COSEWIC
Assessment and Status Report

on the

Copper Redhorse
Moxostoma hubbsi

in Canada

ENDANGERED
2014

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

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

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Previous report(s):

COSEWIC. 2004. COSEWIC assessment and update status report on the copper redhorse *Moxostoma hubbsi* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 38 pp. (www.sararegistry.gc.ca/status/status_e.cfm)

Mongeau, J.R, P. Dumont, L. Cloutier, and A.-M Clément. 1987. Status report on the copper redhorse *Moxostoma hubbsi* in Canada. Committee on the Status of Endangered Wildlife in Canada. 1-9 pp.

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COSEWIC
Assessment Summary

Assessment Summary – May 2014

Common name
Copper Redhorse

Scientific name
Moxostoma hubbsi

Status
Endangered

Reason for designation
This long-lived, late-to-mature fish is endemic to Canada where it is known from only three locations, one of which is probably extirpated. The species is exposed to many threats, the most severe of which include habitat degradation and fragmentation, eutrophication, and impacts of invasive species.

Occurrence
Quebec

Status history
Designated Threatened in April 1987. Status re-examined and designated Endangered in November 2004 and May 2014.

COSEWIC
Executive Summary

Copper Redhorse
Moxostoma hubbsi

Wildlife Species Description and Significance

The Copper Redhorse (*Moxostoma hubbsi*) is one of seven species of the genus *Moxostoma* (family Catostomidae) occurring in Canada. Its discovery has been attributed to Vianney Legendre in 1942, but it appears to have been first described by Pierre Fortin in 1866 as an already-known species of the genus *Moxostoma*. The significance of the Copper Redhorse is not limited to scientific and ecological considerations. It extends to social values, sustainable development and biodiversity conservation. In some respects, the species is an indicator of the impact of human activity on the ecosystems of southern Québec. Public interest in the species is strong, and continues to grow.

Distribution

The species, which genetically constitutes a single population, occurs nowhere in the world except Canada in the Great Lakes–Upper St. Lawrence biogeographic zone. Its extremely small range has remained essentially unchanged since the rediscovery of the species. This range is restricted to the St. Lawrence River system and its main tributaries in the lowlands of southwestern Québec (Rivière Richelieu, Rivière L'Acadie, Rivière des Mille Îles, Rivière des Prairies, Rivière Saint-François and Rivière Maskinongé). The persistence of the Copper Redhorse in the Rivière Yamaska and Rivière Noire is increasingly less likely.

The Rivière Richelieu is still the only known Copper Redhorse reproduction site. This river is strategic to the species' life cycle, particularly because it is the only site where young-of-the-year and individuals less than 300 mm (TL) have been captured since the discovery of the species. The Rivière Richelieu therefore provides spawning, nursery and growth habitats and is also a migration corridor for the Copper Redhorse. This river also serves as a feeding area for some adults who establish their home range there during the summer. The St. Lawrence River and its main tributaries (Rivière des Prairies and Rivière des Mille Îles) are used primarily as feeding areas. The Copper Redhorse is a migratory species and is dependent on both the St. Lawrence River and the Rivière Richelieu for completion of its life cycle.

Habitat

The Copper Redhorse inhabits primarily medium-sized rivers where water temperatures exceed 20ºC in summer. Spawning occurs in riffle areas where the current is moderate to slow and the depth ranges between 0.75 and 4 m over fine to coarse gravel, pebble and cobble substrate. Deeper areas (> 8 m) and areas where the current is faster (>1 m/s) are also used for spawning. To date, there are only two known spawning grounds (Chambly archipelago and the tailrace of the Saint-Ours dam), both of which are located in the Rivière Richelieu. Like their congeners (Silver, Greater, Shorthead and River Redhorse), young-of-the-year Copper Redhorse frequent shallow shoreline areas. These areas are ≤1.5 m deep, gently sloped and vegetated. The current is very slow and the substrate is relatively fine (mix of clay-silt and sand). Adult summer feeding habitats consist of gastropod-rich aquatic grass beds of medium to high density. High-quality Copper Redhorse habitat is in decline. Moreover, the probable extirpation of this species from the Rivière Yamaska and Rivière Noire is closely linked to habitat degradation, particularly owing to the fragmentation and significant degradation of aquatic environments and water quality.

Biology

By comparison with the other redhorse species with which it occurs in sympatry (Silver, Greater, Shorthead and River Redhorse), the Copper Redhorse has the longest lifespan (over 30 years), is the most fecund and reaches the largest size (over 70 cm). Its spawning period is later than that of its congeners, occurring from late June to early July, when water temperatures range from 18 to 26ºC. The species also reaches sexual maturity later than its congeners (at about 10 years). The Copper Redhorse feeds almost exclusively on molluscs, which it crushes with its very robust pharyngeal apparatus and molariform teeth. The diet of young-of-the-year differs little from that of the other redhorse species with which it cohabits and is composed mainly of microcrustaceans.

