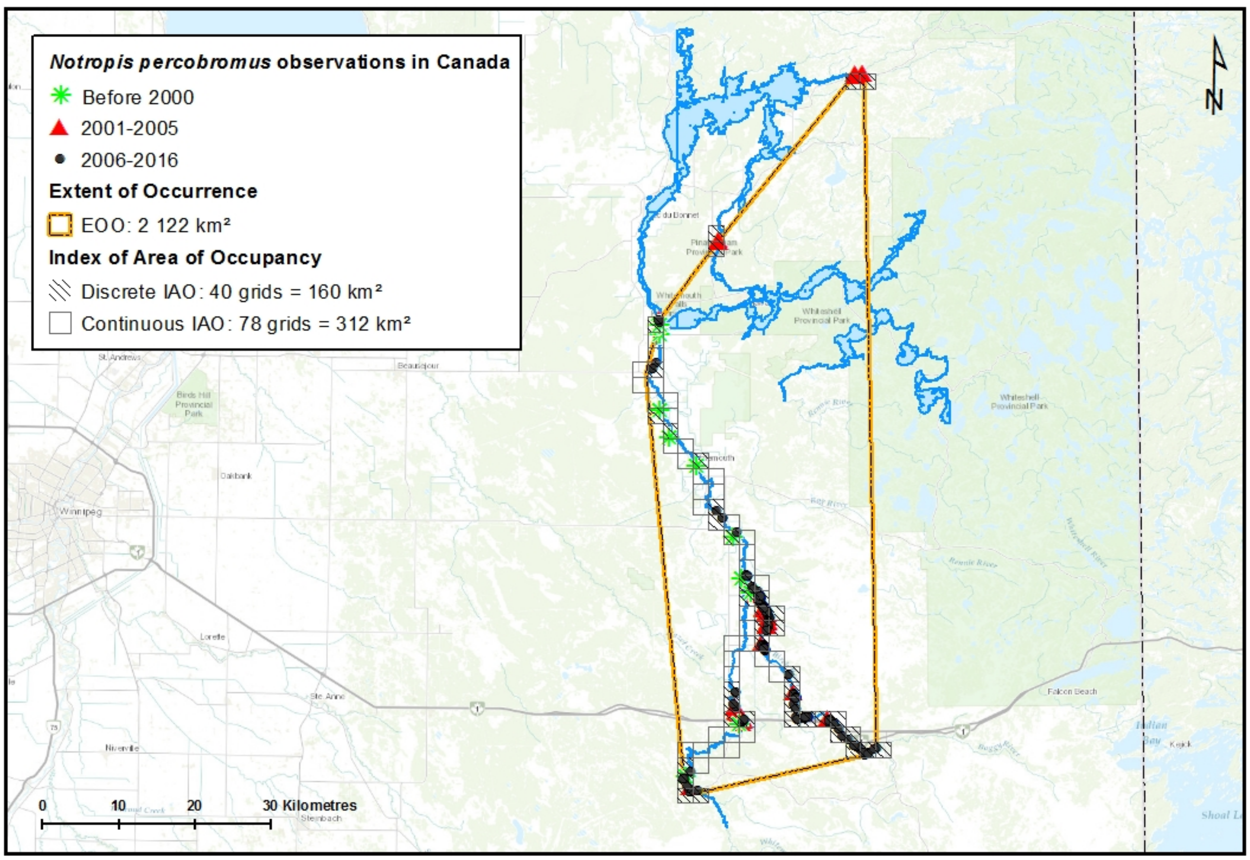

Figure 5. Observations of Carmine Shiner in Canada. Green asterisks represent observations before 2000, red triangles represent observations from 2001 to 2006, and black dots represent observations from 2006 to 2016 along with the discrete (cross-hatched grid squares) and continuous (open grid squares) area of occupancy, and the extent of occurrence (area encompased by yellow lines with black dashes) for Carmine Shiner.

Search Effort

Before 2001, there was no targeted sampling for Carmine Shiner. From 2001 to 2005, Carmine Shiner was collected at 47 of 346 sample sites from electroshocking (boat and backpack) and seine net sampling of the Winnipeg River watershed. Using seine nets, Carmine Shiner was collected at 233 of 515 sites sampled between 2006 and 2016. Sites that were sampled but where Carmine Shiner was not detected (from 2002 onward) are shown in Figure 3 with an open black diamond.

Targeted Seine Netting

Most of the 2006-2016 sampling occurred in 2011. Directed sampling was conducted with three passes of a 9.14 m long by 1.82 m high seine with a 1.82 m by 1.82 m bag and 4.76 mm ace meshing throughout. To maintain equal sampling area between sites, one end of the seine was held stationary on shore and the other end was stretched out along shore in the upstream direction and then pulled fully deployed (i.e., half arc of a circle) to complete the haul. If the water was deeper than 1 m, a boat was used to pull the seine. Fish were removed from the seine after each haul and placed in a holding tub.

Environmental DNA (eDNA)

Two end-point (conventional) Carmine Shiner-specific eDNA assays (for a 134-base pair (bp) fragment of the cytochrome *b* and 288-bp fragment of the COI gene) and one quantitative or real-time PCR (qPCR) assay (amplifying a 168-bp fragment of the cytochrome *b* gene) have been developed and tested for Carmine Shiner (Docker unpubl. data). Species-specificity of the assay was verified by testing for cross-amplification in Emerald Shiner, River Shiner (*N. blennius*), Blackchin Shiner (*N. heterodon*), Bigmouth Shiner (*N. dorsalis*), Sand Shiner (*N. stramineus*), and Common Shiner; no cross-amplification was observed in any of these other shiner species from Manitoba. In 2014–2016, a total of 80 sets of water samples were collected from 51 separate sites in 28 waterbodies as early as May 8 and as late as October 27 (Appendix 1). Sampling effort varied among sites and years during the initial stages of assay development. At each location, 3–5 water samples (0.5–1 L) were collected from the water's surface for subsequent filtration, DNA extraction, and PCR. A total of 3–5 PCRs were performed on each water sample. The effective volume of stream water sampled in each PCR was calculated to be 3.75–7.5 mL (i.e., 0.5–1 L of stream water was filtered and subsequently eluted into 200 µL, of which 1.5 µL was added to each PCR). Therefore, to detect at least one eDNA fragment (copy) per PCR, at least 133 copies would need to be present in each water sample (i.e., 267 and 133 copies/L, respectively, in the 0.5–1 L samples). Thus, given that 9–25 PCRs were performed per water sample, detection of at least one copy in at least one PCR per stream would require 10.6–29.4 or 5.3–14.7 copies per L stream water for the 0.5 L and 1 L samples, respectively (see Gingera *et al.* 2016).

