Proposed

Species at Risk Act
Recovery Strategy Series

Recovery Strategy and Action Plan for the Rainbow (*Villosa iris*) in Canada

Rainbow

2016

Fisheries and Oceans Canada
Pêches et Océans Canada

Canada

Recommended citation:

Fisheries and Oceans Canada. 2016. Recovery strategy and action plan for the Rainbow (*Villosa iris*) in Canada [Proposed]. *Species at Risk Act* Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa. v + 64 pp.

For copies of the recovery strategy and action plan, or for additional information on species at risk, including COSEWIC Status Reports, residence descriptions, action plans, and other related recovery documents, please visit the SAR Public Registry.

Cover illustration: Courtesy of Philip McColl, Graphic Arts Section, Environment and Climate Change Canada

Également disponible en français sous le titre
« Programme de rétablissement de villeuse irisée (*Villosa iris*) au Canada »

ISBN ISBN to come
Catalogue no. Catalogue no. to come

Preface

Under the *Species at Risk Act* (S.C. 2002, c.29) (SARA), the federal competent ministers are responsible for the preparation of recovery strategies for listed Extirpated, Endangered, and Threatened species and are required to report on progress within five years. The federal, provincial, and territorial government signatories under the Accord for the Protection of Species at Risk (1996) agreed to establish complementary legislation and programs that provide for effective protection of species at risk throughout Canada.

This document has been prepared to meet the requirements under SARA of both a recovery strategy and an action plan. As such, it provides both the strategic direction for the recovery of the species, including the population and distribution objectives for the species, as well as the more detailed recovery measures to support this strategic direction, outlining what is required to achieve the objectives. SARA requires that an action plan also include an evaluation of the socio-economic costs of the action plan and the benefits to be derived from its implementation. It is important to note that the setting of population and distribution objectives and the identification of critical habitat are science-based exercises and socio-economic factors were not considered in their development. The socio-economic evaluation only applies to the more detailed recovery measures. The recovery strategy and action plan are considered part of a series of documents that are linked and should be taken into consideration together, along with the COSEWIC status report.

The Minister of Fisheries and Oceans Canada is the competent minister under SARA for the Rainbow and has prepared this recovery strategy and action plan, as per section 37 and 47 of SARA. It has been prepared in cooperation with the Government of Ontario, Environment and Climate Change Canada, Central Michigan University, University of Guelph, Bishop Mills Natural History Centre, St. Clair Region Conservation Authority, Ausable-Bayfield Conservation Authority, Upper Thames River Conservation Authority, Lower Thames River Conservation Authority and Grand River Conservation Authority.

Success in the recovery of this species depends on the commitment and cooperation of many different constituencies that will be involved in implementing the directions set out in this strategy and action plan and will not be achieved by Fisheries and Oceans or Parks Canada Agency, or any other jurisdiction alone. All Canadians are invited to join in supporting and implementing this strategy and action plan for the benefit of the Rainbow and Canadian society as a whole.

Implementation of this strategy and action plan is subject to appropriations, priorities, and budgetary constraints of the participating jurisdictions and organizations.

Acknowledgments

Fisheries and Oceans Canada (DFO) and Parks Canada Agency (PCA) would like to thank the authors, Dr. Daelyn Woolnough (DFO contractor), Pat Dimond (DFO contractor), Amy Boyko (DFO) and Shawn Staton (DFO) as well as the following organizations for their support in the development of the Rainbow recovery strategy and action plan: Ontario Freshwater Mussel Recovery Team, Environment and Climate Change Canada, Ontario Ministry of Natural Resources (OMNR), University of Guelph, Central Michigan University, Ausable-Bayfield Conservation Authority, Grand River Conservation Authority, St. Clair Region Conservation Authority, Upper Thames River Conservation Authority, Lower Thames Valley Conservation Authority and the Bishop Mills Natural History Centre. Mapping was produced by Shady Abbas (DFO contractor).

Executive summary

The Rainbow is a small freshwater mussel with an average length of 55 mm. It has a narrow elliptical shape and interrupted green rays. The beaks are low and compressed and sculpture consists of 4–6 distinct bars. The outside of the shell is yellowish, yellowish-green or brown (in old specimens), with numerous wide, broken dark green rays that cover the whole surface of the shell or are absent anteriorly. This species is considered N2N3 (nationally vulnerable – imperilled) in Canada where it has been assessed as Endangered by the Committee on the Status of Endangered Wildlife in Canada and listed as Endangered under the *Species at Risk Act*. The Canadian distribution is restricted to Ontario. The current distribution of the species includes populations found in the St. Clair River delta and the Saugeen, Maitland, Bayfield, Ausable, Sydenham, Thames (North and Middle), Grand (including Conestogo and Mallet rivers), lower Trent, Salmon and Moira rivers.

The primary threats to Rainbow populations are the presence of exotic species (i.e., Zebra and Quagga mussels), turbidity and sediment loading, contaminants and toxic substances, nutrient loading, altered flow regimes, habitat removal and alterations, as well as any activity that threatens the species' fish host.

The population and distribution objectives for the Rainbow are to return/maintain self-sustaining populations in the following locations where live animals currently exist: St. Clair River delta, East Sydenham River, Ausable River, Maitland River, Saugeen River (including Teeswater River), Bayfield River, Thames River (including North Thames River tributaries and the Middle Thames River), Grand River (including Mallet and Conestogo rivers), Moira River and Salmon River. The populations at these locations could be considered recovered when they have returned to historically estimated ranges and demonstrate active signs of reproduction and recruitment throughout their distribution in each location. In addition, recovered populations would need to be stable or increasing and demonstrably secure with low risk of known threats.

Using the best available information, critical habitat has been identified at this time for the Rainbow in the Saugeen, Maitland, Ausable, Bayfield, Sydenham, Thames, Grand, Moira and Salmon rivers; additional areas of potential critical habitat within the St. Clair River delta region will be considered in collaboration with Walpole Island First Nation. A schedule of studies has been developed that outlines the necessary steps to obtain the information to further refine critical habitat descriptions.

The recovery team has identified a variety of approaches that are necessary to ensure that the population and distribution objectives are met. These approaches have been organized into three categories: (1) Research and Monitoring; (2) Management and Coordination; and, (3) Communication and Outreach. These recovery efforts are best accomplished through cooperation with existing single-species and ecosystem-based recovery programs for fish and mussel species at risk. Most of these actions will prove beneficial to all species at risk and eliminate duplication of effort.

The action plan portion of this document provides the detailed recovery planning in support of the strategic direction set out in the recovery strategy section of the document. The plan outlines what needs to be done to achieve the population and distribution objectives, including the measures to be taken to address the threats and monitor the recovery of the species, as well as the measures to protect critical habitat. Socio-economic impacts of implementing the action plan are also evaluated.

Recovery feasibility summary

Recovery of the Rainbow is believed to be both biologically and technically feasible. The following feasibility criteria[1] have been met for the species:

1. *Individuals of the Rainbow that are capable of reproduction are available now or in the foreseeable future to sustain the population or improve its abundance.*

    Yes. Reproducing populations of the Rainbow exist and are available to improve the population growth rate and abundance. Most likely this would occur using the Maitland River population, as it is the largest and healthiest remaining population in Canada.

2. *Sufficient suitable habitat is available to support these species or could be made available through habitat management or restoration.*

    Yes. Sufficient suitable habitat is available for the Rainbow in multiple locations (e.g., Saugeen, Maitland, Ausable, Bayfield, Sydenham, Thames, Grand, Salmon and Moira rivers). Improved water level management and water quality (e.g., through stewardship and Best Management Practices) could improve and expand the extent of suitable habitat.

3. *The primary threats to the species or its habitats (including threats outside Canada) can be avoided or mitigated.*

    Yes. Significant threats to Rainbow populations, with the exception of dreissenid mussels in the Great Lakes, can be avoided or mitigated through recovery actions.

4. *Recovery techniques exist to achieve the population and distribution objectives or can be expected to be developed within a reasonable timeframe.*

    Yes. Recovery techniques that are necessary to recover Rainbow populations do exist and have been demonstrated to be effective. For example, Best Management Practices and stewardship activities are available to improve habitat quality by reducing primary threats such as nutrient and sediment loading to watercourses.

[1] Draft Policy on the Feasibility of Recovery, *Species at Risk Act* Policy. January 2005.

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1. COSEWIC[2] species assessment information

Date of assessment: April 2006
Common name (population): Rainbow
Scientific name: *Villosa iris*
COSEWIC status: Endangered
Reason for designation: This attractive yellowish green to brown mussel with green rays is widely distributed in southern Ontario but has been lost from Lake Erie and the Detroit and Niagara rivers and much of Lake St. Clair due to Zebra Mussel infestations. It still occurs in small numbers in several watersheds but the area of occupancy and the quality and extent of habitat are declining, with concern that increasing industrial agricultural and intensive livestock activities will impact the largest population in the Maitland River.
Canadian occurrence: Ontario
COSEWIC status history: Designated Endangered in April 2006. Assessment based on a new status report.

2. Species status information

Global status: The Rainbow (*Villosa iris* Lea, 1829) is globally listed as G5 (demonstrably widespread, abundant, and secure). In the U.S., the Rainbow is considered secure, but there are states where this species is listed as Endangered (NatureServe 2012) (Table 1). This species has been declining across the western part of its range in the U.S. (Cummings and Mayer 1992). In Canada, the Rainbow is considered N2N3 (nationally vulnerable – imperilled) and occurs only in Ontario (NatureServe 2012), where it is designated as Endangered (COSEWIC 2006a) (Table 1).

Canadian status: In Canada, the Rainbow has a national ranking of N2N3, and is designated as S2S3 in Ontario (NatureServe 2012). It was designated as Endangered in 2006 by COSEWIC (COSEWIC 2006a). It was listed as Endangered under the federal *Species at Risk Act* (SARA) in 2013 and is listed as Threatened under Ontario's *Endangered Species Act*, 2007.

Percent of global distribution and abundance in Canada: COSEWIC (2006a) estimated the extent of the Rainbow's occurrence in Canada as 53 700 km^2, or between 2–28 % of the global range. The current area of occupancy among nine remaining populations (St. Clair River delta, Saugeen, Maitland, Ausable, Sydenham, Thames, Grand, lower Trent, and Moira rivers) was estimated by COSEWIC (2006a) in Canada as approximately 11 km^2. More recently confirmed populations within the Bayfield and Salmon rivers were not included, however. Population estimates were calculated for the populations in the Maitland (2 019 365 - 6 715 557 individuals), Ausable (36 484–97 208), Sydenham (74 959–389 210) and Thames (670 464–1 340 868) rivers (Bouvier and Morris 2011); however, estimates are not available for remaining populations.

[2] COSEWIC (Committee on the Status of Endangered Wildlife in Canada).

Table 1. Global, national and sub-national ranks for the Rainbow (NatureServe 2012)

Rank	Jurisdiction rank*
Global (G)	G5 (2006)
National (N)	
Canada	N2N3
U.S.	N5
Sub-national (S)	
Canada	Ontario (S2S3)
U.S.	Alabama (S3), Arkansas (S2S3), Illinois (S1), Indiana (S3), Kentucky (S4S5), Michigan (S2S3), Missouri (SNR), New York (S2S3), North Carolina (S1), North Dakota (SNR), Ohio (SNR), Oklahoma (S1), Pennsylvania (S1), Tennessee (S5), Virginia (S4), West Virginia (S2), Wisconsin (S1)

*For an explanation of G, N and S-ranks, see NatureServe (2012)

3. Species information

3.1 Species description

The Rainbow is a small freshwater mussel (average length of 55 mm in length). The following description of the species was adapted from Clarke (1981), Strayer and Jirka (1997) and Parmalee and Bogan (1998). The Rainbow has a narrow elliptical shape and interrupted green rays. The beaks are low and compressed and sculpture consists of 4–6 distinct bars. The outside of the shell is yellowish, yellowish-green or brown (in old specimens), with numerous wide or both narrow and wide broken dark green rays that cover the whole surface of the shell or are absent anteriorly. Rays may become obscure in old specimens. More detailed information can be found in COSEWIC (2006a).

3.2 Population and distribution

Global range: The Rainbow was once widely distributed in eastern North America from New York and Ontario west to Wisconsin and south to Oklahoma, Arkansas, and Alabama. In the U.S., it has been recorded from Alabama, Arkansas, Illinois, Indiana, Kentucky, Michigan, Missouri, New York, Ohio, Oklahoma, Pennsylvania, Tennessee, Virginia, West Virginia, and Wisconsin (NatureServe 2012) (Figure 1). The current distribution of the Rainbow is similar to its historical distribution, but it has been declining in many places, particularly the Great Lakes (NatureServe 2012). In Canada, the Rainbow occurs only in Ontario (Figures 1 and 2) (COSEWIC 2006a).

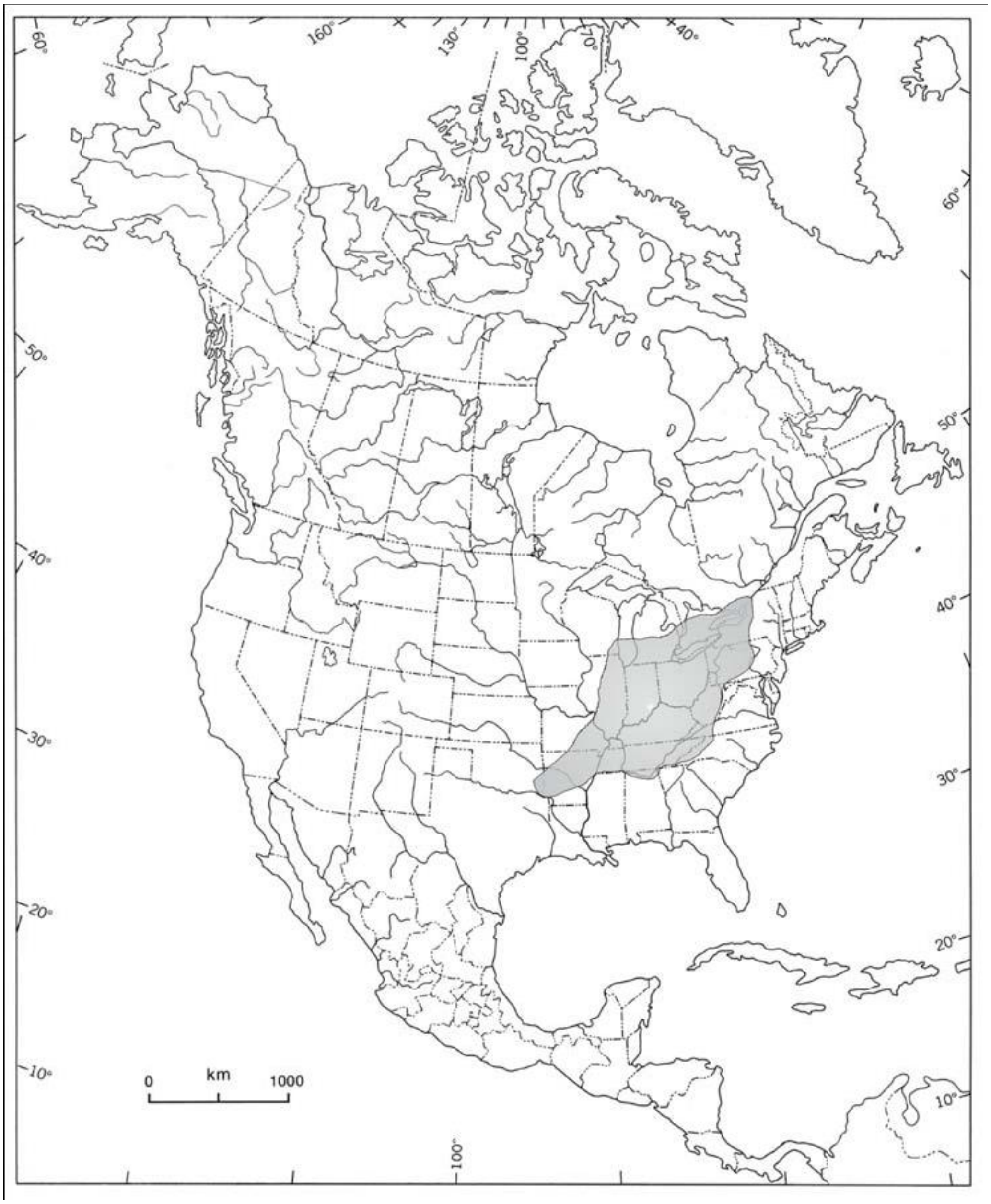

Figure 1. North American distribution (shaded area) of the Rainbow (based on records provided by jurisdictional authorities)

Canadian range: In Canada, the Rainbow is known only from southern Ontario. The current distribution of the species, collected between 1995 and 2012, is shown in Figure 2. Live specimens have been found in the St. Clair River delta and in the Saugeen, Maitland, Bayfield, Ausable, Sydenham, Thames (North and Middle), Grand, lower Trent, Moira and Salmon rivers. Overall, the Rainbow has been lost from approximately 30% of its former range, in terms of extent of occurrence, in Canada.