Population Sizes and Trends

Archeological excavations provide evidence that the species was formerly more abundant at various periods of history and prehistory. Since the mid-1980s, the relative abundance of the Copper Redhorse compared to its congeners has declined significantly. The population is aging, recruitment is extremely low and considered insufficient to offset natural mortality. The upward shift in size distribution in the past 30 to 40 years is significant. There have been virtually no catches of naturally reproduced juveniles aged 2+ years in the last 30 years. The total number of mature individuals appears to be several thousand at the most. In view of these findings, an artificial reproduction and stocking program was implemented in 2004 in order to rebuild the spawning stock. To date, nearly 3,300,000 larvae and 168,400 fall fry have been stocked in the Rivière Richelieu. The contribution of stocked juveniles to recruitment is quite significant; the ratio of specimens from artificial reproduction to natural reproduction is around 9:1 on average. Recruitment monitoring data are still insufficient to confirm whether the species has been able to reproduce naturally. In the absence of stocking, the relative abundance of young-of-the-year Copper Redhorse compared to its congeners is always less than 0.5% when juveniles have been captured. The survival of stocked juveniles has been demonstrated up to age 2, but it is still too early to draw any conclusions concerning their net contribution to the abundance of the current adult population.

Threats and Limiting Factors

A number of biological characteristics of the Copper Redhorse, such as its longevity, late age of sexual maturity, late spawning activities and specialized diet, make it unique among its congeners. However, these characteristics also contribute, in some respects, to its higher vulnerability. Because the waters inhabited by the Copper Redhorse are located in the most densely populated areas of Québec, anthropogenic factors come into play. The impacts of those factors cannot, however, be determined with certainty and act in combination. The degradation and fragmentation of its habitat and its low reproductive success are believed to be key reasons for its decline. Contamination, siltation, eutrophication, introductions of invasive species, dam construction (which impedes the free passage of fish) and the disturbance of spawners on spawning sites all constitute factors in the species' decline.

Protection, Status, and Ranks

The World Conservation Union (IUCN) has considered it vulnerable since 1996. The species is considered critically imperilled at the provincial (rank S1), national (rank N1) and global scale (rank G1) by NatureServe. In 1999, the Copper Redhorse was designated threatened under the Québec *"Loi sur les espèces menacées ou vulnérables"* (RLRQ, c E-12.01) (LEMV) *(Act respecting threatened or vulnerable species)* (CQLR, c E-12.01). It was designated Threatened by COSEWIC in 1987 and the status was re-examined and designated Endangered in 2004. The species was officially designated Endangered in December 2007 under the *Species at Risk Act* and listed on Schedule 1. In 2008, the American Fisheries Society assigned the Copper Redhorse the status of threatened species.

The survival of the Copper Redhorse is currently dependent on actions to protect the species and its habitat as well as on reintroduction efforts. As is the case for other fish species, the "*Loi sur la conservation et la mise en valeur de la faune"* (RLRQ, c. C-61.1) (LCMVF) (*Act respecting the conservation and development of wildlife*) (CQLR, c. C-61.1) and the "*Loi sur la qualité de l'environnement*" (RLRQ, c. Q-2) (*Environment Quality Act*) (CQLR, c. Q-2) provide some degree of protection of the species and its habitat.

A number of measures have been taken for the protection and recovery of the Copper Redhorse, such as the construction of the Vianney-Legendre fish ladder at Saint-Ours Canal National Historic Site in 2001 and the creation of the Pierre-Étienne-Fortin Wildlife Preserve at Chambly in 2002. Various other regulatory measures also afford some measure of protection to the Copper Redhorse. The use of Redhorse (all species) as bait-fish was banned in the 1980s and commercial fishing of the Copper and River Redhorse has been prohibited since 1995. In 1998, sport fishing of all Redhorse and Sucker species was also banned in the Rivières Richelieu, Yamaska and Noire. These regulations were amended in 2009 and now cover the entire known range of the Copper Redhorse except for Lake Saint-Pierre and its archipelago. Finally, a ban on commercial bait fishing has been in place since April 1, 2008, in the Rivière Richelieu, from downstream of the Chambly dam to the St. Lawrence River.

TECHNICAL SUMMARY

Moxostoma hubbsi

Copper Redhorse — Chevalier cuivré

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

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines (2008) is being used) Current generation time approximately 25 years due to the aging of the population; normal generation time probably 20 years.	Approximately 25 yrs
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals? Stocking since 2004 not considered because it is still too early to draw any conclusions concerning its net contribution to the abundance of the current adult population. Estimation of the number of mature individuals: ≤ 2000. Aging population, frequent recapture of spawners, low natural recruitment and small pool of spawners.	Decline observed and inferred
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown
Are the causes of the decline clearly reversible and understood and ceased? A number of factors are involved and likely act in combination. Corrective actions have been taken (fish ladder, protection of spawning grounds and other critical habitats, artificial reproduction plan, reduction in the direct causes of mortality). However, it is too early to measure the effects of these actions.	No
Are there extreme fluctuations in number of mature individuals?	Unknown Monitoring under way

Extent and Occupancy Information

Estimated extent of occurrence Historical extent of occurrence, which includes the Rivière Yamaska and Rivière Noire, is estimated at 4,981 km²	3,471 km²