HABITAT

Habitat Requirements

In 2006 and 2011, Carmine Shiner was sampled in the Whitemouth watershed in flowing water less than 3 m deep over primary bottom substrates of silt, sand, gravel, cobble, boulder, and bedrock (Watkinson pers. comm. 2017). Small individuals (<42.5 mm) were slightly less likely to be found in sites with sand than larger (>42.5 mm) individuals. Carmine Shiner was sampled in larger numbers in sites with sand (large: 39% of individuals) and smaller numbers in sites with silt (small: 13%, large: 11% of individuals) than would be expected if the fish were randomly distributed across substrate types (sand: 30% and silt: 19% of sites sampled).

Smart (1979) did not capture Carmine Shiner in the headwaters, lower course, or other tributaries of the Whitemouth where the bottom substrate was silt and there were fewer riffles.

Carmine Shiner may move into deeper pools and eddies in winter and is sometimes present in lakes near stream mouths. This minnow may be intolerant of sustained turbidity (Trautman 1981; Becker 1983), but have to tolerate pulses of turbidity in the Whitemouth River watershed associated with natural flood events (Stewart and Watkinson 2004).

An analysis in the Birch River was performed using a method that allows for the identification of river reaches exhibiting similar geomorphic structure and provides a link between the hydrological regime and species habitat preference. Results of this study indicate that 58% of immature Carmine Shiner prefer geomorphically variable reaches while 50% of mature Carmine Shiner prefer low-sinuosity reaches punctuated by increases in slope (Carr *et al.* 2015).

During periods of heavy runoff, Rosyface Shiner in Ontario will retreat to the slower-flowing edges of flooded rivers and onto the floodplain (Baldwin 1983). While it has not been observed, Carmine Shiner in Manitoba may show similar behaviour. Where available, flooded habitats may offer additional food resources and better feeding opportunities during periods of high turbidity. Their use may also lead to mortality by stranding. Wintering habitats are not well known for either Rosyface or Carmine shiners. In Ontario, Rosyface Shiner occupies deeper pools during the winter, where it is believed to remain inactive (Baldwin 1983). Data are not available on the habitat preferences of young-of-the-year Carmine Shiner; however, Baldwin (1983) caught young-of-the-year Rosyface Shiner in pool habitats that were relatively turbid in summer and clearer in the autumn. These fish were concentrated in areas with less than 5% plant cover of the bottom substrates and partially forested shores.

Little is known of where spawning occurs, location of nursery, rearing, feeding or food-supply areas, and timing or extent of migrations should they occur. Adults do frequent shallow riffles with clear water and clean gravel or stone bottom in the Whitemouth River, but it is not known whether these habitats are critical to the species' continued persistence. It has been collected in a wider range of habitats elsewhere in the Winnipeg River system. Critical habitat for Carmine Shiner was identified in the Recovery Strategy by the Carmine Shiner Recovery team for the Whitemouth and Birch rivers using the Bounding-Box Approach (Fisheries and Oceans Canada 2013).

Habitat Trends

There is projected to be ongoing cumulative degradation of the watersheds that Carmine Shiner occupy in Canada over the next 10 years. Specifically, increased deforestation and drainage for agriculture, peat mining, and potentially forestry, will likely modify stream discharge and add to sediment entering the watercourses. Transportation and service corridors will likely continue to be built or improved and contribute to minor changes in drainage as well as add sediment to streams.

Carmine Shiner habitat in the United States has been transformed due to changes in agricultural practices and reservoirs and will be subjected to further alterations with expected climate-change scenarios. In the United States, increases in the amount of silt from changes to agricultural practices may be causing the observed decline in Carmine Shiner in Smoky Hill River, Arkansas, and lower Kansas River basin (Gido *et al.* 2010). Downstream habitat changes from reservoir construction have led to the extirpation of Carmine Shiner from all the streams analyzed by Falke and Gido (2006) in Kansas. Conversely, a predictive model that incorporated the effect of warming on small-scale variation in stream conditions applied to 86,898 km of stream in Wisconsin found that an increase of 0.8-4°C has the potential to increase the amount of suitable habitat for Carmine Shiner by 22.6% to 36.8% (Lyons *et al.* 2010). Pandit *et al.* (2017) modelled the predicted changes in habitat of Carmine Shiner across its global range based on climate models for temperature and precipitation and found that ideal habitat for Carmine Shiner will shift northward. Predictions indicated that the southern extent of the distribution would become unsuitable, but the amount of suitable habitat farther north (e.g., in Manitoba) would increase. However, it is unclear if Carmine Shiner will be able to access this habitat naturally due to barriers to movement (Pandit *et al.* 2017).

BIOLOGY

Information on the Carmine Shiner is limited and somewhat confounded because many studies of the Rosyface Shiner species complex were conducted on eastern populations before the western populations were recognized as a distinct species (i.e., Carmine Shiner). The COSEWIC review by Houston (1996) included information on both species, as did Becker (1983). To avoid this problem, surrogate information from the closely related Rosyface Shiner is presented only where there is no information for Carmine Shiner.

Life Cycle and Reproduction

Carmine Shiner in Manitoba can live to at least 3 years of age, some fish may reach age 4 or 5; however, this is most likely rare (Watkinson unpubl. data). The sex ratio of Carmine Shiner in a subsample of the Birch River population collected in 2011 shows a ratio of 1.5 females to every male (Watkinson unpubl. data); it is unclear if this is the population-level sex ratio. The average age of the mature individuals (generation time) sampled in Birch river was 2.9 years (Watkinson unpubl. data).

Little is known of the species' spawning habitat. Spawning of Carmine Shiner in the southern part of its range and of Rosyface Shiner in Great Lakes watersheds typically occurs in riffles in May and June at temperatures of 20 to 28.9ºC (Starrett 1951; Pfeiffer 1955; Reed 1957a; Miller 1964; Pflieger 1975; Baldwin 1983; Becker 1983). Similarly in Manitoba, female Carmine Shiner collected in the Birch River in 2011 had mature eggs in July when water temperatures were 20 to 30°C with a spawning period between late June and July. Carmine Shiner in spawning condition have been caught in the Pinawa Channel, Whitemouth River and in the Birch River (Watkinson unpubl. data). Substrates at collection sites included sand, gravel, cobble, boulder, and bedrock. The spawning frequency of individuals in Canadian populations is unknown; however, there is some evidence from collected specimens of repetitive spawning during the spawning season (Watkinson unpubl. data). Cold weather has been observed to delay the spawning of Rosyface Shiner (Reed 1957a) and, in the Des Moines River, Iowa, populations of early-spawning species—including Carmine Shiner—may be limited by normal high river stages in May and June (Starrett 1951). Farther south, in Missouri, Carmine Shiner spawns from mid-April to early July, with the peak of activity in May and early June (Pflieger 1975).