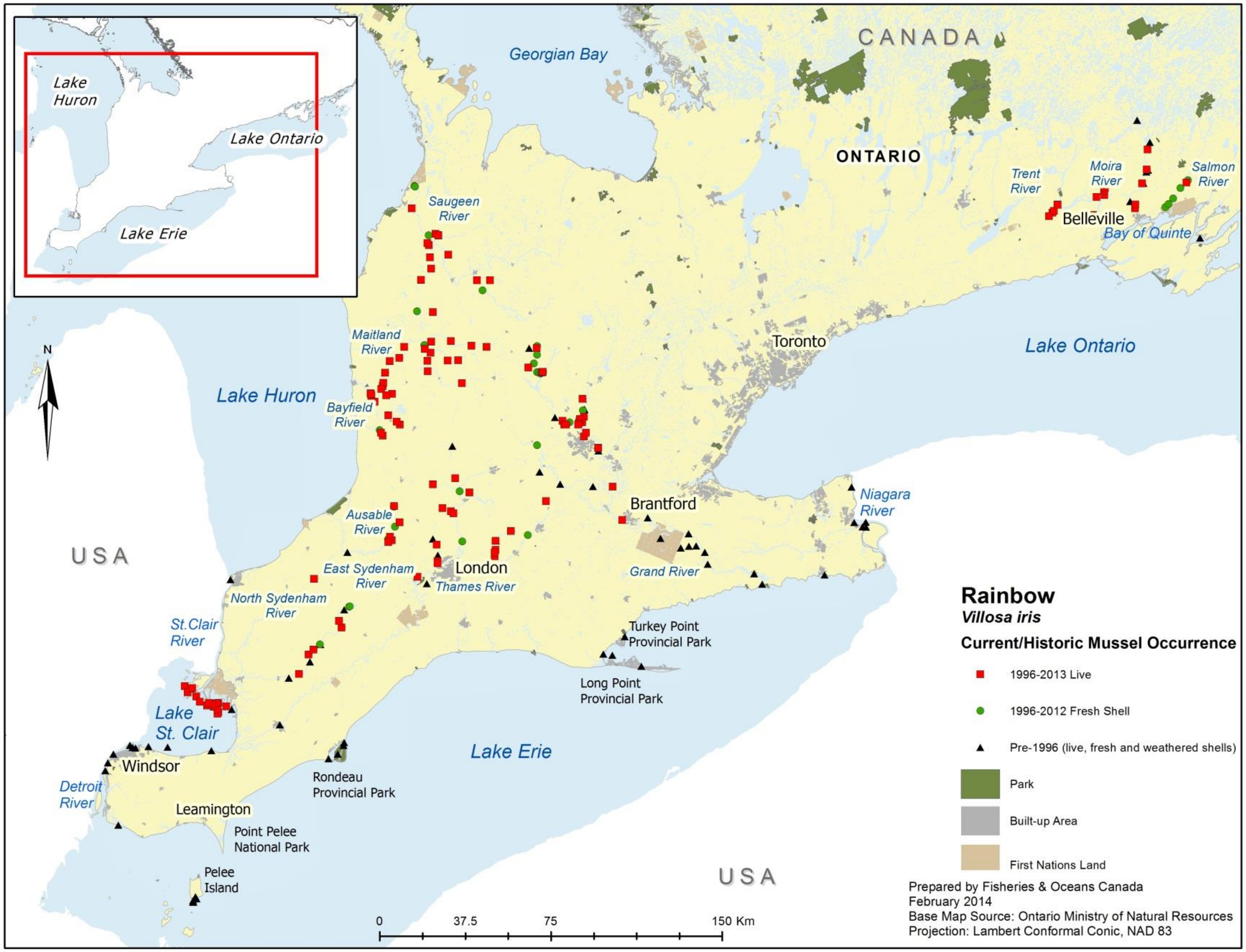

Figure 2. Current distribution (1996–2013) of the Rainbow in Canada

Canadian population size: To date, it appears that there are 11 remaining populations of Rainbow in Ontario. Canadian population estimates were developed by Bouvier and Morris (2011), see Table 2 for detailed information. The following descriptions of the known occurrence of Rainbow in Canada were adapted from Bouvier and Morris (2011).

St. Clair River delta: It is possible that small isolated populations of Rainbow inhabit the St. Clair River delta, as live animals have been observed sporadically in low numbers since 1999 (COSEWIC 2006a). Based on sampling conducted by Metcalfe-Smith et al. (2004), it appears that the species is far more common in the nearshore waters of the U.S. than in Canada.

Saugeen River: The Rainbow was first observed in the Saugeen River in 1993 when a single live specimen was captured. Subsequent sampling in this system has yielded an additional 53 live individuals from ten different sites, including sites in the main branch, the south Saugeen River and the Teeswater River (tributary of the Saugeen River).

Maitland River: The Rainbow was first recorded from the Maitland River in the 1930s and was not recorded again until 1998. More than 700 live individuals from 19 different sites have been collected during extensive sampling of the Maitland River over the past ten years. The Maitland River is believed to support the largest remaining population of the Rainbow in Canada (COSEWIC 2006a).

Ausable River: The Rainbow was first detected in the Ausable River in 1998 when a single individual was found. Records of the species remained sparse until 2002 when timed-search and quadrat sampling yielded 54 live individuals, with 16 individuals detected during a single sampling event.

Bayfield River: A single fresh shell collected in 2005 represents the first record of the Rainbow in the Bayfield River. In 2007, an intensive survey of the Bayfield River was completed and yielded 28 live individuals (Fisheries and Oceans Canada [DFO], unpubl. data). This survey represents the only known sampling targeted towards freshwater mussels in this river.

Sydenham River: The Rainbow was first observed in the Sydenham River in 1963, and over subsequent years the species has been observed infrequently; a total of 22 live specimens have been detected since the first recorded observation. Quantitative surveys conducted at 15 monitoring sites during 1999-2003 by Metcalfe-Smith et al. (2007) resulted in the capture of only five live animals. The Rainbow is believed to be a rare species throughout the Sydenham River.

Thames River: Timed-search surveys were conducted 2004–2005 at 37 sites throughout the upper and lower reaches of the watershed. Live individuals were found only in tributaries of the upper watershed with more than 90 live specimens located (Morris and Edwards 2007). Sites with the highest numbers of Rainbow were located in Otter Creek, Fish Creek and North Branch Creek.

Grand River: The overall abundance of the Rainbow in the Grand River is low, although there are numerous historic records of the species. The first record of the Rainbow in the Grand River is from 1890 (COSEWIC 2006a) and since 1970, there have been a total of 27 live records, with only 11 live records over the past ten years. However, over this same period, numerous fresh shells have been collected from tributaries of the Grand River, such as the Conestogo River and the Mallet River (A. Timmerman, Ontario Ministry of Natural Resources [OMNR], unpubl. data). Historic Rainbow records indicate that the species' distribution extends to the lower reaches of the river; however, a live individual has not been observed in this stretch of the Grand River since 1971 (Kidd 1973).

Great Lakes and connecting channels: Historic Rainbow records exist for the nearshore area of Lake Erie (Long Point Bay, Rondeau Bay), Lake Ontario and Lake St. Clair (south shore), as well as the Niagara and Detroit rivers and a single location in the St. Clair River. The last Rainbow record from any of these waterbodies was from 1992, when three individuals were found in the Detroit River. Surveys have occurred post-dreissenid mussel (Zebra Mussel [*Dreissena polymorpha*) and Quagga Mussel [*Dreissena bugensis*]) invasion at all historic Rainbow locations and no live individuals have been found. As is the case with most other freshwater mussels, it is believed that this species is now extirpated from the Great Lakes and its major connecting channels due to the invasion of dreissenid mussels.

Moira, Salmon and Trent rivers: In eastern Ontario, the Rainbow is known from the Moira, Trent and Salmon rivers, which have not been sampled extensively for freshwater mussels. A total of 32 live individuals have been collected from the Moira River in 1996, while only two live individuals were collected from the Trent River in that year. Surveys conducted in 2013 within the Trent River system resulted in 195 live individuals (from 9 sites total), although most sites were located within small tributaries (Rawdon, Cold, Burnley and Percy creeks); few live animals were found at the two sites located in the main stem of the Trent River at Meyer's Reach and Glen Ross where Zebra Mussel were in high abundance (S. Reid, OMNR, pers. comm.). In the Salmon River, more than 100 weathered and a few fresh shells were found during shoreline surveys between 2005 and 2010 (Schueler 2013), but it was not until 2011 that 4 live individuals were reported from two sites (S. Reid, OMNR, unpublished data). Further quantitative sampling is required throughout eastern Ontario to provide more information on the freshwater mussel community in this area.

Bouvier and Morris (2011) derived population estimates for all current Rainbow populations in Canada (Table 2). The Great Lakes and connecting channels were not included in their estimates as the Rainbow is believed to be extirpated from these areas. Refer to Bouvier and Morris (2011) for details on the methodology.

Table 2. Population estimates for all current Rainbow populations in Canada
NA – information is not available. (Table reproduced from Bouvier and Morris 2011)

Population	**Average total unionid density (#/m^2) (SE)**	**Rainbow density (#/m^2) (SE)**	**Rainbow area of occupancy (m^2)**	**Rainbow estimated population size**
St. Clair River delta	NA	NA	9 612 469	NA
Saugeen River	NA	NA	6 402 870	NA
Maitland River	1.208 (± 0.403)	0.715 (± 0.384)	6 112 182	2 019 365–6 715 557
Bayfield River	NA	NA	462 129	NA
Ausable River	5.687 (± 3.523)	0.119 (± 0.054)	563 467	36 484–97 208
Sydenham River	8.835 (± 5.285)	0.038 (± 0.026)	6 071 670	74 959–389 210
Thames River	5.355 (± 1.755)	0.075 (± 0.025)	13 408 680	670 464–1 340 868
Grand River	NA	NA	10 853 482	NA
Trent River	NA	NA	91 127	NA
Moira River	NA	NA	1 274 219	NA
Salmon River	NA	NA	622 892	NA

Nearly 50% percent of historic Rainbow records occur in areas that are now infested with dreissenid mussels. Due to the dreissenid invasion in the late 1980s, the largest remaining population of the Rainbow in Canada persists in the Maitland River.

Populations of Rainbow were ranked by Bouvier and Morris (2011), with respect to abundance and trajectory. Population abundance and trajectory were then combined to determine the population status (Table 3). A certainty level was also assigned to the population status, which reflected the lowest level of certainty associated with either population abundance or trajectory. Refer to Bouvier and Morris (2011) for further details on the methodology.

Table 3. Abundance index, population trajectory, and population status of the Rainbow
Certainty associated with abundance index or population trajectory is listed as: 1=quantitative analysis; 2=standardized sampling; 3=expert opinion; certainty for population status reflects the lowest level of certainty associated with either abundance index or population trajectory.
(Table modified from Bouvier and Morris 2011)

Population	Abundance index	Certainty	Population trajectory	Certainty	Population status	Certainty
St. Clair River delta	Low	1	Unknown	3	Poor	3
Great Lakes and connecting channels	Extirpated	2	-	-	Extirpated	2
Saugeen River	Low	2	Unknown	3	Poor	3
Maitland River	High	2	Stable	3	Good	3
Bayfield River	Low	2	Unknown	3	Poor	3
Ausable River	Low	2	Unknown	3	Poor	3
Sydenham River	Low	1	Unknown	3	Poor	3
Thames River	Medium	1	Unknown	3	Poor	3
Grand River	Low	2	Stable	3	Poor	3
Trent River	Low	3	Unknown	3	Poor	3
Moira River	Low	3	Unknown	3	Poor	3
Salmon River	Unknown	3	Unknown	3	Unknown	3

3.3 Needs of the Rainbow

Habitat and biological needs

Spawning: The reproductive biology of the Rainbow is similar to that of most unionid mussels (adapted from Clarke 1981, Kat 1984 and Watters 1999). During spawning, males release sperm into the water and females living downstream filter the sperm out of the water with their gills. Once the ova are fertilized, they are held until they reach a larval stage called the glochidium. The Rainbow is bradytictic (long-term brooder) such that it spawns in late summer, broods the glochidia over the winter and subsequently releases the glochidia in early spring (COSEWIC 2006a). Upon release, the glochidia must attach to an appropriate host fish. Females of this species use a visual display to attract their host fish and thus water clarity may be important for successful reproduction. They have a modified mantle flap that mimics a crayfish in shape and movement. When a fish approaches or strikes at the lure, the female mussel expels her glochidia, which facilitates the attachment of the glochidia to the gills of the fish. Further development to the juvenile stage cannot continue without a period of encystment on the host.

Encysted glochidia stage: The glochidia become encysted on the host and develop for 21–69 days (depending on temperature) until they metamorphose into juveniles (Woolnough et al. 2007). Fishes known to be glochidial hosts in laboratory transformations for the Rainbow in the United States are: Mottled Sculpin (*Cottus bairdii*), Greenside Darter (*Etheostoma blennioides*), Rainbow Darter (*Etheostoma caeruleum*), Green Sunfish (*Lepomis cyanellus*), Striped Shiner (*Luxilus chrysocephalus*), Smallmouth Bass (*Micropterus dolomieu*) and Yellow Perch (*Perca flavescens*), many of which commonly occur throughout the mussel's range in Canada (Watters and O'Dee 1997; Scott and Crossman 1998; Watters et al. 2005); the Striped Shiner, Greenside Darter and Green Sunfish do not occur within the more easterly portions of Rainbow's range To date, three hosts for the Rainbow have been identified in Ontario through laboratory studies: Largemouth Bass (*Micropterus salmoides*), Mottled Sculpin (*Cottus bairdi*), and Rock Bass (*Ambloplites rupestris*) (Woolnough et al. 2007). Glochidia will remain encysted until they metamorphose into juveniles.

The most significant natural controls on the size and distribution of mussel populations are the distribution and abundance of their host fishes and predation. Unionids cannot complete their life cycle without access to the appropriate glochidial host. If host fish populations disappear or decline in abundance to levels below that which can sustain a mussel population, recruitment will no longer occur and the mussel species may become functionally extinct (Bogan 1993).

Juvenile: After metamorphosis, juveniles release themselves from the host and fall to the substrate to begin life as free-living mussels. Juveniles of most species of freshwater mussels live completely buried in the substrate, where they feed on similar foods obtained directly from the substrate or from interstitial water (Yeager et al. 1994; Gatenby et al. 1997). Juvenile mussels remain buried until they are sexually mature, at which point they move to the surface for the dispersal/intake of gametes (Watters et al. 2001).

Adult: The Rainbow (like all freshwater mussels) is a sedentary animal that buries itself partially or completely in the substrates of rivers or lakes. It is most abundant in small- to medium-sized rivers (van der Schalie 1938; Strayer 1983; Parmalee and Bogan 1998), but can also be found in inland lakes and once occurred throughout the shallow nearshore areas of the lower Great Lakes and connecting channels in firm sand or gravel substrates (Clarke 1981; Strayer and Jirka 1997; Zanatta et al. 2002). In rivers, the Rainbow is usually found in or near riffles and along the edges of emergent vegetation in moderate to strong current (Metcalfe-Smith et al. 2005; COSEWIC 2006a). The species occupies substrate mixtures of cobble, gravel, sand, and occasionally mud or boulder (COSEWIC 2006a). The Rainbow is most numerous in clean, well-oxygenated reaches at depths of less than 1 m (van der Schalie 1938; Gordon and Layzer 1989; Parmalee and Bogan 1998).

Adult Rainbow have very limited dispersal abilities. Although adult movement can be directed upstream or downstream, studies have found a net downstream movement through time (Balfour and Smock 1995). The primary means for large-scale dispersal, upstream movement, and the invasion of new habitat or evasion of deteriorating habitat, is limited to the encysted glochidial stage on the host fish.

Nutritional requirements of unionid mussels are poorly understood and species-specific studies on Rainbow food requirements are unavailable. Adult freshwater mussels are filter-feeders that obtain nourishment by siphoning particles of organic detritus, algae, and bacteria from the water column and, as recently shown, sediments (Nichols et al. 2005).

Ecological role: Freshwater mussels play an integral role in the functioning of aquatic ecosystems, including water column and sediment processes (Vaughn and Hakenkamp 2001). They are sensitive indicators of the health of freshwater ecosystems, including water and habitat quality and especially the fish community on which they depend for successful reproduction. In North America, there are 18 species in the genus *Villosa* (recognized by Turgeon et al. 1998), but only the Rainbow and Rayed Bean (*V. fabalis)* have ranges that extend into Canada. The Rainbow may be a particularly good indicator of ecosystem health because it is more sensitive to environmental contaminants than most other mussel species tested to date.

Mussels can also be important prey for a few species including the Muskrat (*Ondatra zibethicus*) (Neves and Odom 1989), which results in a transfer of energy from the aquatic to the terrestrial environment.

Limiting factors: The Rainbow may be limited by its complex life cycle and by its dispersal mechanism. The dependency on a host for development may limit the reproduction of the Rainbow because any change that affects the host species can also affect the mussel. The availability and health of the host species may therefore pose a limitation to the species.

Freshwater mussels are among the most sensitive aquatic organisms to environmental contaminants and there is growing evidence that Rainbow may be particularly sensitive (Goudreau et al. 1993; Mummert et al. 2003). Juvenile freshwater mussels remain buried in the sediment for the first few years of life where they feed exclusively on particles in the interstitial water. Such behaviour may increase their exposure to sediment-bound contaminants (Yeager et al. 1994) and this could have implications for the survival of species that are especially sensitive to toxic chemicals.

4. Threats

4.1 Threat assessment

Table 4, adapted from Bouvier and Morris (2011), provides a summary of threats to Rainbow populations in Canada. Known and suspected threats were ranked with respect to threat likelihood and threat impact for each population. The threat likelihood and threat impact were then combined to produce an overall threat status. A certainty level was also assigned to the overall threat status, which reflected the lowest level of certainty associated with either threat likelihood or threat impact. See Bouvier and Morris (2011) for further details. Additional information is provided in the threat descriptions that follow the table.

Table 4. Threat levels for Canadian Rainbow populations
Threat Level (H – High; M – Medium; L – Low; U – Unknown) was produced from an analysis of both the Threat Likelihood and Threat Impact. The number in brackets refers to the level of certainty assigned to each Threat Level, which relates to the level of certainty associated with Threat Impact. Certainty has been classified as: 1= causative studies; 2=correlative studies; and 3=expert opinion. Gray cells indicate that the threat is not applicable to the location due to the nature of the aquatic system. Clear cells do not necessarily represent a lack of a relationship between a location and a threat; rather, they indicate that either the Threat Likelihood or Threat Impact was Unknown. (Table modified from Bouvier and Morris 2011)

Threat	St. Clair River delta	Saugeen River	Maitland River	Ausable River	Bayfield River	Sydenham River	Upper Thames River	Grand River	Trent River	Moira River	Salmon River
Exotic species	H (2)	M (2)	M (2)	M (2)	M (2)	M (2)	H (2)	H (2)	H (2)	H (2)	H (2)
Turbidity and sediment loading	M (3)	H (3)	H (3)	H (3)	H (3)	H (3)	H (3)	H (2)	M (3)	M (3)	M (3)
Contaminants and toxic substances	H (3)	H (3)	H (3)	H (3)	H (3)	H (3)	H (3)	H (2)	H (3)	H (3)	M (3)
Nutrient loading	M (3)	H (3)	H (3)	H (3)	H (3)	H (3)	H (3)	H (2)	M (3)	M (3)	M (3)
Altered flow regimes		M (3)	M (3)	M (3)	H (3)	M (3)	H (3)	M (2)	H (3)	M (3)	M (3)
Habitat removal and alterations	M (3)	H (3)	M (3)	M (3)	M (3)	H (3)	H (3)	H (2)	H (3)	M (3)	M (3)
Fish hosts	H (3)	H (3)	M (3)	M (2)	M (3)	H (3)	H (3)	H (3)	H (3)	M (3)	M (3)
Predation and harvesting	L (3)	L (3)	L (3)	L (3)	L (3)	L (3)	L (3)	L (3)	U (3)	L (3)	L (3)
Recreational activities	L (3)	L (3)	L (3)	L (3)	L (3)	L (3)	L (3)	L (3)	L (3)	L (3)	L (3)

N.B. The Threat Level represents a combination of the **current** Threat Impact and Threat Likelihood at a location. It **does not** reflect the potential impact a threat might have on a freshwater mussel population if it was allowed to occur in the future.