Index of area of occupancy (IAO)	168.5 km²
Is the population severely fragmented? In the past yes, particularly in the Rivière Yamaska and Rivière Noire, where impassable obstacles were constructed. However, the species is most likely extirpated from these two rivers. The current population, which is restricted to the St. Lawrence River and Rivière Richelieu, remains relatively unfragmented by partially passable obstacles.	Currently no
Number of locations* • St. Lawrence River system and its main tributaries (current) • Rivière Richelieu (current) • Yamaska-Noire rivers system (historical)	Three, one of which is considered historical
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence? Observed and inferred decline owing to its probable extirpation from the Rivière Yamaska and Rivière Noire.	Yes
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy? Observed and inferred decline owing to its probable extirpation from the Rivière Yamaska and Rivière Noire.	Yes
Is there an [observed, inferred, or projected] continuing decline in number of populations? There may have been two relatively independent populations, but this hypothesis cannot be tested. With the extirpation of the Copper Redhorse from the Rivière Yamaska and Rivière Noire system, there is now only a single population.	No
Is there an [observed, inferred, or projected] continuing decline in number of locations*? Inferred loss from one of the three known locations. The location of the Rivière Yamaska and Rivière Noire system should likely be considered historical.	Yes
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat? Observed and inferred decline especially in habitat quality.	Yes
Are there extreme fluctuations in number of populations? There is only a single population.	No
Are there extreme fluctuations in number of locations*? Likely loss of one of the three known locations since the rediscovery of the species in 1942.	No
Are there extreme fluctuations in extent of occurrence? Loss of 30% of the extent of occurrence since the rediscovery of the species in 1942.	No

* See Definitions and Abbreviations on the COSEWIC website and IUCN 2010 for more information on this term.

Are there extreme fluctuations in index of area of occupancy? Even though the species most likely no longer occurs in the Rivière Yamaska and Rivière Noire, these rivers represent a very small proportion of the entire area of occupancy (estimated at 1.56 km^2 based on a 2 km X 2 km grid)	No

Number of Mature Individuals (in each population)

Population	N Mature Individuals
Total	Several hundred to several thousand at most

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	Not applicable

Threats (actual or imminent, to populations or habitats)

Actual

- Intensification of agricultural activities, which leads to eutrophication, siltation and contamination of rivers and streams;
- Deforestation;
- Urbanization causing shoreline alteration and destruction of aquatic grass beds and exposing fish to toxic contaminants;
- Increasing commercial shipping traffic causing erosion and development of port infrastructure in the St. Lawrence River;
- Pleasure craft traffic in the largest and most promising of the only two known spawning grounds, in the Chambly rapids, during the spawning and egg incubation period;
- Introduction and spread of the Tench and the Round Goby, ubiquitous and potentially competing species, in the Rivière Richelieu (Tench) and in the St. Lawrence River (Tench and Round Goby);
- Commercial and sport fishing by-catches;
- Changes in benthic communities that generally occur when Zebra Mussels are abundant and habitat degradation (siltation and contamination).

Potential

- Construction of new dams that would impede the free passage of the species within its range and that would restrict in particular free passage between the St. Lawrence River and the Rivière Richelieu;
- Declining water levels of the St. Lawrence River and their effects.

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? Not applicable since this species is a Canadian endemic.	
Is immigration known or possible?	No
Would immigrants be adapted to survive in Canada?	Not applicable
Is there sufficient habitat for immigrants in Canada?	Not applicable
Is rescue from outside populations likely?	No

Data-Sensitive Species

Is this a data-sensitive species? Yes, but spawning grounds are commonly known.

Status History

COSEWIC: Designated Threatened in April 1987. Status re-examined and designated Endangered in November 2004 and May 2014.

Status and Reasons for Designation:

Status:	**Alpha-numeric code:**
Endangered	B1ab(i,iii,iv,v)+2ab(i,iii,iv,v)
Reasons for Designation:	
This long lived, late-to-mature species is endemic to Canada where it is known from only three locations, one of which is probably extirpated. The species is exposed to many threats, the most severe of which include habitat degradation and fragmentation, eutrophication and impacts of invasive species.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals):
Meets Threatened under A2c with an estimated reduction in the number of mature individuals based on a greater than 30% decline in extent of occurrence.
Criterion B (Small Distribution Range and Decline or Fluctuation):
Meets Endangered B1ab(i,iii,iv,v)+2ab(i,iii,iv,v) based on small distribution, few locations and observed and inferred continuing declines in distribution, quality of habitat and number of mature individuals.
Criterion C (Small and Declining Number of Mature Individuals):
Not applicable. Number of mature individuals not known but may be under the threshold.
Criterion D (Very Small or Restricted Population):
Not applicable. Number of mature individuals not known but may be under the threshold.
Criterion E (Quantitative Analysis):
Not applicable. Quantitative analysis has not been done.

PREFACE

The Copper Redhorse (*Moxostoma hubbsi*) was designated threatened in 1987 by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). It was re-examined in 2004 and assessed as endangered (COSEWIC 2004). The Copper Redhorse was legally designated as endangered in December 2007 under the *Species at Risk Act* (SARA). Because of the need for more detailed data in order to identify appropriate protection and recovery activities as well as to meet the requirements imposed by the designation of the species under SARA, a number of studies were conducted in the 2000s. Significant advances in the acquisition of knowledge have now made it possible to more accurately determine the species' range as well as the genetic structure of the population and to provide a description of the critical habitats. These studies confirmed that the Copper Redhorse inhabits the entire known historical range except for the Rivière Yamaska and Rivière Noire and also revealed that the species is present in several new tributaries of the St. Lawrence River. The current range therefore differs from that presented in the previous status report of 2004. Additional information was obtained on the species' movements and the home range of adults at various periods of the year as well as on the description and the location of adult feeding grounds. Genetic characterization studies on the population have confirmed that there is currently only a single population and that its genetic diversity is still relatively high. At the same time, a significant recovery program has been implemented, including the rebuilding of the spawning stock through the implementation of an artificial reproduction plan and stocking of larvae and fall fry. Monitoring of recruitment in the Rivière Richelieu, now supplemented by genetic analyses, has also continued.