During spawning, schools of Rosyface Shiner break up into groups of eight to 20 fish that spawn over depressions in the gravel (Pfeiffer 1955; Miller 1964). Often, these depressions are nests constructed by other cyprinids, such as Hornyhead Chub and Creek Chub (*Semotilus atromaculatus*) (Miller 1964; Vives 1989), and some are also occupied by Common Shiner (Reed 1957a; Miller 1964; Baldwin 1983; Vives 1989).

The proportion of fish that reproduce per age was estimated from fish sampled in Birch River (Figure 5) by fitting a logistic equation to the individual maturity data (1 = mature, 0 = immature) with bootstrapped confidence intervals (Figure 6). For this population, ~38% of the fish were mature by age 2 and ~97% by age 3 (Watkinson unpubl. data).

The total egg count of Carmine Shiner sampled during the spawning period in June and July in 2006 and 2011 in Manitoba (n=112) ranged from 144 to 2806 eggs per female (Watkinson unpubl. data). The observed variation in egg count is likely explained by the protracted spawning period of the species, along with the number of eggs per female increasing with increasing fish size.

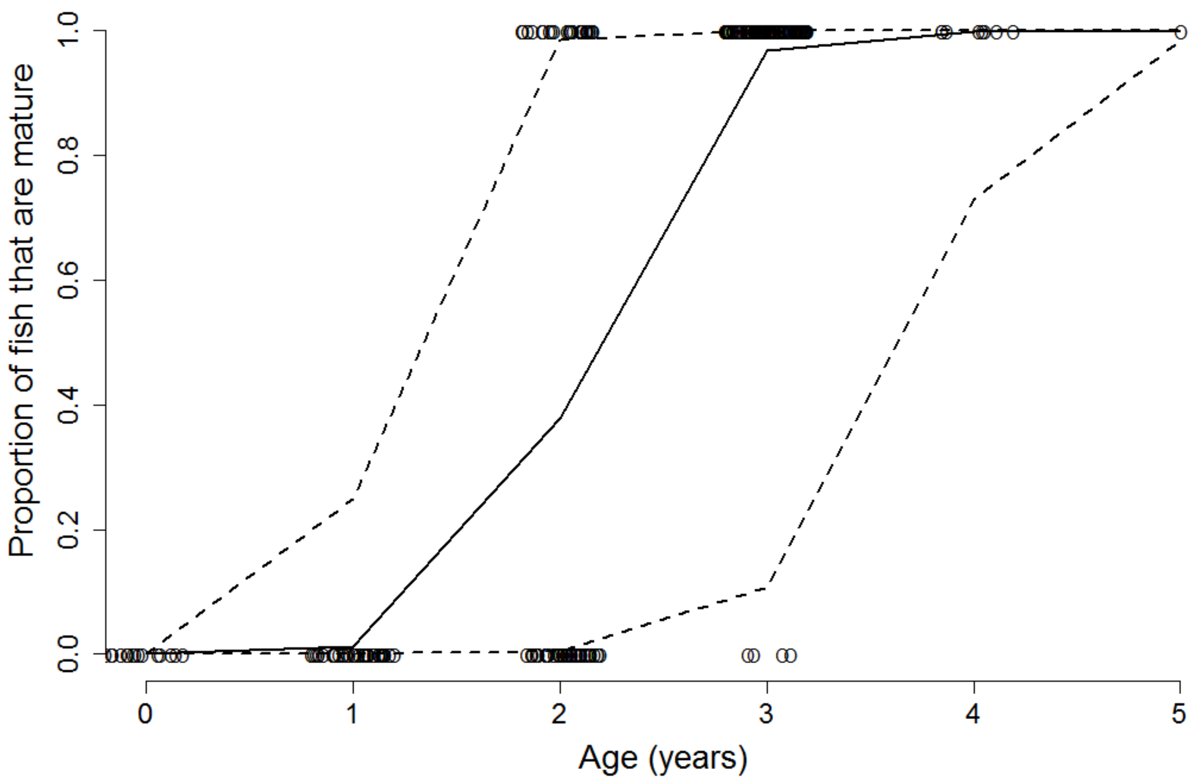

Figure 6: Maturity schedule for Carmine Shiner sampled from Birch River, Manitoba (Watkinson unpubl. data). The proportion of mature fish per age was calculated by fitting a logistic equation (solid black line) and bootstrapped confidence intervals (dashed black lines) to individual maturity data (237 fish, open circles, 1 = mature, 0 = immature). Random noise was added to fish age in the plot in order to see the number of fish in each category more clearly.

Unfertilized Rosyface Shiner eggs are spherical and dull grey (Reed 1958). They are 1.2 mm in diameter within the female and expand to 1.5 mm on contact with water. Fertilized eggs turn bright yellow and become water-hardened and adhesive. At 21.1ºC, they hatch in 57 to 59 hours. Newly hatched larvae take cover in the interstices of bottom gravel (Pfeiffer 1955), presumably until yolk absorption is complete.

Hybridization of Carmine Shiner with other species has not been described, but is possible given that the Rosyface Shiner hybridizes naturally with several species including Common Shiner (Raney 1940; Pfeiffer 1955; Miller 1964), a species that has an overlapping distribution with Carmine Shiner in Manitoba.

Carmine Shiner is a mid-level consumer (Hoover 1989; Enders pers. comm. 2017). Aquatic insects constitute the bulk of its diet, but it also consumes terrestrial insects and fish eggs. In the Birch River, insects that dwell on the water surface and terrestrial plants are the dominant items found in Carmine Shiner stomachs (Enders pers. comm. 2017). Competition for prey among minnow species in an Ozark stream led to greater dietary specialization by Carmine Shiner on midges (Chironomidae) (Hoover 1989). The breadth of its diet decreased in the presence of Smallmouth Bass (*Micropterus dolomieu*) and increased at higher light levels, which indicates that prey are located by sight.

Physiology and Adaptability

Little is known of its physiology or ability to adapt to different conditions. The closely related Rosyface Shiner has a narrow range of habitat requirements and responds quickly to changes in habitat and water quality (Cherry *et al.* 1977; Smith 1979; Trautman 1981; Humphries and Cashner 1994; Houston 1996). For example, the Rosyface Shiner exhibits long-term avoidance of pollutants (Cherry *et al.* 1977) and avoids water temperatures greater than 27.2°C (Stauffer *et al.* 1975). Carmine Shiner prefer temperatures of 23.6ºC (± 1.4ºC) (Stol *et al.* 2013). This temperature is within the range experienced by Carmine Shiner in its natural environment. Respirometry experiments conducted in the lab on Carmine Shiner indicated that standard metabolic rates (SMR) increased with body mass (0.64-2.46g) and water temperature (SMR average from 0.13-0.92 mg O_2 /h, from 10-20ºC) (Enders pers. comm. 2017).