4.2 Description of threats

The following brief descriptions emphasize the principal threats currently acting on Rainbow populations throughout Ontario. Much of the information has been summarized from Bouvier and Morris (2011).

Exotic species: Zebra Mussel (as well as Quagga Mussel) have decimated populations of freshwater mussels in the Lower Great Lakes by virtually eliminating historical habitats in Lake St. Clair (Nalepa et al. 1996) and western Lake Erie (Schloesser and Nalepa 1994). These biofouling organisms continue to threaten the population in the St. Clair River delta. Nearly 50% of sites where Rainbow was known to occur historically are now infested with Zebra Mussel. Although the Rainbow is primarily a riverine species, and therefore at lower risk to Zebra Mussel infestation than some species of mussels, the presence of impoundments may increase the risk. Zebra Mussels have been reported in two reservoirs on the Thames River (UTRCA 2003) and throughout the lower Thames River from Fanshawe Reservoir to the mouth of the river (Morris and Edwards 2007). Should Zebra Mussel be introduced into the Wildwood or Pittock reservoirs in the upper reaches of the watershed, they would pose a major threat to the Rainbow population in the river. Within the Trent River, Zebra Mussels are abundant throughout and at the sites where Rainbow were collected in 2013; they are abundant at many sites within the Moira River and also present in the Salmon River watershed (e.g., Beaver Lake) (S. Reid and S. Hogg, OMNR, pers. comm.). Freshwater mussel populations in the Grand River are highly susceptible to Zebra Mussel, as the Grand River is heavily impounded. Infestation by Zebra Mussel of the Luther, Belwood, Guelph, or Conestogo reservoirs could have a significant impact on the freshwater mussel populations (Bouvier and Morris 2011). Zebra Mussel are unlikely to endanger the most significant population of Rainbows in Ontario (i.e., the population in the Maitland River) because the river is not navigable by boats and has few impoundments that could support a permanent colony.

Other exotic species may indirectly affect the Rainbow by disrupting host fish relationships. For example, Mottled Sculpin has shown recruitment failure and steep declines in abundance in the Great Lakes basin since the introduction of the non-native Round Goby (*Neogobius melanostomus*) (Dubs and Corkum 1996; Janssen and Jude 2001). More recent work by Poos et al. (2010) has documented the upstream invasion by Round Goby into the lower portions of several rivers, including the Sydenham, Ausable, Thames and Grand between 2003 and 2008. In eastern Ontario, Round Goby is abundant and widespread along the Trent River and at sites where Rainbow were collected in 2013 (S. Reid and S. Hogg, OMNR, pers. comm.).

Turbidity and sediment loading: High silt inputs can affect freshwater mussels by clogging gill structures and inhibiting oxygen intake, clogging siphons, and disrupting reproductive functions by decreasing the likelihood of attracting a suitable host fish through their visual display (which requires clear water) (Strayer and Fetterman 1999). Susceptibility to siltation varies from species to species and freshwater mussels have been shown to be only mildly tolerant of high silt conditions during periods of low flow (Dennis 1984).

Increased agricultural use, which can include clearing of riparian vegetation and unrestricted access to the river by livestock, is often associated with increased sediment loads (WQB 1989a). In addition, increased drainage, also related to intensive agricultural practices, often results in large inputs of sediments to the watercourse. Erosion due to poor agricultural practices can result in siltation and shifting substrates that can smother mussels.

The primary land use in the Ausable and Sydenham river basins is agriculture. Row crops (e.g., corn, beans) predominate in the Ausable River watershed; cash crops dominate the Sydenham River watershed (Nelson et al. 2003). The Ausable River watershed has been drastically altered (Bouvier and Morris 2011). It is estimated that by 1983, 85% of the land in this watershed had been converted from forest and wetland to agricultural land, and that 70% of the land is now in tile drainage (Nelson et al. 2003). Over 85% of the Sydenham River watershed is agricultural land, with large areas of the river having little or no riparian vegetation (Dextrase et al. 2003). Suspended solids have been reported as high as 900 mg/L (Dextrase et al. 2003), a level that would negatively impact freshwater mussel populations (Bouvier and Morris 2011).

In the Grand River, increased agricultural pressure (from 68% in 1976 to 75% in 1998) has affected water quality, resulting in increased turbidity and sediment loads (WQB 1989a; COSEWIC 2006b; Bouvier and Morris 2011). Water quality in the Thames River basin has historically suffered from agricultural activities. Tile drainage, wastewater drains, manure storage and spreading, and insufficient soil conservation have all contributed to poor water quality within the Thames basin (COSEWIC 2006a). It is estimated that over 78% of the land in the upper Thames River, where Rainbow is found, is used for agricultural purposes (Taylor et al. 2004). The upper Thames River is considered to be moderately turbid (COSEWIC 2006b), with large areas of the river having little or no riparian vegetation (Taylor et al. 2004). The St. Clair River delta is considered to be less affected by this threat, as it is afforded protections by the Walpole Island First Nation Territory (Bouvier and Morris 2011).

Contaminants and toxic substances: The life history characteristics of freshwater mussels make them particularly sensitive to increased levels of sediment contamination and water pollution. Adult mussels are primarily filter feeders, while juveniles remain buried in the sediment feeding on particles associated with the sediment. The glochidial stage appears to be particularly sensitive to heavy metals (Keller and Zam 1990), ammonia (Goudreau et al. 1993; Mummert et al. 2003; Augspurger et al. 2003), acidity (Huebner and Pynnonen 1992) and salinity (Gillis 2011). Glochidia are also sensitive to copper (Jacobson et al. 1997).

Juvenile stages of freshwater mussels are sensitive to ammonia and it has recently been reported they are among the most sensitive aquatic organisms to unionized ammonia toxicity, typically showing adverse responses at levels well below those used as guidelines for aquatic safety in U.S. waterways (Newton 2003; Newton et al. 2003; Newton and Bartsch 2007).

The sensitivity of glochidia to chloride levels is of particular concern to at-risk mussels in southern Ontario. Gillis (2011) has shown that glochidia of the Wavyrayed Lampmussel (*Lampsilis fasciola*) were acutely sensitive to sodium chloride. Assuming that the salt sensitivity of the Rainbow is similar to that of the Wavyrayed Lampmussel, chloride from road salt is a substantial threat to the early life stages; the range of both species overlap and is limited to southern Ontario which is Canada's most road-dense and heavily salted region. Although natural water does buffer the toxic effects of chloride to the glochidia, chloride levels in mussel habitats of southern Ontario have been reported at levels (>1300 mg/L) that are toxic to the Wavyrayed Lampmussel (Gillis 2011). Although federal water quality guidelines for the protection of aquatic life have been set at 120 mg/L for chronic exposure to chloride, this guideline may not be sufficiently protective of glochidia of some species at risk mussels in southern Ontario (CCME 2011). Further work by Todd and Kaltenecker (2012) suggests that long-term road salt use is contributing to increases in baseline chloride concentrations in at-risk mussel habitats in southern Ontario that may affect recruitment of at-risk mussel populations; Rainbow are found in many of these habitats.

Copper levels exceed federal guidelines in several sub-basins of the Thames River in which the Rainbow is still found (Metcalfe-Smith et al. 2000), and mean ammonia concentrations exceed federal guidelines in all sub-basins (Morris et al. 2008). Within the Grand River watershed, only the upper reaches of the river have copper levels that are within federal guidelines. Copper levels exceed federal guidelines in the Middle Maitland River (D. Kenny, MVCA, pers. comm. July 2003).

Mackie (1996) reported that anthropogenic stressors (e.g., sewage pollution), occurring below urban centres, were responsible for much of the harm to the freshwater mussel assemblage in the Grand River. The Grand River watershed has a population of approximately 780 000 people and is expected to increase by nearly 40% over the next 20 years (GRCA 1998; COSEWIC 2006a). Wastewater discharge is a major input in these urban areas and will only increase with increasing population. A recent study that assessed the cumulative impacts of urban runoff and municipal wastewater effluent on freshwater mussels in the Grand River concluded that chronic exposure to multiple contaminants (e.g., ammonia, chloride and metals such as Cu, Pb, and Zn) contributed to the decline of mussel populations in this watershed (Gillis 2012); the author also confirmed this negative impact through a follow up (unpublished) study which revealed the existence of a ‘dead zone’ immediately downstream of one wastewater treatment outfall near Kitchener where no live mussels were detected for several kilometers (P. Gillis, Environment and Climate Change Canada, pers. comm). There is also increasing concern of possible endocrine and reproductive effects resulting from municipal wastewaters. Tetreault et al. (2011) documented feminization of fishes in the Grand River. Although such impacts have not been documented for mussels within rivers of southern Ontario, in Quebec, Gagné et al. (2011) determined that Eastern Elliptios (*Elliptio complanata*) showed a dramatic increase in the proportion of females, and that males showed a female-specific protein downstream of a municipal effluent outfall, indicating that pollution is disrupting gonad physiology and reproduction of this species.

Nutrient loading: The primary concern of nutrient loadings for freshwater mussels relates to eutrophication effects, namely algal blooms that can result in oxygen depletion and algal toxins. A negative correlation was found between concentrations of phosphorus and nitrogen and Wavyrayed Lampmussel (*Lampsilis fasciola*) abundance in a variety of southwestern Ontario streams (Morris et al. 2008).

Phosphorus and nitrogen loadings reported for the Thames River watershed are some of the highest loadings for the entire Great Lakes basin (WQB 1989b). Phosphorus levels in the Sydenham River often exceed the provincial water quality objective (Dextrase et al. 2003), with concentrations of total phosphorus associated with agricultural runoff increasing in the east branch, affecting populations of Rainbow and Mapleleaf (*Quadrula quadrula*) (COSEWIC 2006b). The recently discovered Maitland River population of the Rainbow faces threats from agricultural runoff with 75% of nitrate samples on the Middle Maitland exceeding the federal guidelines for negatively impacting aquatic health, while 56% of total phosphorus levels exceed those indicating a high likelihood of algal blooms (D. Kenny, MVCA, pers. comm. July 2003).

Water quality in the Ausable River is generally considered poor resulting from agricultural runoff and manure seepage (Nelson et al. 2003). Total phosphorus levels in the Ausable River are often above the provincial water quality objective and nitrate levels also exceed guidelines (COSEWIC 2006b).

Altered flow regimes: Damming of the stream channel has been shown to detrimentally affect mussels in many ways. Reservoirs alter downstream flow patterns and disrupt the natural thermal profiles of the watercourse while impoundments act as physical barriers, potentially separating mussels from their host fish(es). Evidence has linked mussel extinction to construction and operation of dams in multiple rivers (Theler 1987; Layzer et al. 1993). Impoundments also act to increase water retention times, thereby making river systems more susceptible to invasion of exotic species, such as dreissenid mussels, and to changes in species composition, based on habitat changes. High flow conditions may result in dislodgement of adults and disruption of larval forms, while low flow can lead to low dissolved oxygen, silt accumulation, elevated temperatures and, at the extreme, desiccation. Freshwater mussels are particularly vulnerable to reductions in water depth as they are frequently found in very shallow water (10–20 cm) (Metcalfe-Smith et al. 2007). A significant negative correlation between mean annual stream flow and growth of a variety of freshwater mussel species has been demonstrated (Rypel et al. 2008), indicating the profound role impoundments and artificial flow manipulation may have on freshwater mussel assemblages.

There are a total of 173 water control structures (e.g., dams and weirs) in the upper watershed of the Thames River (COSEWIC 2006b). Although there are 21 known dams in the Ausable River watershed (COSEWIC 2006a), none are located within the known distribution of the Rainbow; the two most significant dams (which create small reservoirs) are located in the headwaters region of the Ausable River near Exeter. Other systems that are known to have a high level of flow alteration include the Trent River (with navigational locks present) and the Bayfield River which is a particularly ‘flashy’ system with highly variable flows.

Habitat removal and alterations: Destruction of habitat through dredging, ditching, and other forms of channelization may compromise this species. River channel modifications, such as dredging, can result in the direct destruction of mussel habitat and lead to siltation and sand accumulation of local and downstream mussel beds. The construction of impoundments can lead to the fragmentation of habitat, altered water levels, habitat conversion, and the clearing of riparian zones, resulting in the loss of cover, increased rates of siltation and thermal shifts. These are all factors that can be deleterious to Rainbow survival in areas under development.

Fish hosts: Any factors that directly or indirectly affect host fish distributions may impact Rainbow distributions. For example, the introduction of an exotic species that may cause a decline in the Rainbow host fish(es) will indirectly affect Rainbow populations. Also, decreased water quality may create an unsuitable habitat for the host fish(es), or may affect the likelihood of the fish host locating the mussel, a result of reduced visibility (Bouvier and Morris 2011). Unionids cannot complete their life cycle without access to the appropriate glochidial host. If host fish populations disappear or decline in abundance to levels below that which can sustain a mussel population, recruitment will no longer occur and the mussel species may become functionally extinct (Bogan 1993). Therefore, knowledge of the distribution and status of host fish(es) is required to determine if access to glochidial hosts is a threat for populations of this mussel species in Ontario.

Predation and harvesting: Predation by terrestrial predators such as muskrat (*Ondatra zibethicus*) and raccoon (*Procyon lotor*) has been shown to be an important limiting factor for some populations (Neves and Odom 1989). Raccoons have been reported to prey on mussels in Ontario waters; however, they do not appear to target Rainbow (COSEWIC 2006a). Muskrats are both size- and species-selective in their foraging, and can therefore significantly affect both the size structure and species composition of mussel communities (Hanson et al.

1989; Tyrrell and Hornbach 1998). There have been several studies of muskrat predation on freshwater mussels (Neves and Odum 1989; Watters 1993–1994; Tyrrell and Hornbach 1998). None of these studies reported the presence of Rainbow shells in muskrat middens, suggesting that this mussel is not a preferred prey species. Human-related activities, such as the adoption of conservation tillage practices, have resulted in surges in predator populations, which may increase the importance of predation related threats in the future (COSEWIC 2006a). This anecdotal observation needs verification to quantify the effects of human-related activities on predator populations.

Harvesting mussels for human consumption could be a potential concern; however, to date, there are no reports of the harvest of Rainbow for human consumption (Bouvier and Morris 2011). Poaching of unionid mussels is suspected but unknown in its intensity or occurrence.

Recreational activities: Recreational activities that may impact mussel beds include (Bouvier and Morris 2011):

- Driving all-terrain vehicles (ATVs) through river beds – this has been identified as a threat in the Thames and Sydenham rivers. ATVs have also been observed driving through the mussel bed where live Rainbow were present in the Salmon River (S. Hogg, OMNR, pers. comm.).
- Propellers on recreational boats and jet skis – propeller channels have been noted through the mussel beds in the St. Clair River delta.
- Paddling action disturbance (kayaks, etc.) of the mussel bed.

Reaches of the Grand River where Rainbow occurs are popular areas for canoeists. Metcalfe-Smith et al. (2000) observed that paddlers in shallow water often disturbed the riverbed creating the potential for dislodging mussels and promoting downstream transport. Increasing popularity of recreational activities such as canoeing may further increase stresses on unstable populations. Mehlhop and Vaughn (1994) found that “recreational activities” were contributing to the decline of many species of native freshwater mussels.

5. Population and distribution objectives

The long-term recovery goal (>20 years) is to promote the down-listing or de-listing of the Rainbow in Canada by:

1. protecting existing populations to prevent further declines, and
2. restoring degraded populations to healthy self-sustaining levels by improving the extent and quality of habitat (where feasible).

The population and distribution objectives for the Rainbow are to return/maintain self-sustaining populations in the following locations where live animals currently exist:

1. St. Clair River delta
2. East Sydenham River
3. Ausable River
4. Maitland River
5. Saugeen River (including Teeswater River)
6. Bayfield River

7. Thames River (including North Thames River tributaries and the Middle Thames River)
8. Grand River (including Mallet and Conestoga rivers)
9. Moira River
10. Salmon River

The populations at these locations could be considered recovered when they have returned to historically known ranges and demonstrate active signs of reproduction and recruitment throughout their distribution in each location. In addition, recovered populations would need to be stable or increasing and demonstrably secure with low risk from known threats.

The Great Lakes and connecting channels are specifically excluded from the recovery objectives as these areas have been devastated by dreissenid mussels and no longer provide suitable habitat for freshwater mussels (DFO 2011b). More quantifiable objectives will be developed once necessary surveys and studies have been completed (refer to Section 7.5 Schedule of studies to identify critical habitat).

Rationale: Very little is known about the Rainbow and additional information is required before the population and distribution objectives can be further refined. Population demographics (extent, abundance, trajectories, and targets) are currently known for some populations but not others. Note that the Trent River locations (including several small tributaries) of the Rainbow have not been included within the population and distribution objectives as this population is highly fractured with the dreissenid infestation of the Trent River (main stem).

6. Broad strategies and recovery actions

Recommended scale for recovery: Currently, a single-species recovery strategy (and action plan) is best suited for the Rainbow. Although its range and distribution overlaps partially with other mussel species at risk in some watersheds, it also occurs in several watersheds where other species at risk mussels do not occur (e.g., Maitland, Saugeen, Salmon and Moira rivers). The Rainbow is within the range of several multi-species or ecosystem-based recovery strategies or action plans that have been drafted or completed (See Section 6.1 Actions already completed or underway); it is expected that the Rainbow will receive benefit from the implementation of these initiatives.

6.1 Actions already completed or currently underway

Several multi-species and ecosystem-based recovery strategies that are currently being implemented that may benefit the Rainbow, include:

- *Sydenham River Action Plan [proposed]:* This action plan is a multi-species, ecosystem-based plan that addresses the needs of seven freshwater mussels as well as two species of fishes – the Eastern Sand Darter ((*Ammocrypta pellucida*) and Northern Madtom (*Noturus stigmosus*) (DFO 2013). The plan builds on the recovery program established ten years earlier by the Sydenham River Recovery Team (Dextrase et al. 2003); it targets stewardship actions for maximum effectiveness in threat mitigation at the landscape level to recover multiple aquatic species at risk that share similar threats and habitat.
- *Thames River ecosystem recovery strategy:* The goal of the strategy is to develop "a recovery plan that improves the status of all aquatic species at risk in the Thames River through an ecosystem approach that sustains and enhances all native aquatic communities" (TRRT 2005). This recovery strategy addresses 25 COSEWIC-designated species, including seven mussels, 12 fishes, and six reptiles.
- *Ausable River ecosystem recovery strategy:* The Ausable River Recovery Team (ARRT) is developing an ecosystem recovery strategy for the 14 COSEWIC-designated aquatic species in the Ausable River basin. The overall goal of the strategy is to "sustain a healthy native aquatic community in the Ausable River through an ecosystem approach that focuses on species at risk" (ARRT 2005). The ARRT (2005) has also established species-specific recovery goals for mussels to maintain existing populations and restore self-sustaining populations to areas of the river where they formerly occurred.
- *Grand River fish species at risk recovery strategy:* The goal of this strategy is to "conserve and enhance the native fish community using sound science, community involvement and habitat improvement measures" (Portt et al. 2003). Although the draft recovery strategy specifically addresses fish species at risk in the Grand River, it is anticipated that many of the recovery actions will also benefit other rare species (Portt et al. 2003).
- *Walpole Island ecosystem recovery strategy:* The Walpole Island Ecosystem Recovery Strategy Team was established in 2001 to develop an ecosystem-based recovery strategy for the area containing the St. Clair River delta, with the goal of outlining steps to maintain or rehabilitate the ecosystem and species at risk (Walpole Island Heritage Centre 2002). Although the strategy is initially focusing on terrestrial ecosystems (Bowles 2004) there are future plans to include aquatic components of the ecosystem.