COSEWIC HISTORY

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

COSEWIC MANDATE

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

COSEWIC MEMBERSHIP

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

DEFINITIONS
(2014)

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

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

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

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

Environment Canada / Environnement Canada
Canadian Wildlife Service / Service canadien de la faune

Canada

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

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Class: Actinopterygii

Order: Cypriniformes

Family: Catostomidae

The Copper Redhorse (“Chevalier cuivré” in French) (*Moxostoma hubbsi*, Legendre) (Figures 1 and 2) is one of seven species of the genus *Moxostoma* (family Catostomidae) that occur in Canada. Its discovery has been attributed to Vianney Legendre in 1942 (Legendre 1942, 1943), but it appears to have been first described by Pierre Fortin in 1866 as an already-known *Moxostoma* (Branchaud and Jenkins 1999). Believing that it was a species previously described by Valenciennes, Legendre first named it *Megapharynx valenciennesi*, considering *Megapharynx* a new genus. More detailed studies later indicated that it was an entirely new species. On the basis of his description of 10 years earlier, Legendre (1954) officially designated the Copper Redhorse a new species and renamed it *Moxostoma hubbsi* in recognition of the famous ichthyologist Carl L. Hubbs. Robins and Rainey (1956) later placed it in the subgenus *Megapharynx*. However, the most recent study no longer recognizes *Megapharynx* as a valid taxon (Harris *et al.* 2002).

In 1998, the French common name of the species was changed from “suceur cuivré” (Tr.= copper sucker) to “chevalier cuivré” in order to facilitate the task of raising public awareness about the need to protect the species by eliminating any pejorative connotation associated with the word “sucker” (Branchaud *et al.* 1998). The French generic term “chevalier” (Tr.= knight) is now used to designate all species of the genus *Moxostoma*. This name refers to their large scales, which recall a knight’s armour. However, the second part of its common name has remained unchanged because it refers directly to the general colouration of the dorsal surface, head and sides, which ranges from a bright coppery sheen to olive. The ventral surface of the body is generally a paler shade of the colour of the sides or off-white and the fins are usually coppery to dusky (Scott and Crossman 1973).

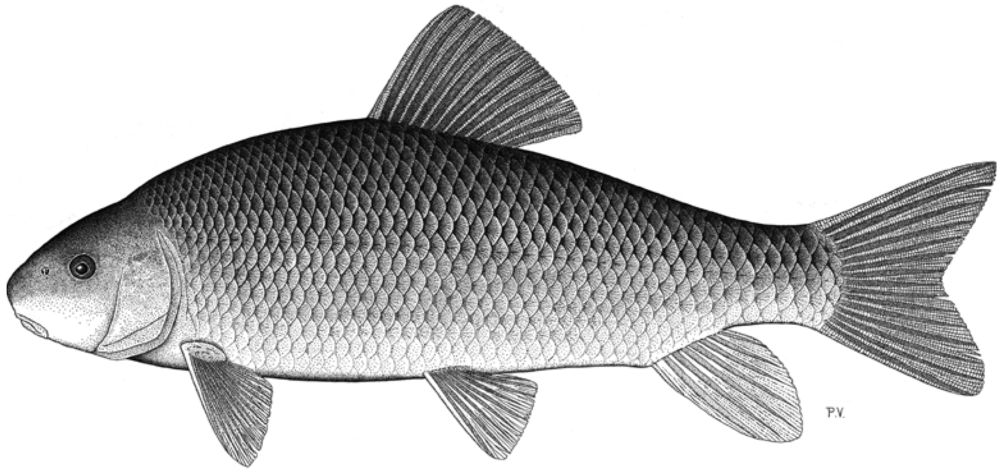


Figure 1.   Adult Copper Redhorse (illustration by Paul Vecsei).

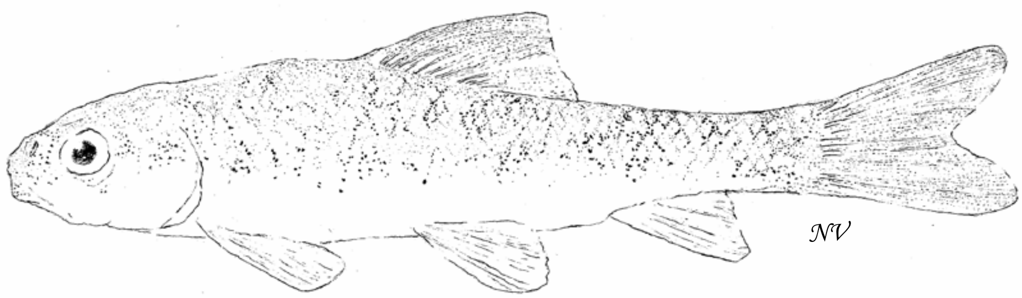


Figure 2.   Juvenile Copper Redhorse, 38 mm (illustration by Nathalie Vachon, from Vachon 2003a).

Morphological Description

The Copper Redhorse is a large-scaled catostomid fish of the genus *Moxostoma*, a group of relatively large fish, with an inferior, protrusible mouth, lips with plicae and a pharyngeal apparatus with teeth arranged in an arch around the opening of the esophagus. It has 15 to 16 rows of scales around the caudal peduncle, like its congener the Greater Redhorse (*Moxostoma valenciennesi*), whereas there are usually 12 or 13 in the other species with which it occurs in sympatry in southern Québec, namely the Silver Redhorse (*M. anisurum*), Shorthead Redhorse (*M. macrolepidotum*) and River Redhorse (*M. carinatum*). Its short, massive head, shaped like an equilateral triangle, with a moderately high arch rising sharply behind the head, creating a humpback appearance, and its pharyngeal apparatus, exceptionally robust with molariform teeth (18 to 21 per arch) (Figure 3) are the main characteristics by which it can be distinguished from the other species (Scott and Crossman 1973; Mongeau 1984; Mongeau *et al.* 1986, 1988; Massé and Leclerc 2008).