Dispersal and Migration

Carmine Shiner is not known to migrate, although they likely move into deeper water to overwinter. In the Whitemouth River, individuals may disperse downstream or into flooded riparian habitat during heavy rainfall. Its natural predisposition to disperse is unknown. The species' apparent absence from the lower Red River, between Grand Forks and Lake Winnipeg, suggests that turbidity may limit establishment. However, this does not mean that it cannot use turbid rivers for dispersal. The detailed distribution of both Carmine and Rosyface shiners suggests that they disperse via large lakes and rivers, but colonize and establish in tributaries to these waters, occupying them to the first impassable obstacle upstream from the mouth.

Interspecific Interactions

Little is known of the predators, parasites, and diseases of Carmine Shiner. In Manitoba, it is likely preyed upon by Walleye (*Sander vitreus*), Northern Pike (*Esox lucius*), and fish-eating birds. Rosyface Shiner eggs are eaten by darters, suckers, Common Carp (*Cyprinus carpio*), and minnows (Baldwin 1983). Hoffman (1999) found two parasitic species of Monogenea infecting Carmine Shiner and 10 parasite species (two Monogenea, seven Trematoda and one Nematoda) infecting Rosyface Shiner. This low number likely reflects limited sampling effort rather than few parasite species, as many more species have been found in Common Shiner (Hoffman 1999). Most, if not all, Carmine Shiner caught in the Birch River appeared parasitized and further examination of the parasites and degree to which they are parasitized is underway (Enders pers. comm. 2017; Macnaughton pers. comm. 2017).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

The sampling effort and methods for seine netting and eDNA analysis of Carmine Shiner are described in the Distribution section. Catch per unit effort from the seine netting was calculated as the number of fish per standardized net pass.

Abundance

Prior to its designation by COSEWIC, Carmine Shiner had only been reported incidentally in Manitoba (e.g., Smart 1979). Since assessment, effort has been focused on improving knowledge of the distribution of Carmine Shiner. Some assumptions can be made regarding its relative abundance from electroshocking, netting (seine), and eDNA; however, there has been no targeted effort to obtain abundance estimates.

Electroshocking and Seine Netting

Catch-per-unit-effort (CPUE) estimates from targeted sampling for Carmine Shiner in Birch River ranged from 0 to 97 individuals per standardized seine haul. Boat electrofishing CPUE was higher in the Birch and Whitemouth rivers, on average, than in sites on the Pinawa Channel and Peterson Creek.

Environmental DNA (eDNA)

Frequency of detection for Carmine Shiner was highest in the Birch and Whitemouth rivers. In the Birch River, 0–80% of the water samples (average 30.9%) tested positive for Carmine Shiner in early July, and 0–100% of the water samples (average 50%) tested positive in late September when the water levels were lower. In the Whitemouth River, 33–100% of the water samples (average 66.7%) tested positive for Carmine Shiner and 100%

of the water samples tested positive in late September. In the Pinawa Channel just downstream of the Old Pinawa Dam and in Peterson Creek, only 20% of the water samples tested positive for Carmine Shiner (i.e., 1/5 water samples) and, in fact, only 1/5 PCRs in the water sample tested positive. Higher frequency of detection in the Birch and Whitemouth rivers than in Pinawa Channel and Peterson Creek is consistent with the observations made via conventional sampling that Carmine Shiner occurs in higher abundance in the Birch and Whitemouth rivers than in Pinawa Channel and Peterson Creek. Because many factors influence detectability of eDNA (e.g., flow rate (Gingera *et al.* 2016) and temperature (Lacoursière-Roussel *et al.* 2016a)), eDNA cannot yet be used to strictly quantify abundance. However, using qPCR and collections from non-flowing waters where environmental variability was minimized (i.e., all lakes were sampled in spring), Lacoursière-Roussel *et al.* (2016b) found a significant positive relationship between Lake Trout (*Salvelinus namaycush*) relative abundance (as CPUE) and eDNA concentration. With better understanding of the factors that influence detectability of Carmine Shiner eDNA in flowing waters and an appropriately standardized collection protocol, eDNA frequency of detection or concentration might eventually be useful for inferring relative Carmine Shiner abundance.

Fluctuations and Trends

The CPUE for samples collected since 2002 were rarely made at the same site as most of the survey effort was directed at collecting fish in new sites. There is no evidence that Carmine Shiner populations have declined over time but, because of its limited distribution and suspected low abundance, the species may be vulnerable to future anthropogenic disturbances.

Rescue Effect

Hydroelectric dams have partitioned fish habitat in the Winnipeg River mainstem. Rapids and falls in Pinawa Channel, Peterson Creek, and at the mouth of the Whitemouth River prevent re-colonization of Carmine Shiner from the Winnipeg River. These barriers significantly reduce any natural rescue potential for the species. In addition, the original dispersal route, presumed to be from the Red Lakes area of Minnesota, is no longer available (see Distribution above). The percentage of the global range of Carmine Shiner in Canada remains uncertain pending additional sampling in the Winnipeg River and Lake Winnipeg watersheds.

THREATS AND LIMITING FACTORS

To identify the nature and magnitude of threats to Carmine Shiner, a threats calculator was completed based on the IUCN-CMP (World Conservation Union-Conservation Measures Partnership) unified threats classification system (IUCN and CMP 2006; Salafsky *et al.* 2008). Based on the threats calculator, the overall threat impact was estimated as “Medium-Low”, with the most important threats being: dams and water management/use; agricultural effluents; habitat alterations; and invasive or introduced species (Appendix 2). Threats considered negligible include: livestock farming; roads and railroads; utilities and service lines; bait fishing; recreational activities; and scientific sampling (Appendix 2).Based on the generation time of 2.9 years, the timeframe for severity and timing was considered to be 10 years. For scope, Pinawa Channel and Peterson Creek were considered to represent a smaller proportion of the total Canadian population than Birch and Whitemouth rivers.

Natural System Modifications

Natural system modifications including water management and use, shoreline/riparian development, and landscape changes are ongoing and pose a threat to the species as these threats can alter and or reduce habitat quantity and quality.