Other activities

- *Host fish identification:* Host fish identification experiments led by Dr. J.D. Ackerman and Dr. G.L. Mackie have begun at the University of Guelph, where three (*) of six fish species (Largemouth Bass*, Mottled Sculpin*, Rock Bass*, Yellow Perch [*Perca flavescens*], Greenside Darter [*Etheostoma blennioides*], and Rainbow Darter [*Etheostoma caeruleum*]) (Woolnough et al. 2007) examined produced Rainbow juveniles.
- *Source protection planning:* A White Paper on watershed-based Source Protection Planning was released in February 2004 (OMOE 2004). Source Protection Planning will identify potential sources of contamination to the surface water and groundwater, determine how much water is readily available, evaluate where that water is vulnerable

to contamination, and implement programs to minimize risk of contamination to water quality as well as minimizing threats to water quantity.

6.2 Recovery and action planning

Three broad strategies were identified to address threats to the species and meet the population and distribution objectives: 1) research and monitoring; 2) management and coordination; and, 3) communication and outreach. Approaches are identified for each of the broad strategies. These approaches or activities are further divided into numbered recovery measures with priority ranking (high, medium, low), identification of the threat(s) addressed and associated timeline (Tables 5 and 6). Table 5 provides the implementation schedule for recovery measures led by DFO; Table 6, includes collaborative recovery measures undertaken jointly by DFO and its partners. More detailed narrative for recovery measures is included after the tables (Section 6.3). It should be noted that many of the activities identified in tables 5 and 6 meet the requirements of SARA, subsection 49(1)(d) - i.e., research and management activities needed to meet the population and distribution objectives.

Implementation of these measures will be accomplished in coordination with relevant ecosystem-based recovery teams and other organizations. Of the broad strategies, higher priority will generally be given to the research and monitoring measures, as the data produced will be used to inform the other two strategies (i.e., management and coordination, and communication and outreach).

Table 5. Implementation schedule: measures for the recovery of the Rainbow, to be led by Fisheries and Oceans Canada

#	Recovery Measures	Priority*	Threats or Concerns Addressed	Timeline
Broad Strategy: Research and Monitoring				
	Approach: Research and Monitoring - Inventory			
1(a)	Conduct further surveys to determine the extent and abundance of Rainbow in Canada.	High	All	2016-2017
1(b)	Conduct intensive surveys to quantify distribution and abundance of any newly discovered populations.	High	All	2016–2018
	Approach: Research - Habitat Requirements			
2	Determine habitat requirements of all life stages of the Rainbow.	High	All	2017–2019
	Approach: Monitoring - Host Fish Populations			
3(a)	Identify/confirm functional host fish species for Rainbow.	High	Fish hosts	2016–2018
3(b)	Determine distribution and abundance of the identified host species.	High	Fish hosts	2018–2019

(cont'd)

Table 5 (cont'd). Implementation schedule: measures for the recovery of the Rainbow, to be led by Fisheries and Oceans Canada

#	Recovery Measures	Priority*	Threats or Concerns Addressed	Timeline
	Approach: Monitoring - Populations and Habitat			
4(a)	Establish routine quantitative surveys to monitor changes in the distribution and abundance of extant Rainbow populations and exotic species in the area.	High	Exotic species	2017–2019
4(b)	Establish stations to monitor changes to Rainbow habitat. This monitoring will compliment and be integrated into the routine population surveys.	High	All habitat threats	2017–2019
	Approach: Research - Threat Evaluation			
5	Determine glochidia, juvenile, and adult sensitivity to environmental contaminants that populations of the Rainbow may be exposed to.	High	Contaminants and toxic substances	2018–2019
6	Evaluate threats to habitat for all extant locations to guide local stewardship programs to improve conditions within critical habitat and other occupied habitats.	High	All	2016–2018

(cont'd)

Table 5 (cont'd). Implementation schedule: measures for the recovery of the Rainbow, to be led by Fisheries and Oceans Canada

#	Recovery Measures	Priority*	Threats or concerns Addressed	Timeline
Broad Strategy: Management and Coordination				
	Approach: Coordination of activities			
7(a)	Promote and enhance expertise in freshwater mussel identification, biology, ecology and conservation.	Medium	All	On-going
7(b)	Work with recovery teams and relevant groups (e.g., conservation authorities and stewardship groups) to aid in implementation of all recovery actions.	High	All	On-going
Broad Strategy: Communication and Outreach				
	Approach: Communication and Outreach			
10(a)	Hold annual mussel identification workshop that incorporates identification, biology, ecology, threats and conservation of freshwater mussel species in Ontario.	High	All	ongoing
10(b)	Encourage public support and participation in mussel recovery by developing awareness materials and programs. Will encourage participation in local stewardship programs to improve and protect habitat for the Rainbow.	Medium	All	2016–2019

* "Priority" reflects the degree to which the action contributes directly to the recovery of the species or is an essential precursor to an action that contributes to the recovery of the species.

Table 6. Collaborative recovery measures for the Rainbow, to be undertaken jointly by Fisheries and Oceans Canada, its partners, volunteer agencies, organizations, and individuals

#	Recovery Measures	Priority*	Threats or concerns addressed	Timeline (short, medium or long term)	Potential Partnerships
Broad Strategy: Management and Coordination					
	Approach: Coordination of activities				
8	Work with existing ecosystem recovery teams and relevant groups to implement stewardship programs to improve habitat conditions and reduce threats within areas of critical habitat. Priorities and mitigation approaches to be informed through threat evaluation research.	High	All	Medium – Long term	Ecosystem Recovery Teams, Conservation Authorities
9(a)	Develop an implementation plan to respond to the direct threat of Zebra Mussels on the Rainbow in the St. Clair River delta.	Medium	All	Medium	Walpole Island First Nation
9(b)	Work with municipal planning authorities so that they consider the protection of critical habitat within official plans.	Medium	All	Medium – Long term	Municipal Planning Departments
9(c)	Support the development and implementation of legislation and policies at all levels of government that will aid in the protection of existing populations and enhance recovery of those populations.	Medium	All	Long term	All levels of government

(cont'd)

Table 6 (cont'd). Collaborative recovery measures for the Rainbow, to be undertaken jointly by Fisheries and Oceans Canada, its partners, volunteer agencies, organizations, and individuals

#	Recovery Measures	Priority*	Threats or concerns addressed	Timeline (short, medium or long term)	Potential Partnerships
Broad Strategy: Communication and Outreach					
	Approach: Communication and Outreach				
11(a)	Development of an overall communications plan to increase awareness and support for the protection and recovery of the Rainbow. This communications plan will provide direction and coordination for all communications and outreach activities related to the species.	Medium	All	Medium	Conservation Authorities
11(b)	Increase awareness within the angling community about the role of hosts for the Rainbow.	Medium	Exotic species, fish hosts	Medium	Conservation Authorities, Angling groups
11(c)	Increase public awareness of the potential impacts of transporting/releasing exotic species (including baitfish).	High	Exotic species, fish hosts	Medium	OMNR, Ontario Federation of Anglers and Hunters

* "Priority" reflects the degree to which the action contributes directly to the recovery of the species or is an essential precursor to an action that contributes to the recovery of the species.

6.3 Narrative to support the recovery planning and implementation tables

1(a-b): Further surveys are required to confirm the current distribution and abundance of the Rainbow in Canada. Sampling methods to determine density and demographic information need to be quantitative (i.e., include the excavation of defined quadrats) and could be informed by the work of Metcalfe-Smith et al. (2007). An improved understanding of all extant populations is necessary for the refinement of critical habitat as well as to inform effective recovery actions.

2: The identification of critical habitat is a legal requirement under SARA and its identification is one of the best tools for conserving Rainbow populations. The information collected through this research will help to refine the identification of critical habitat.

3(a-b): To determine if the Rainbow is host limited, it is necessary to confirm the host fish(es) and then determine their distributions. The identification of host specificity in some mussel species, requires that hosts be identified for local populations wherever possible. Once the functional Canadian host(s) have been confirmed, it is necessary to determine the distribution, abundance and health of the host species.

4(a-b): A network of detailed monitoring stations should be established throughout the current range of the Rainbow similar to that developed for freshwater mussels within the Sydenham River (Metcalfe-Smith et al. 2007). This network would build on existing monitoring stations already established for several watersheds (e.g., Sydenham, Ausable, Thames and Grand rivers). The results of the monitoring program will allow for assessment of the progress made towards achieving the recovery objectives/goals. Monitoring sites should be established in a manner so as to permit:

- quantitative tracking of changes in mussel abundance and demographics (size, age, sex), or that of their hosts;
- detailed analysis of habitat use and the ability to track changes in the use or availability; and
- the ability to detect exotic species - monitoring stations should be set up in areas where there is a likely source location for establishment Zebra Mussel (e.g., reservoirs) to permit early detection of the exotic species.

5: Some initial research has been completed on selected contaminants for early life stages of freshwater mussels – including chloride, ammonia and copper. However, further work is required that is specific to the Rainbow.

6: Although some preliminary work has been done on evaluating threats for all populations of Rainbow (refer to Section 4), little is known regarding threats to populations where only recent work on mussels has taken place (e.g., Saugeen, Maitland and Bayfield rivers). More comprehensive threat evaluations for all extant populations will help inform stewardship programs to ensure the most efficient and effective use of limited resources while promoting an ‘ecosystem approach’ wherever possible.

7(a): Expertise in freshwater mussel identification, distribution, life history, and genetics is limited to a small number of biologists in Ontario. This capacity could be increased by training personnel and encouraging graduate and post-graduate research aimed at the conservation of freshwater mussels that would aid in filling knowledge gaps.

7(b): Implementation of many recovery actions would be accomplished through partnership with many groups actively involved in stewardship or research and monitoring within watersheds where Rainbow populations are present. In particular, these groups would include Conservation Authorities (e.g., Saugeen, Maitland Valley, Ausable Bayfield, St. Clair Region, Grand River, Upper Thames River, Lower Trent and Quinte Region), as well as existing ecosystem-based recovery initiatives including those for the Sydenham, Ausable, Thames and Grand rivers.

8: Many of the threats affecting Rainbow populations are similar to those that affect other fish and mussel species at risk. Therefore, efforts to remediate these threats (where spatial overlap exists) should be done in close cooperation with other recovery teams and relevant groups to eliminate duplication of efforts (refer to Section 6.1 for relevant ecosystem-based recovery initiatives; refer to 7(b) above). For rivers not currently covered by existing watershed recovery programs (e.g., Maitland, Bayfield and Saugeen rivers), threat evaluations will inform local stewardship programs for mitigation priority. As with other mussels, measures to improve habitat for the Rainbow may include stewardship actions involving BMPs for agricultural properties (Agriculture Canada and OMAFRA 1992-2011) and residential properties (School of Environmental Design and Rural Development 2007) within catchment areas impacting the critical habitat identified.

9(a): If exotic species (Zebra Mussel/ fish species/ invertebrates) are detected via routine monitoring practices, a coordinated plan should ensure a quick response. Dreissenid mussels in Lake St. Clair cannot be eliminated; however, their presence in the delta can be monitored to determine if their numbers are increasing or decreasing. At present, dreissenid mussels threaten multiple populations of at-risk mussels within the St. Clair River delta and is an area of great concern.

10(a-b): Increasing freshwater mussel knowledge and identification can be assisted though the development of awareness material, such as the *Photo Field Guide to the Freshwater Mussels of Ontario* (Metcalfe-Smith et al. 2005) and the recently completed identification "app" - *Canadian Freshwater Mussel Guide* now available for free download from iTunes. In addition, an annual hands-on mussel identification workshop is offered by DFO to government, agency, non-government organizations, Aboriginal peoples and the public. Increased public knowledge and understanding of the importance of the Rainbow, and mussels in general, will play a key role in the recovery of freshwater mussels.

11(a-c): A communications plan to increase awareness and support for the protection and recovery of the Rainbow will provide overall direction for all outreach. Such activities should include increasing awareness of the potential impacts of transporting/releasing exotic species (including baitfish) into new waters.

7. Critical habitat

7.1 General identification of critical habitat for the Rainbow

The identification of critical habitat for Threatened and Endangered species (on Schedule 1) is a requirement of the SARA. Once identified, SARA includes provisions to prevent the destruction of critical habitat. Critical habitat is defined under section 2(1) of SARA as:

> "…*the habitat necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in the recovery strategy or in an action plan for the species*". [s. 2(1)]

SARA defines habitat for aquatic species at risk as:

> *"… spawning grounds and nursery, rearing, food supply, migration and any other areas on which aquatic species depend directly or indirectly in order to carry out their life processes, or areas where aquatic species formerly occurred and have the potential to be reintroduced."* [s. 2(1)]

Critical habitat for the Rainbow has been identified to the extent possible, using the best information currently available. The critical habitat identified in this recovery strategy describes the geospatial areas that contain the habitat necessary for the survival or recovery of the species. The current areas identified may be insufficient to achieve the population and distribution objectives for the species. As such, a schedule of studies has been included to further refine the description of critical habitat (in terms of its biophysical functions/features/attributes as well as its spatial extent) to support its protection.

7.2 Information and methods used to identify critical habitat

Using the best available information, critical habitat has been identified using a 'bounding box' approach for extant riverine populations of Rainbow in the Saugeen, Maitland, Ausable, Bayfield, Sydenham, Thames, Grand, Moira and Salmon rivers; additional areas of potential critical habitat within the St. Clair River delta region will be considered in collaboration with Walpole Island First Nation.

This approach requires the use of essential functions, features and attributes for each life stage of this species to identify patches of critical habitat within the 'bounding box', which is defined by occupancy data for the species. Life stage habitat information was summarized in chart form using available data and studies referred to in Sections 3.3 (Needs of the Rainbow). The 'bounding box' approach was the most appropriate, given the limited information available for this species and the lack of detailed habitat mapping for these areas. This approach and the methods used to identify reaches of critical habitat are consistent with the approaches recommended by DFO (2011a) for freshwater mussels.

Within the rivers currently occupied by the Rainbow, an ecological classification system was used in the identification of critical habitat. The OMNR's Aquatic Landscape Inventory System (ALIS version 1) (Stanfield and Kuyvenhoven 2005) was used as the base unit for defining reaches within riverine systems. The ALIS system employs a valley classification approach to define river segments with similar habitat and continuity on the basis of hydrography, surficial geology, slope, position, upstream drainage area, climate, landcover and the presence of instream barriers, all of which are believed to have a controlling effect on the biotic and physical processes within the catchment. Therefore, if the species has been found in one part of the ecological classification, it would be reasonable to expect that it would be present in other spatially contiguous areas of the same valley segment. Within all identified river segments (i.e., valley segments), the width of the habitat zone is defined as the area from the mid-channel point to bankfull width on both the left and right banks. Critical habitat for the Rainbow was therefore identified as the reach of river that includes all contiguous ALIS segments from the uppermost stream segment with the species present to the lowermost stream segment with the species present; segments or reaches were excluded only when supported by robust data indicating species' absence and/or unsuitable habitat conditions. Current occupancy for this species was defined by recent records of live individuals (and/or fresh shells) from 1996 onward; this is the point in time when systematic surveys of freshwater mussel communities in southern Ontario began. Unoccupied ALIS segments with suitable habitats were also included when limited sampling had occurred (i.e., the species was assumed to be present).

While individual ALIS segments generally represent relatively homogenous habitat conditions, an exception was noted relative to the Rainbow in the Sydenham River. In this case, the very long ALIS segment was broken at the point where the gradient flattens out by using river gradient profiles to exclude the lower stretches of the river below Dresden; as with other mussels (e.g., Kidneyshell (*Ptychobranchus fasciolaris*)), below this point, the Rainbow's preferred flow conditions would not be present due to insufficient stream gradient.

7.3 Identification of critical habitat: biophysical function, features and their attributes

Table 7 summarizes the limited available knowledge of the functions, features and attributes for each life stage of the Rainbow (refer to section 3.3 Habitat and biological needs for full references). Areas within which critical habitat is found must be capable of supporting one or more of these habitat functions. *Note that not all attributes in Table 7 must be present for a feature to be identified as critical habitat.* If the features, as described in Table 7, are present and capable of supporting the associated functions, the feature is considered critical habitat for the species, even though some of the associated attributes might be outside of the range indicated in the table. All attributes may be used to help inform management decisions for the recovery and/or protection of habitat.

Table 7. Essential functions, features and attributes of critical habitat for each life stage of the Rainbow (riverine populations)

Life stage	Function	Feature(s)	Attribute(s)*

Spawning and fertilization
(time period unknown)
 	
Glochidia present in females
(long-term brooder)
	Reproduction	Reaches of rivers and streams with riffles present and sand, gravel and cobble substrates (sometimes found within seams when bedrock is present); includes 'bankfull' channel	• Attributes assumed to be same as for adults (see below)
			• Flow present (distribution of sperm)
			• Contaminants levels below the following thresholds:
			  • long-term chloride levels < 120 mg/L (CCME 2011), and
			  • mean concentrations of < 0.3 mg/L total ammonia as N at pH 8; for protection of all life stages of freshwater mussels (Augspurger et al. 2003)
			• Copper levels < 3 µg/L (CCME 2005) should protect sensitive glochidia (Gillis et al. 2008).

Encysted glochidial stage (10 weeks) on host fish until drop off (summer – early fall)	Development on host for encystment	Same as above with host fish(es) present	• Attributes assumed to be same as below (as these conditions support both fish hosts and adults) • Presence of host fish(es) (e.g., Rock Bass, Largemouth Bass and Mottled Sculpin). • Clear water (for attracting host) • Dissolved Oxygen (DO) levels sufficient to support host (DO > 47% saturation at temperatures from 0-25°C; PWQO [1994] for protection of warmwater species)
Adult/juvenile	Feeding Cover	Reaches of rivers and streams with riffles present and sand, gravel and cobble substrates (sometimes found within seams when bedrock is present); includes 'bankfull' channel	• Moderate to strong current (in sufficient volume to prevent stranding and increased predation) • Supply of food (plankton: bacterial, algae, organic detritus, protozoans) • Clean, well-oxygenated reaches at depths of less than 1 m • Dreissenids absent or in low abundance • Maintenance of an "environmental thermal regime" [3] (gamete production and development)

* Note that not all attributes must be present for a feature to be identified as critical habitat.