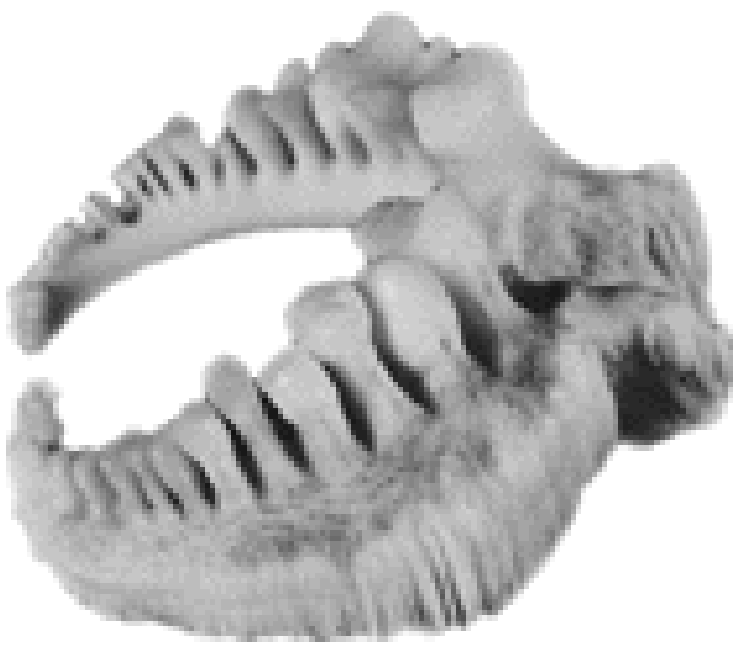
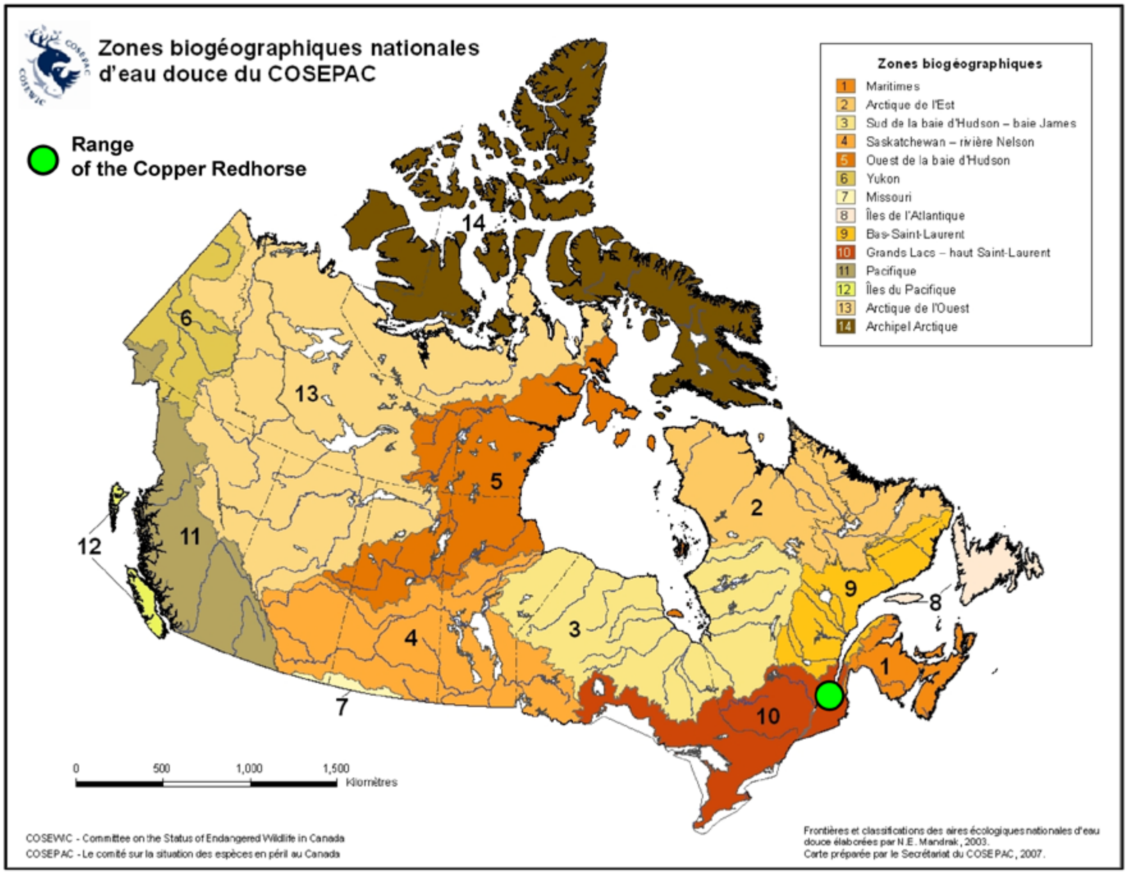


Figure 3. Pharyngeal apparatus of the Copper Redhorse (photograph by Yves Chagnon, Société de la faune et des parcs du Québec).