Dams and Water Management and Use

As Carmine Shiner frequents shallow riffles with clear water in summer, flow alterations that affect these conditions may pose a threat to its existence. A fixed-head weir at the outlet of Whitemouth Lake impacts flow in the entire Whitemouth River. However, this dam impacts <10% of the overall Whitemouth River watershed so the impact is likely minimal on available flow downstream where Carmine Shiner occur. Manitoba’s first hydroelectric station on the Pinawa Channel was completed in 1906. It was retired in 1951 and flow in the channel was reduced significantly as a diversion dam was built at its origin to divert flow to the Seven Sisters Generating Station. Development began in 1909 at Pointe du Bois and ended in 1955 with the completion of the hydroelectric station at McArthur Falls. These developments significantly altered the habitat, with impounded reaches of the river creating forebays, flooding vegetation, and eliminating rapids. These hydroelectric stations are in operation and are unlikely to be removed. While most of the dams in this system are run-of-the-river that do not generally impede flow, the system has a modified hydrograph from the Sturgeon and Kettle falls generating stations on the Rainy River system and Norman Dam on Lake of the Woods that decrease summer flows and increase winter flows. They can have significant effects on seasonal flow in the system and, in turn, Carmine Shiner habitat in the Winnipeg River immediately below the Whitemouth River’s confluence. The impact of this change on Carmine Shiner is unknown and it affects the very small portion of this species’ overall distribution that is in the Winnipeg River. It is uncertain if the hydroelectric development on the Winnipeg River impacted Carmine Shiner populations as this species was not identified in the Winnipeg and Bird rivers or Pinawa Channel prior to the dam’s construction.

Peat mines, agricultural drains, and roads in the watershed have the potential to impact the surface water and shallow part of the water table. There is active agriculture drainage and peat mining in the system with the potential for their scope to increase in the future. Wetlands with peat moss account for 46% of the land cover in the Whitemouth watershed and less than 0.01% were active peat mines as of 2005. Their overall impact on the hydrograph is undetermined as these impacts are cumulative.

Water removal for domestic use, lawn, or agricultural irrigation and watering livestock has the potential to reduce flow and limit habitat, particularly during dry years. Agricultural intensity has been increasing in the watershed over the years, contributing to 5% of the land cover in 2005.

Hydrostatic testing of pipelines has been requested for the Birch River in the winter when flows are low. The amount of available flow in the river needs to be considered carefully if these permit requests are to be approved.

Shoreline/Riparian Development

Shoreline development in areas adjacent or upstream of Carmine Shiner habitat is present in the watershed, but is limited. Altering shorelines could have adverse effects by causing physical disturbances or changes in water quality and physical habitat. Clearing of riparian vegetation to the water's edge for cottage or agricultural development can destabilize banks and increase erosion. Allowing livestock access to the river and adjacent riparian area can disturb habitats by increasing silt and nutrient loading. Fortunately, most impacts of these activities on stream habitats can be mitigated using existing technology and best management practices. Mitigation would typically include the establishment of riparian buffers, livestock fencing, or otherwise restricting access and the deployment of appropriate erosion-control techniques. Some riparian habitat is identified in the Recovery Strategy and will be legally protected by the Federal Critical Habitat Order currently in development.

Landscape Changes

Over a period of around 20 years (mid-1990s-2013), approximately 34 hectares of hardwood floodplain forest was cleared within the agricultural regions of the watershed with most of the clearing occurring along the lower Whitemouth and Birch rivers. This clearing represents about a 1.1% loss in hardwood floodplain forest in the watershed.

Pollution

<u>Agricultural and industrial effluents</u>

Pollution from point sources (e.g., lagoons, chemical spills) and non-point sources (e.g., nutrient loading) occurs within the range of Carmine Shiner in Manitoba and is ongoing. Examples of some pollutants that could affect this species include farm fertilizers, animal waste, herbicides, and pesticides. Runoff that carries additional nutrients from barnyards or intensive livestock operations is an ongoing problem that is being addressed by the Province of Manitoba and Prairie Farm Rehabilitation Administration (PFRA). Clarke (1998) found elevated levels of phosphorus (0.2 mg·L-1 TDP) and nitrogen (0.99 mg·L-1 nitrate/nitrite) in the lower Birch River in April 1996, but not at other times of the year. These levels are likely elevated through mobilization of agricultural chemicals during spring runoff and potentially hydrostatic testing of adjacent pipelines. Other sources of pollution within the region have been identified, including the release of orthophosphate from cottage developments, and tantalum and cobalt from mining operations near the Bird River.

If Carmine Shiner responds in a similar fashion as the closely related Rosyface Shiner, it may exhibit long-term avoidance of pollutants (Cherry *et al.* 1977). The potential to mitigate, through environmental licensing and public education, or recover from pollution impacts is moderate to high except where long-range transport is the main source of pollutants, because these substances are ubiquitous.

Invasive and Other Problematic Species

Sources of introductions may include inter-basin water transfers, possibly associated with hydrostatic pipeline testing, live bait used by anglers, or the stocking of game fishes. The import of live bait into Canada is illegal. Walleye has been stocked by Manitoba in Whitemouth Lake since 1960 and Brook Trout (*Salvelinus fontinalis*) was stocked in 1961-62 (Leroux pers. comm. 2005). The Birch River has been stocked with Rainbow Trout (*Oncorhynchus mykiss*), Brook Trout, Brown Trout (*Salmo trutta*) and Walleye (Clarke 1998). Walleye is the only one of these stocked species that remains in the Birch River. Brown Trout has been stocked in the Pinawa Channel and Smallmouth Bass and Rainbow Smelt (*Osmerus mordax*) have been introduced to the Winnipeg River system. The effects of these introduced species on Carmine Shiner populations are unknown, although Smallmouth Bass and Carmine Shiner do coexist elsewhere. The potential for transfer of species from the Lake of the Woods watershed via overland transportation exists as Rusty Crayfish (*Orconectes rusticus*) was collected in the Birch River in 2011 (Watkinson pers. comm. 2017). Not only does the Rusty Crayfish diet overlap with that of Carmine Shiner, they also deteriorate aquatic insect habitat through consumption of macrophytes leading to declines in the abundance of Carmine Shiner prey (Kreps *et al.* 2015). Other non-fish species have also been introduced into the region including Spiny Water Flea (*Bythotrephes longimanus*; Hann and Salki 2017), Zebra Mussel (*Dreissena polymorpha*; Gingera *et al.* 2017), pathogens, and viruses.

In general, potential threats to Carmine Shiner populations through species introductions include predation (Walleye, Rusty Crayfish (eggs), and Smallmouth Bass), competition (Rusty Crayfish and all fish species), and trophic disruption (Rusty Crayfish, Spiny Water Flea, and Zebra Mussel). Introduced species might also carry diseases and parasites to which Carmine Shiner populations have never been exposed.

Limiting Factors

Too little is known of Carmine Shiner's physiology or ability to adapt to different conditions to identify factors that might limit its survival. The species appears to occupy a relatively narrow ecological niche, which suggests limited adaptive ability.