[3] Maintenance of an 'environmental thermal regime' requires that water temperatures are maintained within the limits of natural variability (daily or seasonal) such that lifecycle processes are completed without impacting the fitness of the organism.

Studies to further refine knowledge on the essential functions, features and attributes for various life stages of the Rainbow are described in Section 7.5 (Schedule of studies to identify critical habitat).

7.4 Identification of critical habitat: geospatial

Using the best available information, critical habitat has been identified for Rainbow populations in the following waterbodies:

1. East Sydenham River
2. Ausable River
3. Maitland River
4. Saugeen River (including Teeswater River)
5. Bayfield River
6. Grand River (Mallet River)
7. Grand River (including Conestogo River)
8. Thames River (Middle Thames River)
9. Thames River (North Thames River tributaries)
10. Moira River
11. Salmon River

Areas of critical habitat identified at these locations may overlap with critical habitat identified for other co-occurring species at risk (e.g., Northern Riffleshell (*Epioblasma torulosa rangiana*), Snuffbox (*Epioblasma triquetra*), Rayed Bean, Mudpuppy Mussel (*Simpsonaias ambigua*), Round Pigtoe (*Pleurobema sintoxia*), Mapleleaf, Kidneyshell, Channel Darter (*Percina copelandi*), and Eastern Sand Darter; however, the specific habitat requirements within these areas may vary by species.

The areas delineated on the following maps (Figures 3–12) represent the extent of critical habitat that can be identified at this time. Note that the areas delineated include the entire 'bankfull' channel (e.g., from the top of the riverbank on one side of the channel to the top of the riverbank on the other); this supports long-term channel forming discharges important in maintaining instream habitat conditions required by freshwater mussels. *Using the 'bounding box' approach, critical habitat is not comprised of all areas within the identified boundaries, but only those areas where the specified essential biophysical features/attributes occur* (refer to Table 7). *Note that permanent anthropogenic structures that may be present within the delineated areas (e.g., marinas, navigation channels) are specifically excluded; it is understood that maintenance or replacement of these features may be required at times.* Brief explanations for the areas within which critical habitat is identified are provided for each of the waterbodies below.

Table 8, below, provides the geographic coordinates that situate the boundaries within which critical habitat is found for the Rainbow; these points are indicated on Figures 3–12.

Table 8. Coordinates locating the boundaries within which critical habitat is found for the Rainbow*

	Coordinates† locating areas of critical habitat					
Location	**Point 1**	**Point 2**	**Point 3**	**Point 4**	**Point 5**	**Point 6**
East Sydenham River	81° 42' 12.309" W 42° 54' 14.978" N	81° 44' 0.289" W 42° 51' 35.425" N	81° 52' 1.573" W 42° 51' 35.535" N	81° 59' 56.182" W 42° 39' 12.599" N	82° 10' 46.307" W 42° 35' 40.417" N	
Ausable River	81° 31' 17.253" W 43° 17' 45.606" N	81° 29' 50.424" W 43° 10' 59.766" N	81° 32' 38.600" W 43° 6' 39.539" N	81° 42' 18.062" W 43° 3' 48.241" N		
Maitland River	80° 58' 9.773" W 43° 50' 57.389" N	81° 7' 14.226" W 43° 48' 47.265" N	81° 6' 20.982" W 43° 42' 32.144" N	81° 29' 33.072" W 43° 41' 33.624" N		
Saugeen River	81° 21' 50.961" W 44° 26' 18.117" N	81° 11' 32.302" W 44° 17' 47.573" N	81° 9' 46.384" W 44° 12' 58.876" N	81° 20' 31.035" W 44° 6' 54.265" N	81° 21' 31.006" W 44° 1' 2.979" N	81° 10' 39.833" W 44° 0' 35.783" N
Bayfield River	81° 32' 38.240" W 43° 36' 15.603" N	81° 28' 5.830" W 43° 33' 20.181" N	81° 36' 12.702" W 43° 32' 47.212" N	81° 33' 52.968" W 43° 31' 10.155" N		
Grand River (Mallet and Conestogo)	80° 41' 16.311" W 43° 52' 4.765" N	80° 41' 47.063" W 43° 44' 15.193" N	80° 40' 55.357" W 43° 44' 55.143" N			
Grand River (Conestogo)	80° 28' 40.173" W 43° 37' 50.277" N	80° 25' 0.176" W 43° 24' 39.718" N	80° 38' 4.762" W 43° 33' 58.907" N			
Thames River (Middle)	80° 53' 33.226" W 43° 8' 20.043" N	80° 57' 56.050" W 43° 0' 43.991" N				
Thames River (North)	81° 18' 10.713" W 43° 20' 8.905" N	81° 12' 30.395" W 43° 12' 2.627" N	81° 11' 21.395" W 43° 21' 4.475" N	81° 5' 43.424" W 43° 17' 14.193" N		
Moira River	77° 18' 14.806" W 44° 21' 37.244" N	77° 23' 31.142" W 44° 11' 33.799" N				
Salmon River	77° 1' 18.376" W 44° 20' 35.897" N	77° 14' 35.348" W 44° 11' 6.843" N				

*Riverine habitats are delineated to the midpoint of channel of the uppermost stream segment(s) and lowermost stream segment.
†All coordinates obtained using map datum NAD 83.

East Sydenham River: The area within which critical habitat is found for the Rainbow in the East Sydenham River is currently identified as the reach of river represented as a single ALIS segment with the species present (Figure 3). Also connected with this segment are the lower reaches (< 3 km) of the following tributaries: Fansher, Brown and Spring creeks. This critical habitat description includes the entire 'bankfull' channel. These areas represent a total river reach of approximately 120 km. The downstream extent of critical habitat ends at the County Road 21 (George Street) bridge in the town of Dresden; by this point, the gradient of the river has flattened out causing low current velocities that no longer support the required habitat. The upstream extent of critical habitat in the East Sydenham River is the bridge at Murphy Drive (approximately 15 km northeast of Alvinston).

Ausable River: The area within which critical habitat is found for the Rainbow in the Ausable River is currently identified as the reach of river that includes all contiguous ALIS segments from the uppermost stream segment with the species present to the lowermost stream segment with the species present (Figure 4). This critical habitat description includes the entire 'bankfull' channel and represents a stretch of river approximately 70 km long. This reach extends from Crediton Road downstream on the main stem of the Ausable River, to a point about 1 km downstream of Centre Road (#81). Also included are the lower reaches of two tributaries where the Rainbow has been found: Nairn Creek (< 2 km length) and the Little Ausable River (< 3 km length).

Maitland River: The area within which critical habitat is found for the Rainbow in the Maitland River is currently identified as the reaches of river that include all contiguous ALIS segments from the uppermost stream segment with the species present to the lowermost stream segment with the species present (Figure 5). This includes the reaches of the main stem of the Maitland River from its confluence with the North branch in Wingham , downstream to the confluence with the South Maitland River; the North Maitland River is included from Wingham, upstream to a point approximately 5 km upstream of the town of Fordwich. Also included are the lower reaches of the following tributaries with the species present: South Maitland River (< 10 km length); Middle Maitland River from Wingham upstream to point approximately 12 km east of Brussels (< 40 km length) and the Little Maitland River (<25 km length). The entire 'bankfull' channel is included in this critical habitat description for all 4 rivers.

Saugeen River (including Teeswater River): The two areas within which critical habitat is found for the Rainbow in the Saugeen River watershed is currently identified as the reaches of river that include all contiguous ALIS segments from the uppermost stream segments with the species present to the lowermost stream segments with the species present (Figure 6). The lowermost area includes reaches of the mainstem of the Saugeen River from Port Elgin upstream to a point approximately 15 km southeast of Paisley; the North Saugeen River is included from its confluence with the main stem of the river near Paisley to a point about 7 km upstream. The Teeswater River is also included upstream from its confluence with the main stem of the Saugeen River, upstream to where it enters the Greenock Swamp Wetland Complex. The separate uppermost area of critical habitat includes an approximately 15 km reach of the upper Teeswater River that flows through the town of Teeswater. The entire 'bankfull' channel is included in this critical habitat description for all river segments identified.

Bayfield River: The two areas within which critical habitat is found for the Rainbow in the Bayfield River watershed is currently identified as the reaches of river that include all contiguous ALIS segments from the uppermost stream segments with the species present to the lowermost stream segments with the species present (Figure 7). The lowermost area includes an approximately 1.5 km reach of the mainstem of the Bayfield River in the region below the confluence with the Bannockburn River north of the town of Varna; contiguous with this section are the lower 4 km reaches of the Bannockburn River. The separate uppermost area of critical habitat includes an approximately 15 km reach of the upper Bayfield River beginning at a point just south of the town of Clinton. The entire ‘bankfull’ channel is included in this critical habitat description for all river segments identified.

Grand River (Mallet River): The area within which critical habitat is found for the Rainbow in the Mallet River is currently identified as the reach of river that includes all contiguous ALIS segments from the uppermost stream segment with the species present to the lowermost stream segment with the species present (Figure 8). This critical habitat description includes the entire ‘bankfull’ channel and represents a stretch of river approximately 20 km long. This reach extends from Conestogo Lake, upstream to a point about 6 km north of the town of Rothsay. This section is contiguous with an approximately 2 km reach of the Conestogo River from its confluence with the Mallet River upstream to a point just southeast of the small town of Drayton.

Grand River (including Conestogo River): The area within which critical habitat is found for the Rainbow in the Grand and Conestogo rivers is currently identified as the reach of river that includes all contiguous ALIS segments from the uppermost stream segment with the species present to the lowermost stream segment with the species present (Figure 9). This area includes reaches of the mainstem of the Grand River from a point about 10 km north of the town of Conestogo and downstream to a point just south of Kitchener; the Conestogo River is also included from its confluence with the Grand River and upstream to the town of Hawkesville. This critical habitat description includes the entire ‘bankfull’ channel for all river segments identified.

Thames River (Middle Thames River): The area within which critical habitat is found for the Rainbow in the Middle Thames River is currently identified as the reach of river that includes all contiguous ALIS segments from the uppermost stream segment with the species present to the lowermost stream segment with the species present (Figure 10a). This critical habitat description includes the entire ‘bankfull’ channel. This reach of the Middle Thames River extends from about 6 km south of Thamesford to a point approximately 3 km south of Embro.

Thames River (North Thames River tributaries): The two areas within which critical habitat is found for the Rainbow in the North Thames River watershed is currently identified as the reaches of tributaries that include all contiguous ALIS segments from the uppermost stream segments with the species present to the lowermost stream segments with the species present (Figure 10b). The area identified within Fish Creek includes an approximately 20 km reach of river from the confluence with the North Thames River upstream to a point about 1 km northeast of the town of Kirkton; contiguous with this is a short approximately 2 km section of the North Thames River downstream from the confluence. The separate area of critical habitat identified near St. Marys includes the lower 6 km reach of Otter Creek as well as an approximately 8 km reach of the North Thames River upstream of the confluence (with Otter Creek). The entire ‘bankfull’ channel is included in this critical habitat description for all river segments identified.

Moira River: The area within which critical habitat is found for the Rainbow in the Moira River is currently identified as the reach of river that includes all contiguous ALIS segments from the uppermost stream segment with the species present to the lowermost stream segment with the species present (Figure 11). This critical habitat description includes the entire ‘bankfull’ channel and includes the reach of the Moira River from the Highway 401 bridge near Belleville to a point approximately 25 km upstream.

Salmon River: The area within which critical habitat is found for the Rainbow in the Salmon River is currently identified as the reach of river that includes all contiguous ALIS segments from the uppermost stream segment with the species present to the lowermost stream segment with the species present (Figure 12). This critical habitat description includes the entire 'bankfull' channel and includes the reach of the lower Salmon River from about Shannonville to a point approximately 25 km upstream.

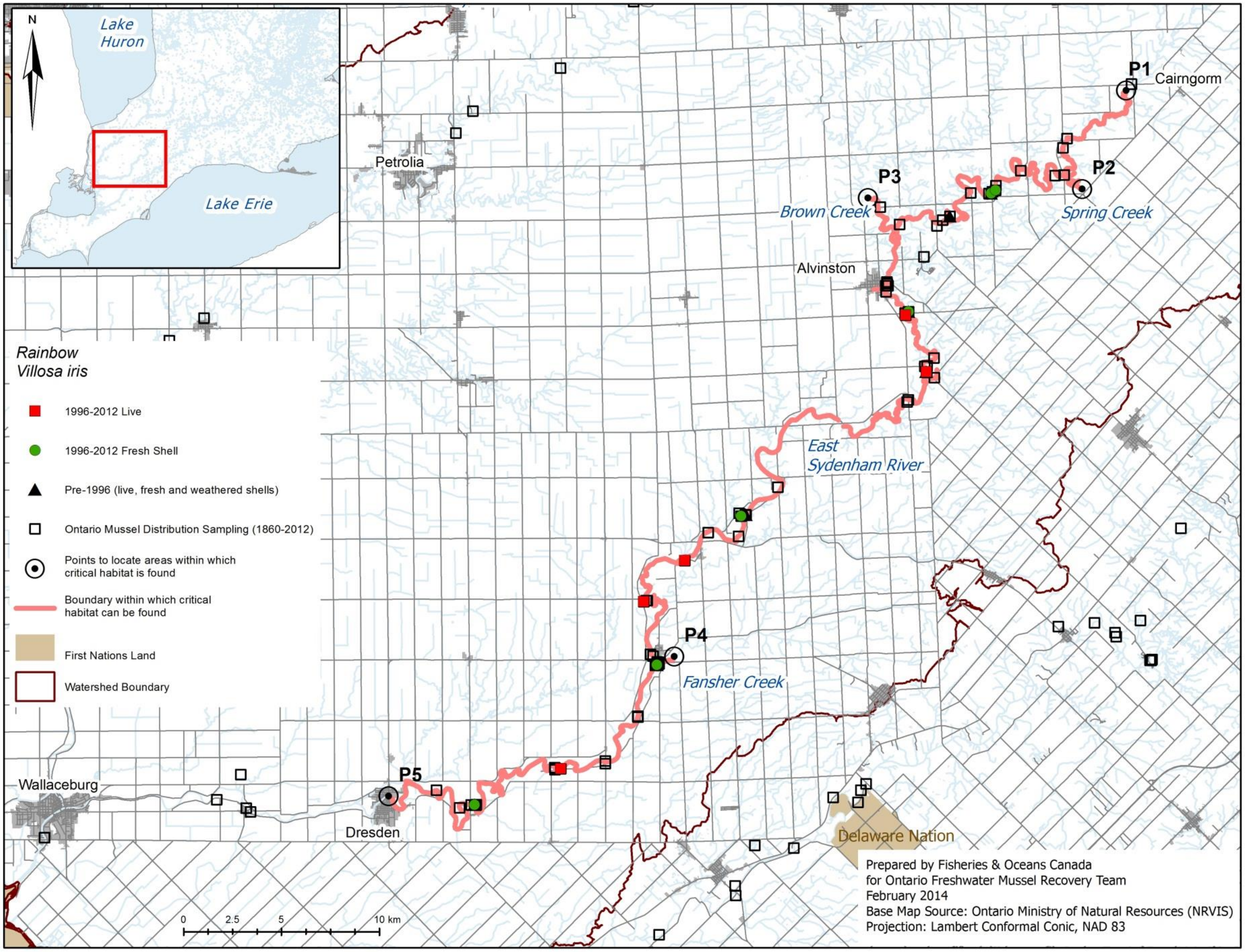

Figure 3. Critical habitat identified for the Rainbow within the East Sydenham River