Gendron and Branchaud (1991) have described the morphometric, meristic and pigmentation characteristics of the larval (flexion mesolarvae) and juvenile stages, and Branchaud *et al.* (1996) and Lippé *et al.* (2004) have developed genetic analysis techniques for identification. Several authors (Beauchard 1998; Vachon 1999a, 2003a) have described the morphological features of the gill and pharyngeal arches in juveniles, and Grünbaum *et al. (*2003) have studied the sequence of ossification and chondrification of the caudal skeleton in larvae. Despite considerable efforts to develop other larval identification techniques, genetic analysis remains the most reliable method (Branchaud *et al.* 1996). From the first growing season, when the young reach approximately 25 mm (TL), the juveniles of the five species living in sympatry in Québec can be distinguished. In juvenile Copper Redhorse, the reduced number of pharyngeal teeth as well as their molariform appearance, widened base and more robust arches are already evident and can be used to distinguish them from the others. Dissection of the pharyngeal apparatus is still the technique of choice for confirming identification (Vachon 1999a, 2003a and pers. comm.).

Population Spatial Structure and Variability

The Copper Redhorse occurs only in a few rivers in southern Québec, specifically in the St. Lawrence River system and its main tributaries (Figures 4, 5) (see the details in the Distribution, Extent of Occurrence and Area of Occupancy sections). The sector of the St. Lawrence River where the species occurs is part of a rare section of fluvial habitats that is not fragmented by dams. Only the Pointe-des-Cascades and Beauharnois dams restrict the progress of the species to habitats further upstream in the St. Lawrence River. The Carillon dam restricts the species’ movements to the Ottawa River system.



English Translation:

Zones biogéographiques nationales d'eau douce du COSEPAC = COSEWIC National Freshwater Biogeographic Zones

Range of the Copper Redhorse = Copper Redhorse Range

Zones biogéographiques = Biogeographic Zones

Maritimes = Maritimes

Arctique de l'Est = Eastern Arctic

Sud de la baie d'Hudson- baie James =Southern Hudson Bay – James Bay

Saskatchewan –rivière Nelson = Saskatchewan – Nelson River

Ouest de la baie d'Hudson = Western Hudson Bay

Yukon = Yukon

Missouri = Missouri

Îles de l'Atlantique = Atlantic Islands

Bas- Saint-Laurent = Lower St. Lawrence

Grands Lacs-haut Saint Laurent = Great Lakes – Upper St. Lawrence

Pacifique = Pacific

Iles du Pacifiques = Pacific Islands

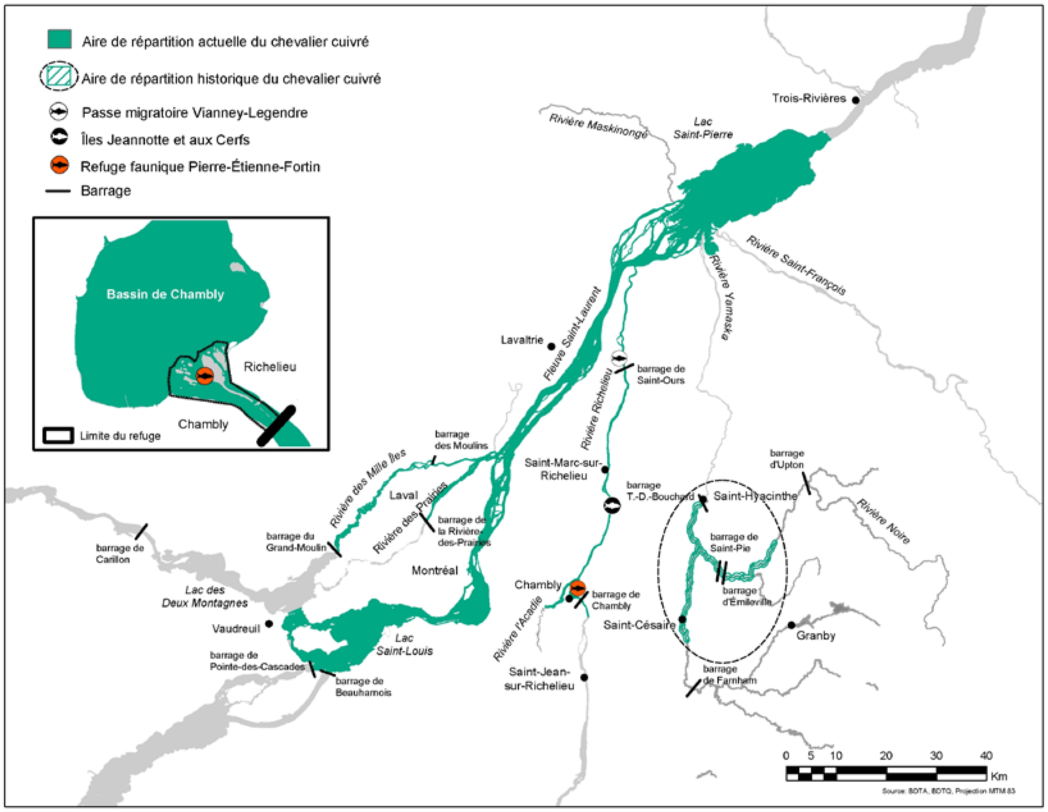
Arctique de l'Ouest = Western Arctic

Archipel de l'Ouest = Arctic Archipelago

Frontières et classifications des aires écologiques nationalesd'eau douce élaborées par N.E. Mandrak,2003 = Freshwater ecological area boundaries and classification developed by N.E. Mandrak, 2003