If Carmine Shiner's responses are similar to those of the closely related Rosyface Shiner, it may show long-term avoidance of pollutants (Cherry *et al.* 1977) and avoid water temperatures that exceed 27.2ºC (Stauffer *et al.* 1975). The apparent high parasitization rates may also be an influential limiting factor. Other factors that may be important include availability of key prey species, competition with and predation by other species, and hybridization with other shiner species. Other shiner species that co-occur with Carmine Shiner in Manitoba include: Common Shiner, Golden Shiner (*Notemigonus crysoleucas*), Emerald Shiner, Blackchin Shiner, Blacknose Shiner (*Notropis heterolepis*), Spottail Shiner (*Notropis hudsonius*), Weed Shiner (*Notropis texanus*), and Mimic Shiner (*Notropis volucellus*).

Number of Locations

The most serious plausible threat to Carmine Shiner is dams and water management and use. As these threats work at a drainage basin scale, two locations exist in Canada, the Whitemouth and Winnipeg river systems. Although the Whitemouth River is a tributary of the Winnipeg River, it is isolated from the Winnipeg River by an impassable waterfall and has a much smaller watershed.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

When the Canadian population of Carmine Shiner, formerly called Rosyface Shiner, was first assessed by COSEWIC in 1994, the species had only been reported from the Whitemouth River (Houston 1996). Given its limited distribution and an apparent geographical separation of about 900 km from the nearest other Canadian populations in Ontario and Quebec, COSEWIC designated the Manitoba population as "Vulnerable", (now called "Special Concern"). In 2001, COSEWIC used the existing report to reassess the population, and reassessed its status as "Threatened". The Manitoba population was subsequently listed as such under Schedule I of the SARA on 5 June 2003.

Listing under SARA confers protection on the Canadian population of Carmine Shiner by prohibiting the killing, harming, harassing, capture or take of any individuals of the species or the possession, collection, or trade in the species. A SARA Critical Habitat Order made under subsections 58(4) and (5) is in development, which will invoke the prohibition in subsection 58(1) against the destruction of the identified critical habitat. Carmine Shiner is not otherwise protected in Manitoba except incidentally by several provincial reserves and parks that overlap its distribution.

The Carmine Shiner Recovery Team developed the first Recovery Strategy, posted on the Species at Risk Public Registry in 2008 (Carmine Shiner Recovery Team 2007). In 2013, the Recovery Strategy was revised (including the identification of critical habitat) and re-posted to the Public Registry (Fisheries and Oceans Canada 2013). A proposed Action Plan was posted on the Species at Risk Public Registry in 2017.

Non-Legal Status and Ranks

Carmine Shiner has a global rank of G5, which means that it is considered secure due to the large number of subpopulations and localities throughout its range, and is listed as Least Concern with the IUCN Red List of Threatened Species (NatureServe 2017).

The Manitoba Conservation Data Centre has assigned it a provincial rank of S2, on the basis that the species is rare in the province (6 to 20 occurrences) and may be vulnerable to extirpation. The Manitoba Endangered Species Advisory Committee, as of February 2003, listed Carmine Shiner as threatened (Stewart and Watkinson 2004). The Manitoba *Endangered Species Act* does not mandate habitat protection for listed species.

Habitat Protection and Ownership

SARA (Ss.58.1) prohibits the destruction of any part of critical habitat identified for any listed endangered, threatened, or extirpated wildlife species. Critical habitat has been identified for Carmine Shiner and is protected by SARA (Fisheries and Oceans Canada 2013). Since the Recovery Strategy was completed, management and regulatory actions have been conducted to protect Carmine Shiner habitat. Through the Habitat Stewardship Program, Manitoba Habitat Heritage Corporation (MHHC) has protected 199 acres of riparian area along the Birch River and a further 70 acres of upland has been restored (Fisheries and Oceans Canada 2015). Furthermore, in 2013 Manitoba Conservation and Water Stewardship Forestry and Fisheries Branches integrated protection of riparian habitat within the provincial forest management plan for the area that includes the Birch and Whitemouth river watershed (Fisheries and Oceans Canada 2015).

Other existing federal and provincial statutes and policies may provide protection to the fish habitat in general. Although not directly protected, the federal *Fisheries Act* (R.S. 1985, c. F-14) provides protection to the species and its habitat where they co-occur with fish that are part of a commercial, recreational, or Aboriginal fishery. Provincially, a 130 ha headwater section of the Whitemouth River, designated as Ecological Reserve in 1986 to protect river-bottom forest, may also provide some incidental protection for Carmine Shiner habitat (Hamel 2003). While most of the land within the Whitemouth watershed is Provincial Forest or Crown lands, a substantial proportion of the land directly bordering the river and tributaries is privately owned. A small section of Carmine Shiner’s distribution is within Whitemouth Falls Provincial Park.

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Gatineau, QC

Melanie VanGerwen-Toyne
Senior Species at Risk Biologist
Fisheries and Oceans Canada
Winnipeg, MB

Carolyn Bakelaar
GIS Specialist
Fisheries and Oceans Canada
Burlington, ON

Colin Murray
Project Biologist
Manitoba Conservation Data Centre
Manitoba Sustainable Development
Winnipeg, MB

Dr. Simon Nadeau
Senior Advisor
Fish Population Science
Fisheries and Oceans Canada
Ottawa ON

Jennifer Shaw
Fish Population Science
Fisheries and Oceans Canada
Ottawa ON

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BIOGRAPHICAL SUMMARY OF REPORT WRITER(S)

Amanda Caskenette is a Research Biologist with Fisheries and Oceans Canada in Winnipeg. She holds a BSc in Environmetrics (2003), and an MSc (2010) and PhD (2015) in Integrative Biology from the University of Guelph. Amanda's previous research spans marine and freshwater focusing on population and community dynamics. Her current research focus includes aquatic invasive species and species at risk. Amanda is a co-author on several *SARA* publications.

Doug Watkinson is a Research Biologist with Fisheries and Oceans Canada in Winnipeg. He has sampled fish in many of the major river systems of the Hudson Bay drainage from northwestern Ontario west to the Rockies, including sampling for Carmine Shiner. His current research focuses on species at risk, habitat impacts, and aquatic invasive species. He has co-written seven COSEWIC species status reports and the field guide, The Freshwater Fishes of Manitoba.

Margaret Docker is a Professor in the Department of Biological Sciences at the University of Manitoba. Her research focuses on the evolution, systematics, and conservation genetics of freshwater fishes, particularly lampreys. Her recent interests include developing and applying environmental DNA techniques for monitoring aquatic invasive species and species at risk. She has written or co-written two other COSEWIC species status reports, and is the editor on a book about the biology of lampreys.

COLLECTIONS EXAMINED

Canadian Museum of Nature's collections were consulted but they did not contain any Carmine Shiner specimens.

Fish samples collected and maintained by Dr. Eva Enders and Doug Watkinson, Fisheries and Oceans Canada (Watkinson unpubl. data), from Birch River were analyzed for length, weight, sex ratio, maturity, fecundity, age, metabolic rate, and diet.