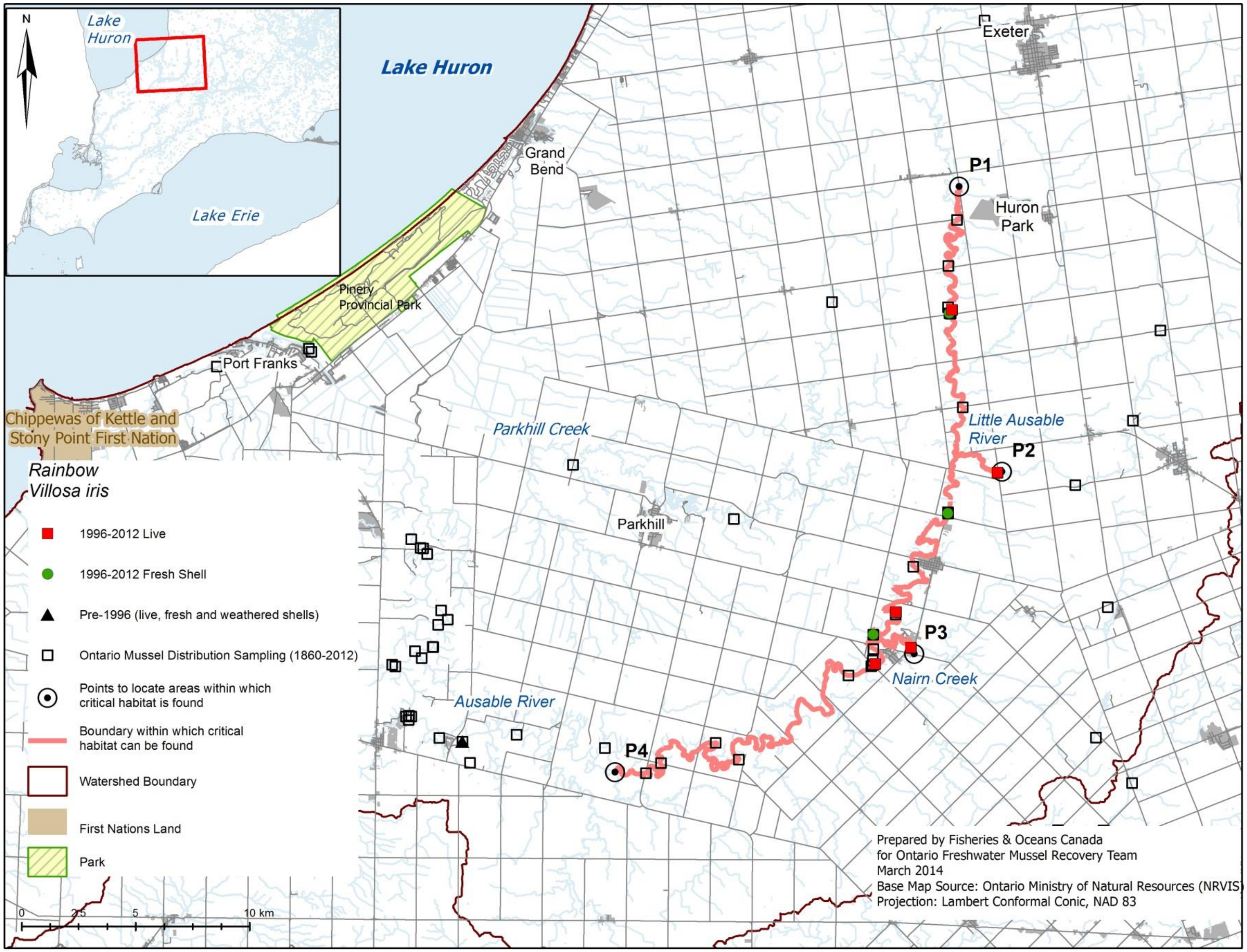

Figure 4. Critical habitat identified for the Rainbow within the Ausable River

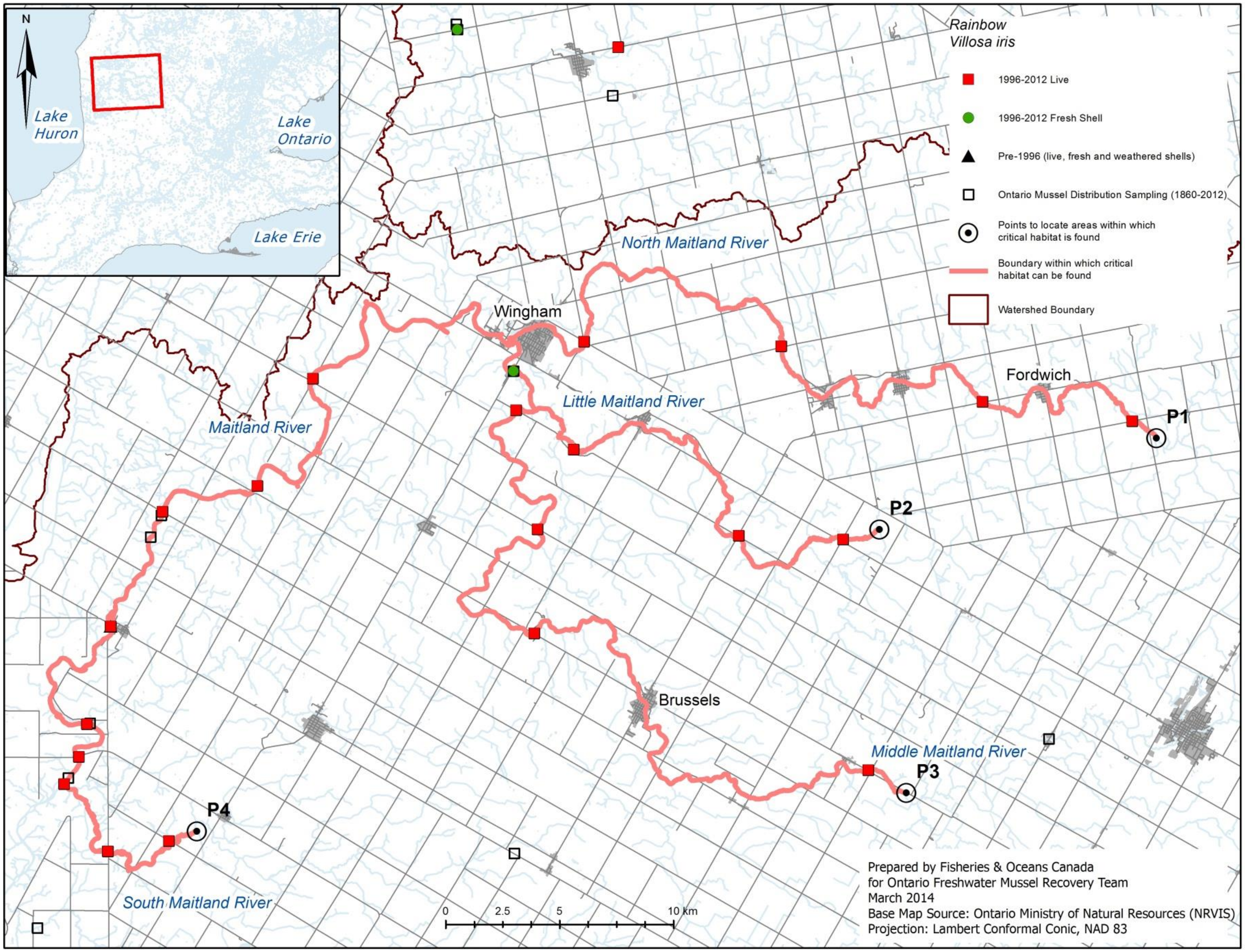

Figure 5. Critical habitat identified for the Rainbow within the Maitland River

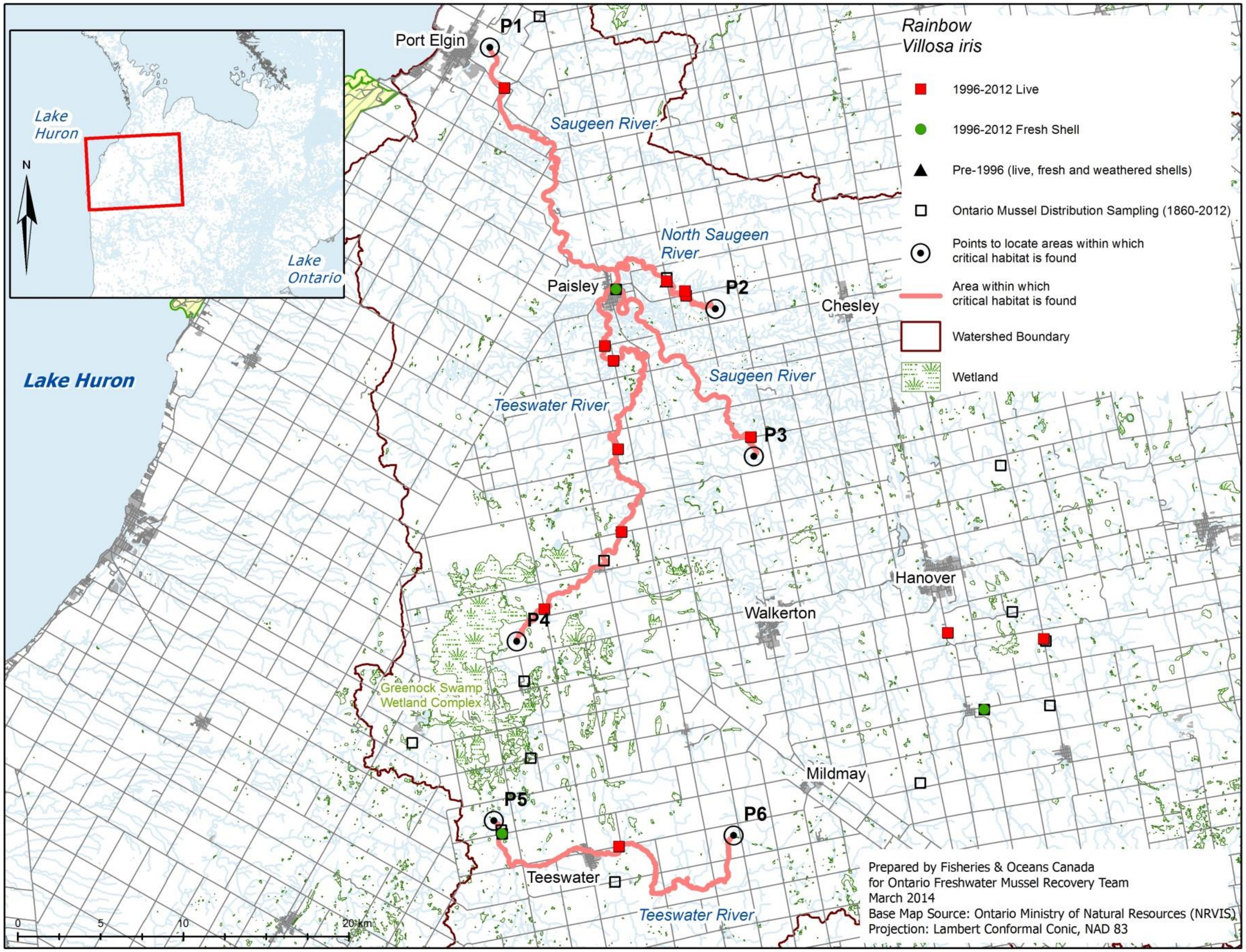

Figure 6. Critical habitat identified for the Rainbow within the Saugeen River

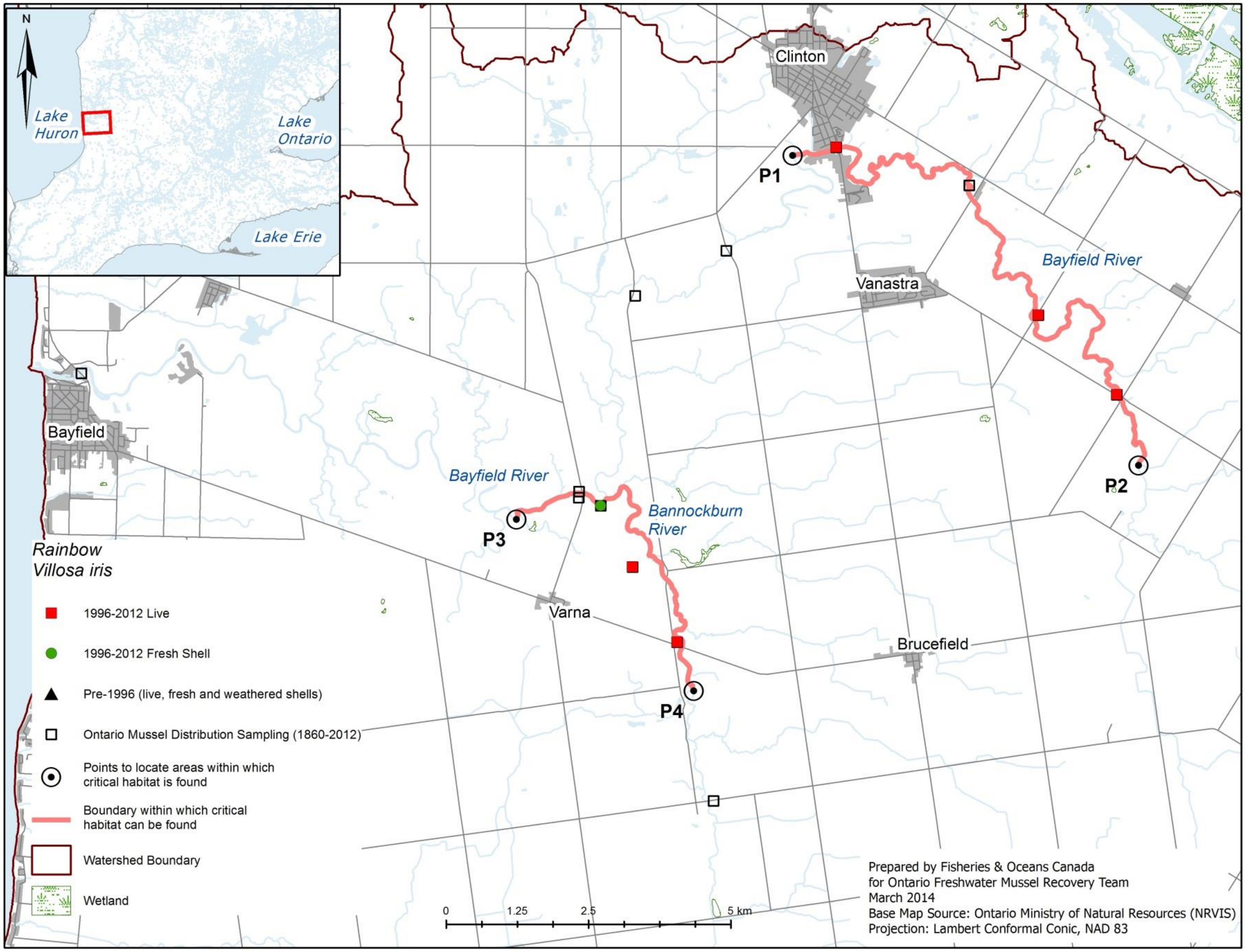

Figure 7. Critical habitat identified for the Rainbow within the Bayfield River

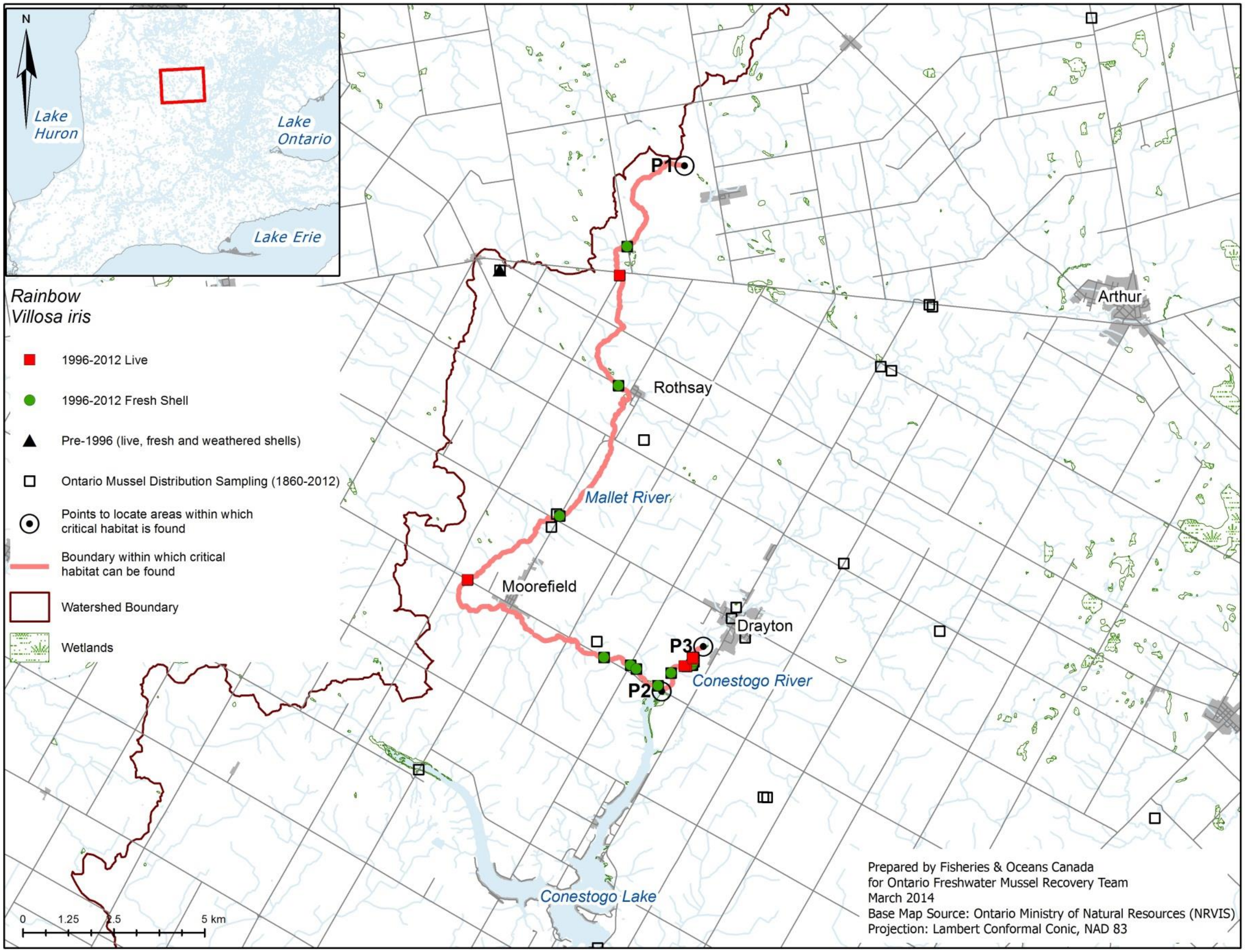

Figure 8. Critical habitat identified for the Rainbow within the Grand River (Mallet and Conestogo rivers)

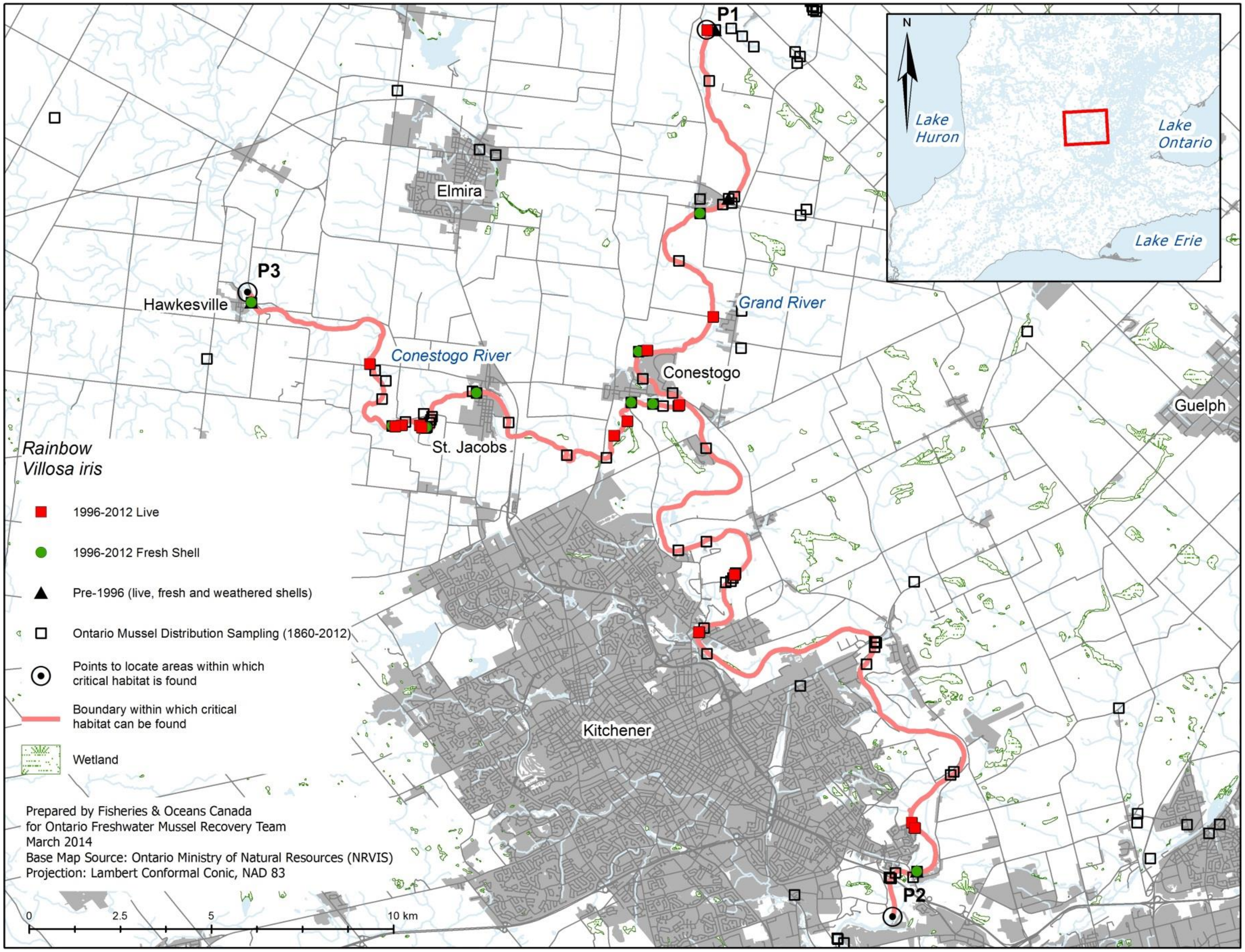

Figure 9. Critical habitat identified for the Rainbow within the Grand River (Conestogo River)