Carte prepare par le Secretariat du COSEPAC, 2007 = Map prepared by the COSEWIC Secretariat, 2007

Figure 4. Canadian range of the Copper Redhorse (map of the biogeographic zones of Canada produced by COSEWIC (2007)). COSEWIC. 2007. COSEWIC National Freshwater Biogeographic Zones. http://www.cosewic.gc.ca/images/Fig2-FreshwaterBiogeographicZones_Eng.jpg



English Translation:

Aire de répartition actuelle du chevalier cuivré = Current range of the Copper Redhorse
Basin de Chambly = Chambly basin
Aire de répartition historique du chevalier cuivré = Historical range of the Copper Redhorse
Passe migratoire Vianney-Legendre = Vianney-Legendre fish ladder
Iles Jeannotte and aux Cerfs = Jeannotte and aux Cerfs Islands
Refuge faunique Pierre-Étienne-Fortin = Pierre-Étienne-Fortin Wildlife Preserve
Barrage Carillon = Carillon dam
Fleuve Saint Laurent = St. Lawrence River
Lac Saint-Pierre = Lake Saint-Pierre
Barrage Pointe-des-Cascades = Pointe-des-Cascades dam
Rivière Richelieu = Rivière Richelieu
Rivière Saint-François = Rivière Saint-François
Barrage Beauharnois = Beauharnois dam
Barrage Chambly = Chambly dam
Barrage Saint-Pie = Saint-Pie dam
Lac Saint-Louis = Lake Saint-Louis
Barrage Saint-Ours = Saint-Ours dam
Barrage Farnham = Farnham dam
Barrage Grand-Moulin = Grand-Moulin dam
Barrage T.-D. Bouchard = T.-D. Bouchard dam
Barrage Émileville = Émileville dam
Barrage Des Moulins = Des Moulins dam
Rivière Yamaska = Rivière Yamaska
Barrage Upton = Upton dam
Barrage Rivière des Prairies = Rivière des Prairies dam
Rivière Maskinongé = Rivière Maskinongé
Rivière Noire = Rivière Noire

Source: BDTA, BDTQ, MTM NAD83 projection

Figure 5. Historical and current range of the Copper Redhorse (map by Lucie Veilleux, MDDEFP).

Elsewhere in its range, the habitat is fragmented by the construction of dams (Figure 5), some of which are impassable, while others significantly restrict the free passage of fish. The Saint-Pie (1940) and Emileville (1913) dams[1] in the Noire River and the T.-D. Bouchard (1900) dam at Saint-Hyacinthe in the Rivière Yamaska are impassable obstacles. The Des Moulins dam (1979) in the Rivière des Mille Îles at Terrebonne partially impedes the passage of fish (Gravel and Dubé 1980).

At Chambly, on the Rivière Richelieu, about 50 km upstream of Saint-Ours, a dam was first built in 1896 for the production of electricity. This dam was replaced in 1963-1964 (Blaquière and Auclair 1974). It was not until 1997 that an eel ladder was installed at the site (Verdon *et al.* 2003), but the dam is still impassable for other species. Although plausible, there is no record of the Copper Redhorse in the Rivière Richelieu upstream of Chambly.

The Saint-Ours dam, on the Rivière Richelieu, obstructed the free passage of spawners to the most important and promising of the two known spawning grounds, namely in the archipelago of the Chambly Basin (Dumont *et al.* 1997). Although various structures were built at Saint-Ours from the 1850s onward to facilitate navigation as far as Chambly, until 1969, these structures did not completely obstruct the free passage of fish because a fish ladder had been installed. In addition, the dam, which at the time was built of rock caissons, was often partially destroyed or even carried away by spring floods. The passage of fish was most likely possible, albeit reduced. However, during the last major reconstruction of the dam, begun in 1967 and completed in 1969, the dam was raised and did not include any kind of structure to allow fish to bypass it (Dumont *et al.* 1997). It was not until the spring of 2001 that a multispecies fish ladder (Vianney-Legendre fish ladder) was installed at the Saint-Ours Canal National Historic Site. A five-year monitoring program was carried out with the aim of optimizing its operation. Although the use of the fish ladder by Copper Redhorse could not be confirmed in its first year of operation (Groupe conseil GENIVAR 2002), individuals were captured in the ladder in subsequent years (Fleury and Desrochers 2003, 2004, 2005 and 2006; Leclerc and Vachon 2008; Desrochers 2009). The structure is also part of the protocol for the capture of spawners for artificial reproduction of the Copper Redhorse.

Based on various studies on the species, several indicators suggest that Copper Redhorse form pre-spawning aggregations and move between the St. Lawrence River and the Rivière Richelieu, particularly during the spawning period. These indicators include: 1. the recurrent presence of Copper Redhorse in the Lavaltrie-Contrecœur sector (St. Lawrence River) during the months of April and May, followed by a drop in the numbers thereafter; 2. interannual comparisons of these captures and recapture results (Vachon and Chagnon 2004); 3. the capture of several adult Redhorse including one Copper Redhorse and one River Redhorse off the left bank of Jeannotte Island

[1] The information in parentheses represents the year of construction of the dam. From http://www.cehq.gouv.qc.ca/Barrages/Default.asp#Nouvelle (Centre d'expertise hydrique 2012).