Appendix 1. Sites sampled for Carmine Shiner environmental DNA (eDNA) in 2014–2016. Sites where Carmine Shiner eDNA was detected are highlighted in bold; * indicates sites where Carmine Shiner eDNA was detected in only one PCR replicate from one water sample (see *Search Effort*); at all other sites, Carmine Shiner eDNA was detected in multiple PCR replicates from multiple water samples.

Waterbody	Location	Latitude	Longitude	Sampling Date
Big Creek	PR 307			19/10/2016
Birch River	**Hwy 507 (Rd. 50N)**			**03/07/2014**
				25/09/2014
				16/07/2015
	Nazar Road (Rd. 46N)			**03/07/2014**
				25/09/2014
				08/05/2015
				16/07/2015
	River Road and Rd. 74E			**03/07/2014**
				25/09/2014
Bird River	Hwy 315 near Bird Lake			05/08/2014
				27/08/2015
				27/10/2015
	Hwy 315 near Lac du Bonnet			05/08/2014
				27/08/2015
				27/10/2015
				23/08/2016
Black River	PR 304			23/08/2016
	PR 314			23/08/2016
Brokenhead River	Hazelridge Road			25/08/2015
				03/11/2015
	Hwy 317			09/10/2014
				25/08/2015
				03/11/2015
	Hwy 1			25/09/2014
	Hwy 44			09/10/2014
	Road 45E			25/08/2015
				03/11/2015
Caribou Creek	PR 307			19/10/2016
Gold Creek	PR 304			23/08/2016
Hazel Creek	Colony Road			25/08/2015
				03/11/2015
	Hwy 15			25/08/2015
				03/11/2015
La Salle River	NA			11/08/2014
	Road 10W			19/08/2015
	Waverley St.			19/08/2015
Manigotagan River	PR 304			23/08/2016

Waterbody	Location	Latitude	Longitude	Sampling Date
	PR 314			23/08/2016
Maple Creek	Hwy 11			18/10/2016
Maskwa River	Broadlands Road			18/10/2016
Moose River	PR 314			23/08/2016
North Coca Cola Creek	Broadlands Road			18/10/2016
O'Hanly River	PR 304			23/08/2016
Peterson Creek	PR 314			23/08/2016
	PR 315			05/08/2014
				09/10/2014*
				27/08/2015
				27/10/2015
				23/08/2016
Picket Creek	PR 307			19/10/2016
Pinawa Channel	**Below Old Pinawa Dam**			**09/10/2014***
	Above Old Pinawa Dam			27/08/2015
				27/10/2015
				23/08/2016
	Hwy 313			05/08/2014
				09/10/2014
				27/08/2015
				27/10/2015
				23/08/2016
	Trans Canada Trail			23/08/2016
Pine Creek	Broadlands Road			18/10/2016
Rabbit River	PR 314			23/08/2016
Rat River	NA			14/09/2014
Red River	NA			11/08/2014
Rice Creek	PR 315			23/08/2016
Sandy River	PR 304			23/08/2016
Seine River	NA			11/08/2014
	Prairie Grove Road			19/08/2015
	Bernat Road			19/08/2015
	PR 210			19/08/2015
	PR 311			19/08/2015
Wanipigow River	PR 304			23/08/2016
Whitemouth River	**Hwy 506**			**25/09/2014**
	Road 50N			**03/07/2014**
				25/09/2014
				16/07/2015
	Road 45N			**16/07/2015**
Whiteshell River	PR 307			19/10/2016
	Nutimik Lake			19/10/2016

Appendix 2. Threats Calculator for Carmine Shiner (*Notropis percobromus*).

Species or Ecosystem Scientific Name	*Notropis percobromus* - Carmine Shiner		
Element ID		**Elcode**	
Date (Ctrl + ";" for today's date):			
Assessor(s):	Dwayne Lepitzki as the moderator, Nick Mandrak as the co-chair, Doug Watkinson and Amanda Caskenette as report writers, and Eva Enders.		
References:	Draft calculator and draft report provided by report writers by teleconference 16 August 2017		

Overall Threat Impact Calculation Help:

Threat Impact		Level 1 Threat Impact Counts: high range	low range
A	Very High	0	0
B	High	0	0
C	Medium	2	0
D	Low	1	3
	Calculated Overall Threat Impact:	Medium	Low
	Assigned Overall Threat Impact:	**CD = Medium - Low**	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
1	Residential & commercial development						
1.1	Housing & urban areas						<1% of watershed is developed. Limited population growth in recent years.
1.2	Commercial & industrial areas						<1% of watershed is developed. Limited population growth in recent years.
1.3	Tourism & recreation areas						Majority of the watershed is crown lands
2	Agriculture & aquaculture		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	

Threat		Impact (calculated)	Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2.1	Annual & perennial non-timber crops					<10% of the Whitemouth River watershed is cropland. Demand for irrigation water falls under dams and water management, and agricultural runoff falls under agricultural and forestry effluents. Probably not applicable because aquatic. Pollution accounted for under 9. Storage will be accounted for under dams and water management (7.2).
2.2	Wood & pulp plantations					<5% cut blocks
2.3	Livestock farming & ranching	Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	Rangeland <5% of watershed. But erosion and runoff of nutrients should be considered under Agriculture and Forestry Effluents. Cattle have access to the rivers so trampling is plausible (but mostly fenced off). Cattle also don't enter the water during the spawning season (June-July) when the rivers can be quite deep. Pollution and siltation associated with livestock accounted for under pollution and ecosystem modification. Turbidity accounted for elsewhere. Trampling of prey habitat could be accounted for under this threat category.
2.4	Marine & freshwater aquaculture					Not aware of any aquaculture facilities in watershed.
3	Energy production & mining					
3.1	Oil & gas drilling					None
3.2	Mining & quarrying					Peat mining exists in the watershed. <5%
3.3	Renewable energy					no known wind farms exist in the watershed. Solar energy and transmission lines accounted for under 4.2.
4	Transportation & service corridors	Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	