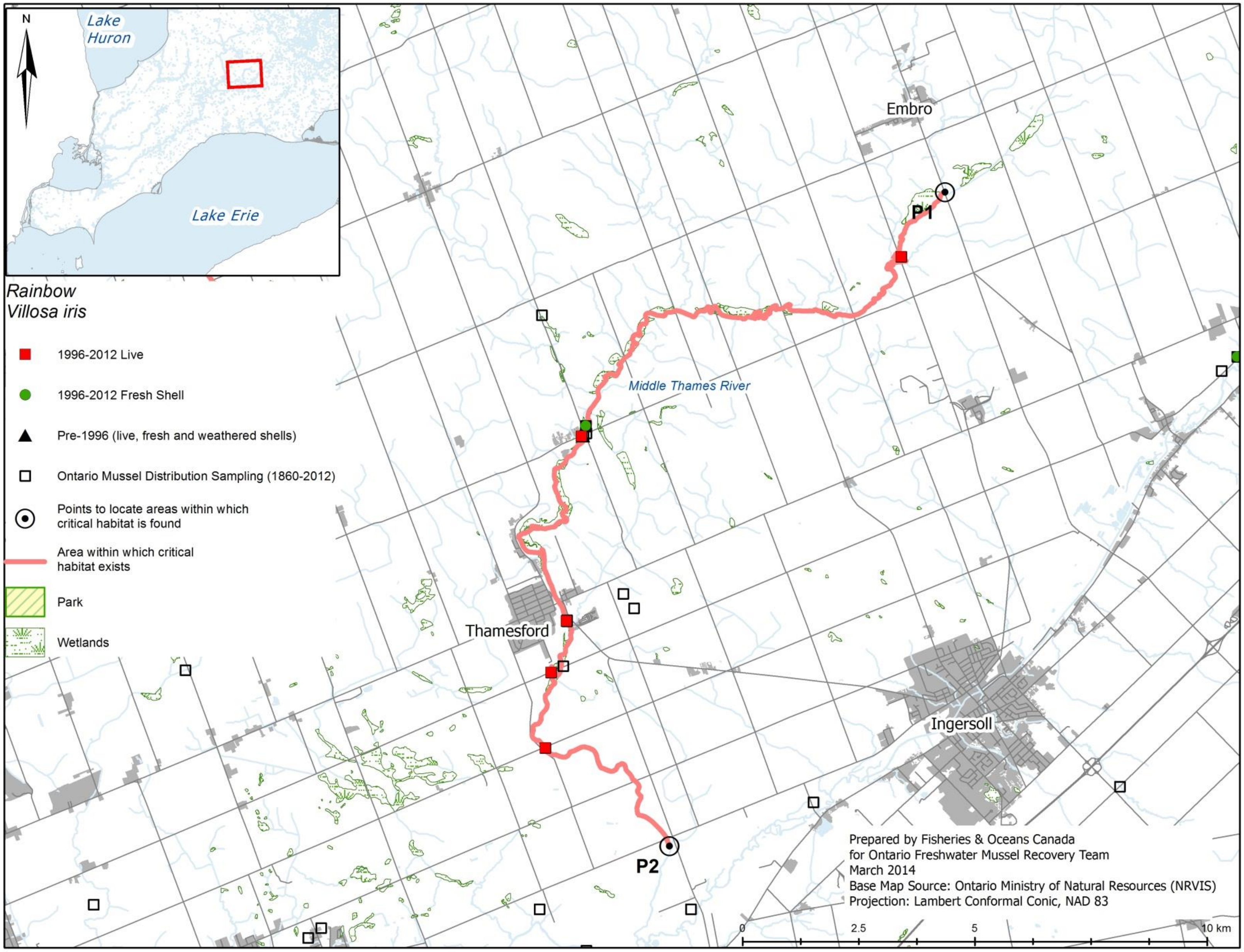

Figure 10(a). Critical habitat identified for the Rainbow within the Thames River (Middle Thames River)

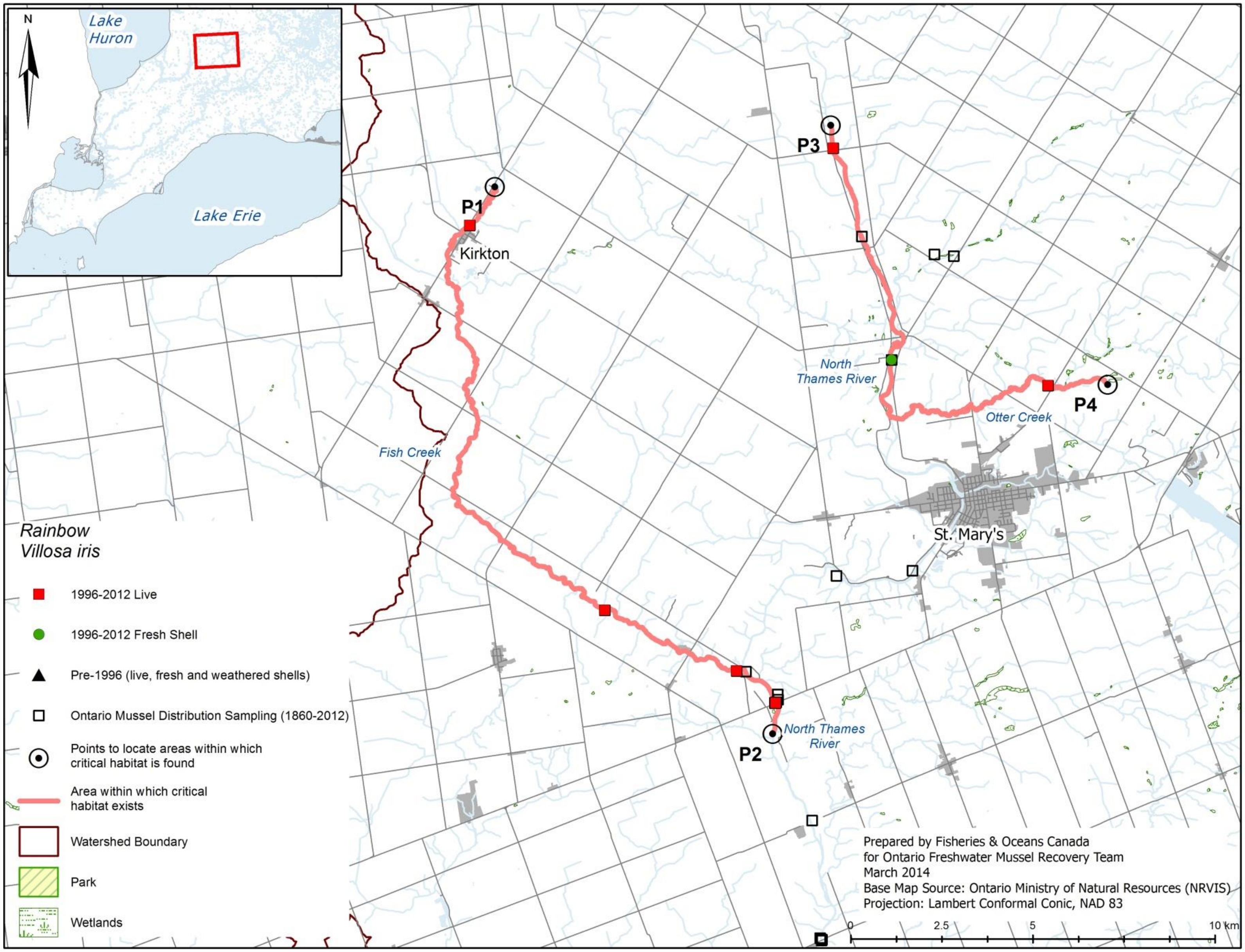

Figure 10(b). Critical habitat identified for the Rainbow within the Thames River (North Thames River tributaries)

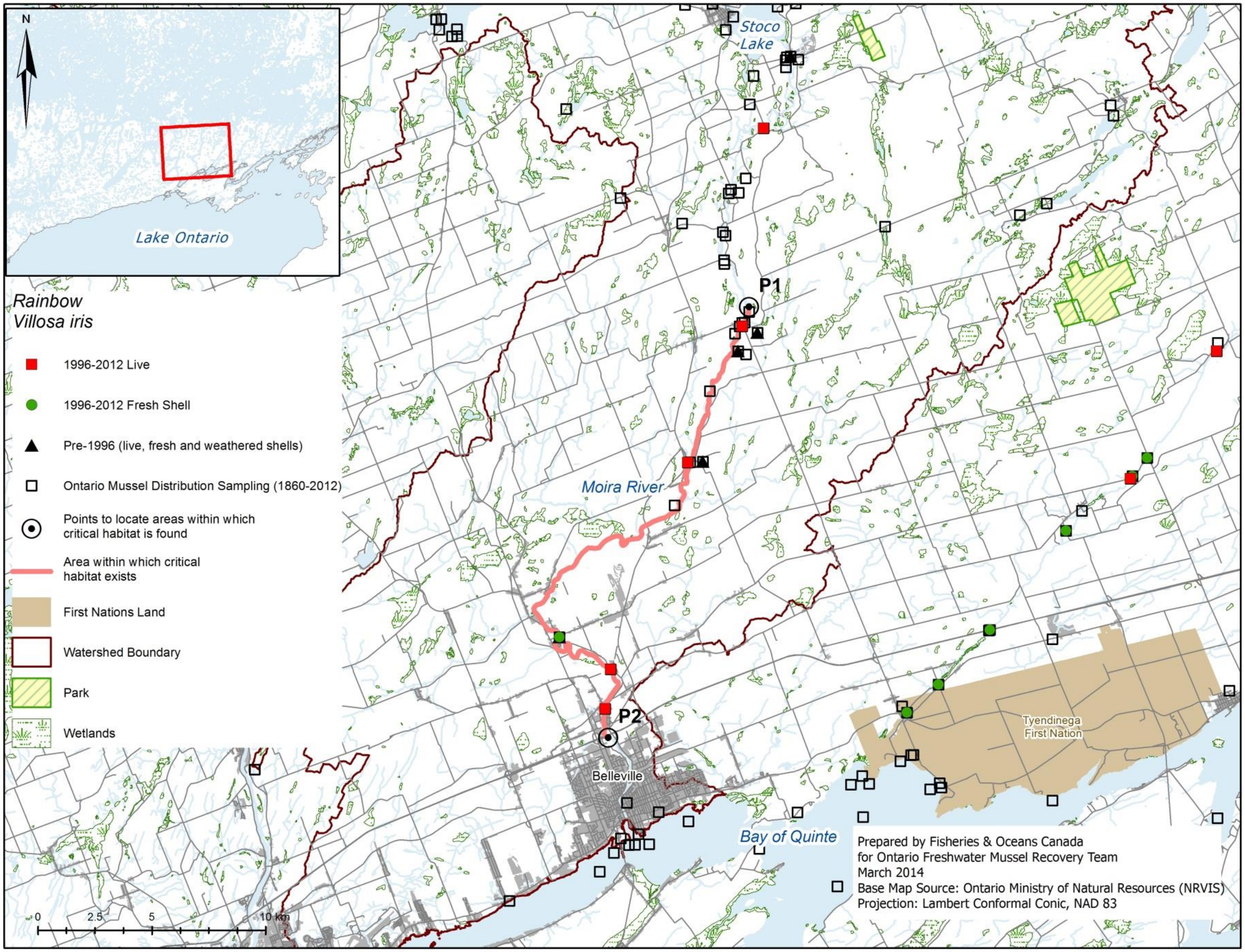

Figure 11. Critical habitat identified for the Rainbow within the Moira River

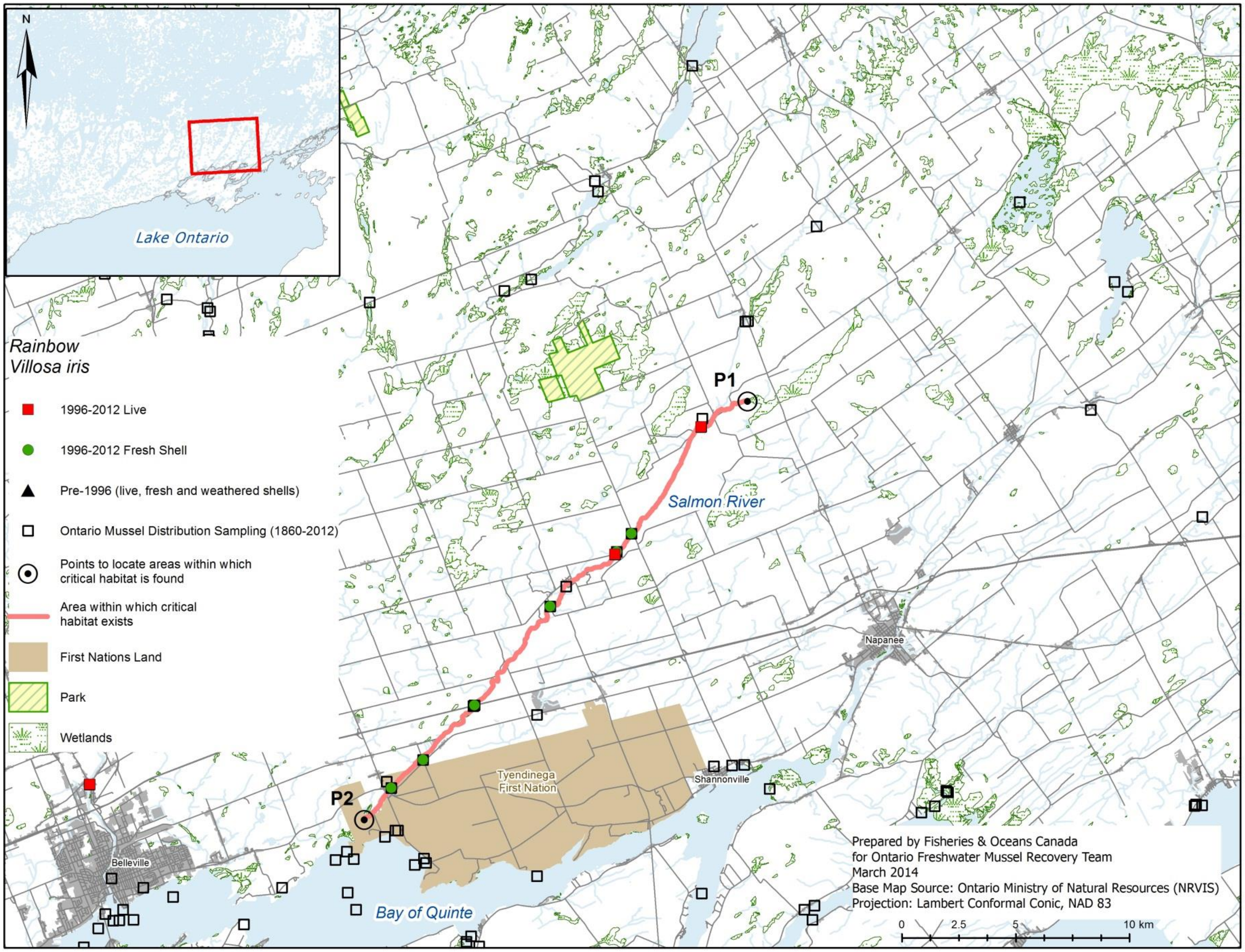

Figure 12. Critical habitat identified for the Rainbow within the Salmon River

The identification of critical habitat within the East Sydenham, Ausable, Maitland, Saugeen (Teeswater River), Bayfield, Grand (Mallet and Conestogo rivers), Thames (Middle Thames River and tributaries of the North Thames River), Moira and Salmon rivers will ensure that currently occupied riverine habitat is protected, until such time as critical habitat is further refined according to the schedule of studies laid out in Section 7.5. The schedule of studies outlines activities necessary to refine the current critical habitat descriptions at confirmed extant locations as well as address locations with limited information (e.g., Lake St. Clair). Critical habitat descriptions will be refined as additional information becomes available to support the population and distribution objectives. Until critical habitat has been fully identified for the Rainbow, the recovery team recommends that any occupied habitat located outside of currently identified critical habitat be recognized as habitat in need of conservation for this species.

7.5 Schedule of studies to identify critical habitat

This recovery strategy includes an identification of critical habitat to the extent possible, based on the best available information. Further studies are required to refine critical habitat identified for the Rainbow and to support the population and distribution objectives for this species. The activities listed in Table 9 are not exhaustive and it is likely that the process of investigating these actions will lead to the discovery of further knowledge gaps that need to be addressed.

Table 9. Schedule of studies to identify critical habitat

Description of activity	Outcome/rationale	Timeline*
Conduct mussel population surveys in areas of known and potential occurrence.	Determine the spatial extent of remaining population locations to identify baseline data required for the identification of critical habitat. Determine if adults and juveniles are occurring in the same locations.	2016–2018
Assess and characterize habitat conditions in occupied areas (e.g., flow, substrate, water clarity and quality).	Refine features and attributes of critical habitat for remaining populations.	2016–2018
Determine any life stage differences in habitat use.	Determine critical habitat at different life stages (adult vs. juvenile vs. glochidia).	2017–2019
Determine/confirm functional host fish species.	Determine host for the glochidia (parasitic larvae) to juvenile transformation.	2016–2018
Conduct host fish population surveys (and collect associated habitat information) within the range of the Rainbow where current data does not exist.	Determine range and abundance of suitable host fish(es) (may help determine why the Rainbow no longer occurs in some areas). Collection of habitat information will provide insight into presence/absence of various host species at different locations.	2017–2019
Based on collected information, review population and distribution objectives. Determine amount, configuration and description of critical habitat required to achieve these objectives if adequate information exists.	Refinement of population and distribution objectives, as well as amount, configuration and description of critical habitat to meet these objectives.	ongoing

* Timelines are subject to change in response to demands on resources and/or personnel and as new priorities arise.