Threat		Impact (calculated)	Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
4.1	Roads & railroads	Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Trans Canada Hwy, and a few provincial hwys. Numerous grid gravel roads exist in the agricultural portions of the watershed. As a whole the watershed has limited roads. Bridge replacement taking place at both Birch River (completed) and Whitemouth River (under construction) but threat is negligible; crossings aren't huge.
4.2	Utility & service lines	Negligible	Negligible (<1%)	Negligible (<1%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Utility and service lines do cross the watershed, TransCanada pipeline in the major one as well as the City of Winnipeg Aqueduct. Risk of breakage or release into the Whitemouth or Birch River is a concern. Threat impact of crossing and maintenance is unknown over the next 10 years. Spill is accounted for under pollution.
4.3	Shipping lanes					No commercial shipping lanes. Recreational boaters (canoe, kayak, inner tube) accounted for under different category. No dredging.
4.4	Flight paths					Flight path density not known. No direct impacts.
5	Biological resource use	Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	
5.1	Hunting & collecting terrestrial animals					Hunting is common, but no impacts.
5.2	Gathering terrestrial plants					Unknown how common this activity is, but it would have minimal impact.
5.3	Logging & wood harvesting					<5% harvesting in watershed. Not sure of future plans for harvest in the watershed.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
5.4	Fishing & harvesting aquatic resources		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	Recreational fishing and baitfish collection allowed in the watershed. Fishing is probably restricted to accessible sections of the river and is not likely a popular activity. Bait fishing by anglers might occur but is likely limited. The Whitemouth, Bird, and Winnipeg rivers are not approved for live baitfish harvest by commercial harvesters; therefore, Carmine Shiner is not likely to be affected by such operations.
6	Human intrusions & disturbance		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	
6.1	Recreational activities		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Recreational activities occur, however they are mostly low impact (i.e., hiking, birdwatching, camping, etc.). Very limited power boating. No boat launches but possible. Mostly un-motorized so negligible or small.
6.2	War, civil unrest & military exercises						No war, civil unrest or military exercises.
6.3	Work & other activities		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Scientific research of Carmine Shiner is likely to continue in the watershed. Necessity of obtaining a SARA permit and Fish Research Licence reduces chances of negatively impacting population. Some lethal sampling from targeted and non-targeted research. Some presence absence sampling which is nonlethal. The area sampled is small.
7	Natural system modifications	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	
7.1	Fire & fire suppression		Not Calculated (outside assessment timeframe)	Large - Small (1-70%)	Serious - Slight (1-70%)	Low (Possibly in the long term, >10 yrs/3 gen)	Active fire suppression in watershed. Impacts on erosion into streams and nutrient input are unknown and accounted for under agricultural and forestry effluents. Grass and forest fire possible, impact unknown. Aerial spraying for fire suppression is accounted for under pollution.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
7.2	Dams & water management/use	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	Low head weir at outlet of Whitemouth Lake impacts flow in the entire Whitemouth River. This dam is however impacting only a small portion of the overall watershed. Groundwater extraction water by municipalities. Species persists despite this ongoing threat. Peat mines and agricultural drains in the watershed create significant drainage ditches that have the potential to impact the surface water and shallow part of the water table. Hydroelectric development has altered flow in the Winnipeg River. Hydrostatic testing of pipelines has been requested for the Birch River in the winter when flows are low.
7.3	Other ecosystem modifications	CD	Medium - Low	Large (31-70%)	Moderate - Slight (1-30%)	High (Continuing)	Some small scale habitat alterations (e.g., rip rap, boulder removal, beach building) may be present, but for the most part, few habitat alterations are present. Scope is towards the higher end of the range. Spraying of herbicides are more concerning than habitat changing. Uncertainty of effect leads to severity range between 1-30%.
8	Invasive & other problematic species & genes	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8.1	Invasive non-native/alien species/diseases	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	Walleye, may predate on Carmine Shiner. Overall impact from Walleye predation is unknown, Carmine Shiner have persisted despite Walleye presence. Walleye occur in low numbers. Rusty Crayfish have been found in the Birch River. Surveys have not been conducted for a number of years. The numbers were low but it is expected that the distribution and abundance is now greater. Zebra Mussels present in Manitoba. Maybe a threat in the future, water quality conditions are suitable. Smallmouth Bass and Rainbow Smelt have been introduced into the Winnipeg River system. Spiny Water Flea have also been introduced into the Winnipeg river. Their impacts are unknown.
8.2	Problematic native species/diseases						Predatory native species such as Northern Pike and Rock Bass may negatively impact Carmine Shiner populations. May be more of a limiting factor rather than a threat. More research needed to determine threat impact by Northern Pike and Rock Bass.
8.3	Introduced genetic material						Not applicable. No stocking of this species.
8.4	Problematic species/diseases of unknown origin						Not applicable.
8.5	Viral/prion-induced diseases						Not applicable.
8.6	Diseases of unknown cause						Not applicable.
9	Pollution	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
9.1	Domestic & urban waste water		Unknown	Large (31-70%)	Unknown	High (Continuing)	Human waste lagoon present at town of Whitemouth (2 cells). Urban waste impact is likely small. This threat accounts for town effluent pumping out or septic leakage, which is rare. Road salt also accounted for under this threat but minimal because roads are minimal in species' range. Definitely some human effluent entering into the river; however limited. Animal waste is likely more prevalent.
9.2	Industrial & military effluents		Unknown	Large (31-70%)	Unknown	High (Continuing)	There is little military activity in the watershed. Oil spills also accounted for under this threat category. Mining extraction as well and are considered low risk. Peat mining activity occurs in this watershed <5% of surface area, effluents from mining are related to sediment and tantalum and cobalt from hard rock mining operations near the Bird River.
9.3	Agricultural & forestry effluents	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	Cattle waste is present, animal waste lagoons are present along the Whitemouth River in several localities. Likely some agricultural runoff and nutrient input from cattle in riparian area as well as row crop. Examples of some pollutants that could affect this species include farm fertilizers, herbicides, and pesticides. The exact extent of this input is unknown. Cattle and hog feces as well. Number of animal waste lagoons in the watershed, potential for spilling into the river. Sediment is likely increase from agricultural practices and drains. Impact is unknown.
9.4	Garbage & solid waste						Minimal solid waste in the watershed and likely no impact on Carmine Shiner population

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
9.5	Air-borne pollutants						Unknown amount of airborne pollutants, but likely low given lack of industrial activity in the area. Possibly smoke from fires. Impact on species unknown but likely minimal. Aerial spraying of row crops is possible, no idea of frequency.
9.6	Excess energy						Some excess noise and light from road crossing and residences along river, but minimal impact.
10	Geological events						
10.1	Volcanoes						Not applicable.
10.2	Earthquakes/tsunamis						Not applicable.
10.3	Avalanches/landslides						Not applicable.
11	Climate change & severe weather		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	
11.1	Habitat shifting & alteration						Habitat shifting due to changing climate is generally unknown. Warmer air temperatures have been modelled for this watershed. May benefit this species.
11.2	Droughts						Drought is uncommon in the area but does occur and can dewater portion of the stream. This could result in decreased survival.
11.3	Temperature extremes						Extreme heat and cold waves are possible and not uncommon. For a species in the northern edge of range and increased temperatures not likely to pose a negative impact on the species. Extreme cold in winter could increase ice extent and reduce overwintering survival, though no indication that these events will increase in severity.
11.4	Storms & flooding						Thunder storms and blizzards relatively common. Hail, snow, rain, and dust probably present no real negative impacts on species.
11.5	Other impacts						None identified.