7.6 Examples of activities likely to result in the destruction of critical habitat

Under SARA, critical habitat must be legally protected from destruction within 180 days of being identified in a recovery strategy or action plan. For the critical habitat of the Rainbow, it is anticipated that this will be accomplished through a SARA Protection Order made under subsections 58(4) and (5), which will invoke the prohibition in subsection 58(1) against the destruction of the identified critical habitat.

The Rainbow, like most mussel species, is sensitive to a wide variety of stressors. Therefore, the activities described in Table 10 are neither exhaustive nor exclusive and their selection has been guided by the general threats described in Section 4 (Threats). The absence of a specific human activity does not preclude, or fetter the Department's ability to regulate it pursuant to SARA. Furthermore, the inclusion of an activity does not result in its automatic prohibition since it is destruction of critical habitat that is prohibited. Since habitat use is often temporal in nature, every activity is assessed on a case-by-case basis and site-specific mitigation is applied where it is reliable and available. In every case, where information is available, thresholds and limits are associated with attributes to better inform management and regulatory decision-making. However, in many cases the knowledge of a species and its critical habitat may be lacking, and in particular, information associated with a species' or habitat thresholds of tolerance to disturbance from human activities, is lacking and must be acquired.

Table 10. Human activities likely to result in the destruction of critical habitat for Rainbow
The pathway of effect for each activity is provided as well as the potential links to the biophysical functions, features and attributes of critical habitat.

Activity	Effect-pathway	Function affected	Feature affected	Attribute affected
Siltation and turbidity: Work in or around water with improper sediment and erosion control (e.g., installation of bridges, pipelines, culverts), overland runoff from ploughed fields, run-off from urban and residential development, use of industrial equipment, cleaning or maintenance of bridges or other structures without proper mitigation.	Improper sediment and erosion control or mitigation can cause increased turbidity and sediment deposition, changing preferred substrates, impairment of feeding and reproductive functions.	Reproduction Feeding Cover Development on host for encystment	• Reaches of rivers and streams with riffles present and sand, gravel and cobble substrates (sometimes found within seams when bedrock is present); includes 'bankfull channel'	• Water clarity • Presence of host fish species • Food supply • Maintenance of an environmental thermal regime
Unfettered livestock access to waterbodies.	When livestock have unfettered access to waterbodies damage to shorelines, banks and watercourse bottoms can cause increased erosion and sedimentation, affecting turbidity and water temperatures.		Presence of host fish(es)	
Removal or cultivation of riparian vegetation.	Agricultural lands, particularly those with little riparian vegetation and without tile drainage, allow large inputs of sediments to the watercourse.			

(cont'd)

Table 10 (cont'd). Human activities likely to result in the destruction of critical habitat for Rainbow
The pathway of effect for each activity is provided as well as the potential links to the biophysical functions, features and attributes of critical habitat.

Activity	Affect-Pathway	Function affected	Feature affected	Attribute affected
Nutrient loading: Over-application of fertilizer and improper nutrient management (e.g., organic debris management, wastewater management, animal waste, septic systems and municipal sewage).	Improper nutrient management can cause nutrient loading of nearby waterbodies. Elevated nutrient levels (phosphorus and nitrogen) can cause increased turbidity causing harmful algal blooms, changing water temperatures, and reduced dissolved oxygen levels. Mussel survival rates are closely related to DO levels. Low DO may also cause mortality of warm water fish hosts, thereby disrupting mussel reproductive cycles. Recent evidence has shown that juvenile mussels are among the most sensitive aquatic organisms to ammonia toxicity.	Same as above	Same as above	• Water clarity • Presence of host fish species • Food supply • Contaminant levels – ammonia • DO levels sufficient to support host • Maintenance of an environmental thermal regime

(cont'd)

Table 10 (cont'd). Human activities likely to result in the destruction of critical habitat for Rainbow
The pathway of effect for each activity is provided as well as the potential links to the biophysical functions, features and attributes of critical habitat.

Activity	Effect-pathway	Function affected	Feature affected	Attribute affected
Altered flow regimes: Water-level management (e.g., through dam operation) or water extraction activities (e.g., for irrigation), that causes dewatering of habitat or excessive flow rates; large increases in impervious surfaces from urban and residential development.	High flow conditions (and 'flashier' flows) can cause dislodgement and passive transport of mussels from areas of suitable habitat into areas of lesser or marginal habitat. Low flows can result in depressed DO levels, desiccation, elevated temperatures and stranding. Host fish may also be impacted, thereby disrupting reproduction. Altered flow patterns can affect habitat availability (e.g., by 'dewatering' habitats) in creeks and rivers, sediment deposition (e.g., changing preferred substrates), and water temperatures.	Same as above	Same as above	• Adequate flow • Food supply • DO levels sufficient to support host • Presence of host fish species • Maintenance of an environmental thermal regime
Decline of host fish(es): Excessive removal of host fish(es) (through harvest) or indirect means (e.g., damming activities) may prevent fish movement.	Any activities that affect the host species' abundance, movements, or behaviour during the period of encystment or release may disrupt the reproductive cycle of these mussels.	Development on host for encystment	Same as above	• Presence of host fish species

(cont'd)

Table 10 (cont'd). Human activities likely to result in the destruction of critical habitat for Rainbow
The pathway of effect for each activity is provided as well as the potential links to the biophysical functions, features and attributes of critical habitat.

Activity	Effect-pathway	Function affected	Feature affected	Attribute affected
Contaminants and toxic substances: Over application or misuse of herbicides and pesticides. Release of urban and industrial pollution into habitat (including the impact of stormwater runoff from existing and new developments). Introduction of high levels of chloride through activities such as excessive salting of roads in winter.	Introduction of toxic compounds (e.g., high chloride levels from stormwater runoff) into habitat used by these species can change water chemistry affecting habitat and host fish availability or use, especially during sensitive life stages (glochidia, juvenile). Chloride levels have shown recent inclines due to an increased use of road salt. High chloride levels can cause direct mortality of sensitive glochidia.	Reproduction Cover Development on host for encystment	Same as above	• Presence of host fish species • Contaminants levels – chloride and copper
Physical habitat loss/modification: • Dredging • Grading • Excavation	Changes in bathymetry, shoreline and channel morphology caused by dredging and nearshore grading and excavation can move mussels, alter preferred substrates, change water depths, change flow patterns potentially affecting turbidity, nutrient levels and water temperatures.	Reproduction Cover Feeding Development on host for encystment	Same as above	• Water clarity • Presence of host fish species • Food supply • Adequate flow • Maintenance of an environmental thermal regime

(cont'd)

Table 10 (cont'd). Human activities likely to result in the destruction of critical habitat for Rainbow
The pathway of effect for each activity is provided as well as the potential links to the biophysical functions, features and attributes of critical habitat.

Activity	Effect-pathway	Function affected	Feature affected	Attribute affected
Placement of material or structures in water (e.g., groynes, piers, infilling, partial infills, jetties) Construction of dams and/or barriers	Placing material or structures in water reduces habitat availability (e.g., the footprint of the infill or structure is lost). Placing of fill can cover organisms and preferred substrates for mussels and their host fish(es). Dams/barriers can result in direct loss of habitat or fragmentation, which can limit the reproductive capabilities of mussels by eliminating or decreasing the number of hosts available.			
Recreational activities: Excessive baitfish collection; baitfish releases. Use of motor vehicles in the river.	Can affect number and health of available host fishes. Spread aquatic invasive species (boats, bait buckets). Disrupt substrate, dislodge mussels.	Reproduction Cover Feeding Development on host for encystment	Same as above	• Presence of host fish species • Water clarity • Dreissenids absent or in low abundance

In future, threshold values for some stressors may be informed through further research. For some of the above activities, Best Management Practices (BMPs) may be enough to mitigate threats to the species and its habitat; however, in some cases, it's not known if BMPs are adequate to protect critical habitat and further research is required.

7.7 Proposed measures to protect critical habitat

Under SARA, critical habitat for aquatic species not found in an area described in subsection 58(2) of the *Act* must be legally protected within 180 days of the final recovery strategy or action plan in which it is identified being posted on the Species at Risk Public Registry. For the critical habitat of the Rainbow, it is anticipated that this will be accomplished through a SARA Critical Habitat Order made under subsections 58(4) and (5), which will trigger the prohibition in subsection 58(1) against the destruction of the identified critical habitat.

8. Socio-economic evaluation of the action plan

The *Species At Risk Act* requires that the action plan component of the recovery document[4] include an evaluation of the socio-economic costs of the action plan and the benefits to be derived from its implementation (SARA 49(1)(e), 2003). This evaluation addresses only the incremental socio-economic costs of implementing this action plan from a national perspective as well as the social and environmental benefits that would occur if the action plan were implemented in its entirety, recognizing that not all aspects of its implementation are under the jurisdiction of the federal government. Its intent is to inform the public and to guide decision making on implementation of the action plan by partners.

The protection and recovery of species at risk can result in both benefits and costs. The Act recognizes that "*wildlife, in all its forms, has value in and of itself and is valued by Canadians for aesthetic, cultural, spiritual, recreational, educational, historical, economic, medical, ecological and scientific reasons*" (SARA 2003). Self-sustaining and healthy ecosystems with their various elements in place, including species at risk, contribute positively to the livelihoods and the quality of life of all Canadians. A review of the literature confirms that Canadians value the preservation and conservation of species in and of themselves. Actions taken to preserve a species, such as habitat protection and restoration, are also valued. In addition, the more an action contributes to the recovery of a species, the higher the value the public places on such actions (Loomis and White 1996; DFO 2008). Furthermore, the conservation of species at risk is an important component of the Government of Canada's commitment to conserving biological diversity under the *International Convention on Biological Diversity*. The Government of Canada has also made a commitment to protect and recover species at risk through the *Accord for the Protection of Species at Risk*. The specific costs and benefits associated with this action plan are described below. The evaluation describes, to the extent possible, the benefits that may accrue, as well as the costs that governments, industry and/or Canadians may incur due to activities identified in this action plan.

It is important to note that the socio-economic evaluation only applies to the detailed recovery measures. The setting of population and distribution objectives and the identification of critical habitat are science-based exercises and socio-economic factors were not considered in their development.

[4] The "action plan component of the recovery document" will simply be referred to as "action plan" from this point forward.

This evaluation does not address the socio-economic impacts of protecting critical habitat for the Rainbow. Under SARA, DFO must ensure that critical habitat identified in a recovery strategy or action plan is legally protected within 180 days of the final posting of the recovery document. Where a Critical Habitat Order will be used for critical habitat protection, the development of the Order will follow a regulatory process in compliance with the Cabinet Directive on Regulatory Management (CDRM), including an analysis of any potential incremental impacts of the Order that will be included in the Regulatory Impact Analysis Statement. As a consequence, no additional analysis of the critical habitat protection has been undertaken for the assessment of costs and benefits of the action plan.

Policy baseline

The policy baseline consists of the protection under the *Species at Risk Act* for the Rainbow (the species was listed under SARA in March 2013), along with continued protection under Ontario's *Endangered Species Act, 2007.* Other legislation that may provide direct or indirect habitat protection for the Rainbow include the federal *Fisheries Act* and existing provincial legislation[5]. The policy baseline also includes any recovery actions that were implemented prior[6] to and after the Rainbow was listed under SARA. These recovery actions included various projects[7] funded by the federal government and province of Ontario.

Socio-economic benefits of implementing this Action Plan

Some of the benefits of recovery actions required to return/maintain self-sustaining populations of the Rainbow outlined in this action plan are difficult to quantify but would generally be positive. Freshwater mussels play an integral role in the functioning of aquatic ecosystems and are sensitive indicators of the health of freshwater ecosystems. The Rainbow may be a particularly good indicator of ecosystem health as it appears more sensitive to environmental contaminants than many other mussel species tested to date. These ecosystem benefits would be maintained as a result of implementing the recovery actions proposed in the action plan.

Some of the unquantifiable non-market benefits mentioned in the second paragraph of this evaluation would be enjoyed by the Canadian public as a result of implementing the recovery actions contained in the action plan. The implementation of local stewardship programs to improve habitat conditions and reduce threats within critical habitat will help to improve riverine habitat and help lead to healthier watersheds through improved water quality.

The benefits of implementing the recovery actions contained in the action plan are anticipated to be low.

Socio-economic costs of implementing this Action Plan

The majority of the recovery activities identified in this action plan are short-term (2016–2019), medium-term or ongoing. Most of these activities focus on research, monitoring, engagement, education, and management to reduce threats and to inform and promote species recovery. Some of the actions are one-time projects (e.g., research and monitoring), likely funded from existing federal government resources. Implementation of local stewardship actions would be supported by programs such as the Habitat Stewardship Program. In addition, most programs

[5] Examples of other provincial legislation that provide habitat protection include, but may not be limited to, considerations under Section 3 of Ontario's *Planning Act* which prohibits development and site alteration in the significant habitat of endangered species and protection under the *Lakes and Rivers Improvement Act* in Ontario.

[6] Recovery actions have been implemented under the *Sydenham River recovery strategy*, *Thames River ecosystem recovery strategy*, *Ausable River ecosystem recovery strategy* and the *Grand River fish species at risk recovery strategy*.

[7] Projects included fish host research.

require a level of direct or in-kind support costs from applicants as matching funds[8]. The costs (direct and in-kind) associated with these short-term actions are estimated to be low[9] and spread over the next five years[10].

Costs would be incurred by the federal government to implement the activities listed in the action plan. In-kind costs such as volunteer time, providing expertise and equipment would be incurred as a result of implementing activities listed in the action plan. Costs (including in-kind support) could be incurred by the province of Ontario and conservation authorities.

Long-term recovery activities will be implemented through a cooperative approach following discussions between other agencies, levels of government, stewardship groups and stakeholders allowing for consideration of costs and benefits during the process.

Distributional impacts
Governments and conservation authorities will incur the majority of costs of implementing the action plan.

The Canadian public will benefit from the implementation of the action plan through expected non-market benefits associated with recovery and protection of the species and its habitat. Recovery actions that improve riverine habitat will help lead to healthier watersheds with benefits such as improved water quality.

9. Measuring progress

The overall success of implementing the recommended recovery approaches will be evaluated primarily through routine population (distribution and abundance) and habitat (quality and quantity) surveys and monitoring (refer to implementation schedule – Table 5, recovery measures #1 and #4). During the next five years, focus will be placed on completing recovery actions identified as "high priority" for the Rainbow. Reporting on implementation of the action plan components, under s. 55 of SARA, will be done by assessing progress towards achieving the broad strategies/approaches outlined in this document. Reporting on the ecological and socio-economic impacts of the action plan, under s. 55 of SARA, will be done by assessing the results of monitoring the recovery of the species and its long term viability, and by assessing the implementation of the action plan. Specifically, long-term mussel population and habitat monitoring results for the Rainbow will be used to assess the ecological impacts of recovery measures to other aquatic species at risk, including fishes and freshwater mussels that co-occur within the same habitats; these impacts are expected to be beneficial (refer to Appendix A).

10. Activities permitted by the recovery strategy

[8] For example, matching funds for the Habitat Stewardship Program can come from landowners and/or provincial funding programs. This helps leverage additional support for recovery actions.

[9] Low costs are defined as less than $1 million annually, as per the Treasury Board of Canada definition.

[10] Future expenditures cannot be determined in great detail as it is expected these activities would continue to be funded through existing government funding, including the Habitat Stewardship Program, where support is determined on a priority basis and based on availability of resources.

Scientific research that will aid in the conservation of the Rainbow will be permitted. Such activities must be conducted by qualified persons. A SARA permit must be obtained to conduct scientific research and the conditions of the permit must be fulfilled.

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12. Recovery team members

The following members of the Ontario Freshwater Mussel Recovery Team were involved in the development of the recovery strategy for the Rainbow:

Dr. Josef Ackerman	University of Guelph
Crystal Allan	Grand River Conservation Authority
Muriel Andreae	St. Clair Region Conservation Authority
Dave Balint	Fisheries and Oceans Canada
Amy Boyko	Fisheries and Oceans Canada
Dr. Alan Dextrase	Ontario Ministry of Natural Resources
Scott Gibson	Ontario Ministry of Natural Resources
Dr. Patricia Gillis	Environment and Climate Change Canada
Kari Jean	Ausable Bayfield Conservation Authority
Dr. Gerry Mackie	University of Guelph
Daryl McGoldrick	Environment and Climate Change Canada
Kelly McNichols	Fisheries and Oceans Canada
Dr. Todd Morris (Co-chair)	Fisheries and Oceans Canada
Dr. Scott Reid	Ontario Ministry of Natural Resources
Dr. Frederick Schueler	Bishop Mills Natural History Centre
Astrid Schwalb	University of Waterloo
John Schwindt	Upper Thames River Conservation Authority
Shawn Staton (Co-chair)	Fisheries and Oceans Canada
Valerie Towsley	Lower Thames River Conservation Authority
Mari Veliz	Ausable Bayfield Conservation Authority
Dr. Daelyn Woolnough	Central Michigan University
Dr. Dave Zanatta	Central Michigan University

Appendix A: Effects on the environment and other species

A strategic environmental assessment (SEA) is conducted on all SARA recovery planning documents, in accordance with the Cabinet Directive on the Environmental Assessment of Policy, Plan and Program Proposals. The purpose of a SEA is to incorporate environmental considerations into the development of public policies, plans, and program proposals to support environmentally sound decision-making and to evaluate whether the outcomes of a recovery planning document could affect any component of the environment or achievement of any of the Federal Sustainable Development Strategy's[11] (FSDS) goals and targets.

Recovery planning is intended to benefit species at risk and biodiversity in general. However, it is recognized that implementation of action plans may inadvertently lead to environmental effects beyond the intended benefits. The planning process based on national guidelines directly incorporates consideration of all environmental effects, with a particular focus on possible impacts upon non-target species or habitats. The results of the SEA are incorporated directly into the action plan itself, but are also summarized below in this statement.

This combined recovery strategy and action plan will clearly benefit the environment by promoting the recovery of the Rainbow. In particular, it will encourage the protection and improvement of riverine habitats in the lower Great Lakes. These habitats support many other aquatic SAR, including fishes and freshwater mussels and thus the implementation of recovery actions for the Rainbow will contribute to the preservation of biodiversity in general. The potential for these recovery actions to inadvertently lead to adverse effects on other species was considered. The SEA concluded that the implementation of this document will clearly benefit the environment and will not entail any significant environmental effects.

[11] www.ec.gc.ca/dd-sd/default.asp?lang=En&n=F93CD795-1