(Rivière Richelieu) in early June 1998 (Vachon 1999a); and, finally, 4. the combination and concentration of certain contaminants found in the tissues of Copper Redhorse from the tailrace of the Saint-Ours dam which are more typically associated with the St. Lawrence River such as cadmium, mirex and PCB congener 77 (de Lafontaine *et al.* 2002a).

The most recent telemetry studies conducted in 2004, 2007 and 2008 confirmed previous data and provided more detailed data about the species' movements within its range (Gariépy 2008; Hatin *et al.* 2009 and unpubl. data). See the Dispersal and Migration section. A few years earlier, genetic characterization studies of tissues from 236 specimens captured between 1984 and 2004 from the St. Lawrence River (Lavaltrie-Contrecœur sector) and from the Rivière Richelieu (Saint-Ours and Chambly) using 22 microsatellite markers demonstrated that all these individuals comprised a single population (F_{ST} = 0.0038; P = 0.0001). Despite the low abundance of the population and the fact that the tissues analyzed came largely from large, old individuals, the level of genetic diversity was still very high compared to values obtained in other freshwater fishes with, on average, 12.5 alleles/locus and H_O of 0.77 ± 0.08. Because the mean relatedness value (r_{xy}) was -0.00013 ± 0.11737, inbreeding among these individuals could not be demonstrated (Lippé *et al.* 2004, 2006). Unfortunately, because of the method used to preserve the specimens from the Rivière Yamaska and Rivière Noire, it was not possible to conduct genetic characterization of individuals from these two rivers. The hypothesis that they may have been two relatively independent populations considering the fragmentation of the habitat is plausible, but cannot be tested. With the likely extirpation of the Copper Redhorse from the Rivières Noire-Yamaska system, there is currently only a single population.

Designatable Units

On the basis of available information, particularly on the species' very restricted range as well as the information presented in the Population Spatial Structure and Variability section (see above), the species constitutes a single designatable unit.

Special Significance

The Copper Redhorse is a species of great scientific and ecological importance. The degree of specialization of its pharyngeal apparatus constitutes an evolutionary peak (Legendre 1964; Jenkins 1970; Eastman 1977; Mongeau *et al.* 1986, 1992). A lithophilous spawner and specialist benthivore, which feeds almost exclusively on molluscs, the Copper Redhorse presents characteristics similar to those of other species known to be most affected by habitat degradation, especially by siltation (Vachon 2003b). The species appears to be a genuine indicator of the impacts of human activities on the ecosystem. Because it is rare, not widely known, and currently without great economic value from a sport and commercial fishing perspective, the species is not sought after except by some members of ethnic communities.

About 15 years ago, the species was the focus of a study, aimed at assigning it an economic value as a threatened species, by a professor and researcher specializing in human and industrial ecology as well as in environmental management, accounting, auditing and ethics at the Université du Québec à Montréal. Although this figure is approximate and should be considered a minimum, the value of the Copper Redhorse has been estimated at $25 million (Clapin-Pépin 1997). At one time considered a simple bottom fish without great value, the negative perceptions of it have over the years gradually given way to a more positive image. The Copper Redhorse is the poster child for biodiversity in Québec and is a test case for raising public awareness of the cause of a threatened species. Public interest is not only strong, but continues to grow. A proposed mini-hydroelectric generating station in the Chambly rapids was cancelled in 1994 following the interventions of the Société de la faune et des parcs du Québec (Dumont *et al.* 1997). Members of the public, municipalities, governmental and non-governmental organizations as well as public institutions have made sustained and concerted efforts to mobilize and implement concrete actions aimed at ensuring the species' survival and recovery and raising public awareness. To date, these initiatives have taken several forms and are aimed at a highly varied target audience (Équipe de rétablissement du chevalier cuivré du Québec 2014, *in press*; Vachon 2007b).

Its meat, although appreciated at one time, is no longer sought after. According to the literature, the Copper Redhorse, like its congeners, was fished and consumed at least until the early 19th century (Mongeau *et al.* 1986; Branchaud and Jenkins 1999; Courtemanche 2003). Today, the Copper Redhorse is not sufficiently abundant to be commercially harvested. Moreover, its harvesting has been prohibited in order to protect the species. Since its rediscovery, there have been no records of Copper Redhorse near Aboriginal reserves located in or near its historical range, namely Kanesatake (Lac des Deux Montagnes), Akwasasne (Lake Saint-François), Kahnawake (St. Lawrence River, Lachine rapids) and Odanak (Saint-François River). Aboriginal Traditional Knowledge on the Copper Redhorse is currently not available (Jones pers. comm. 2012).

DISTRIBUTION

Global Range

The Copper Redhorse is found nowhere in the world except in a few rivers in the St. Lawrence Plain (southwestern Québec). The identification of a fossilized fragment of Copper Redhorse pharyngeal apparatus found in Indiana confirmed that the species was present there during the Pleistocene, i.e., between 11,000 and 1.8 million years ago (Jenkins pers. comm. 2012).

Canadian Range

The Copper Redhorse occurs only in a few rivers in the Québec portion of the

Great Lakes–Upper St. Lawrence biogeographic zone[2] (Figure 4). These rivers currently form two systems isolated from each other and fragmented by partially passable obstacles. The first system is composed of the St. Lawrence River, from upstream of Lake Saint-Louis to downstream of Lake Saint-Pierre, the Rivière des Mille Îles and downstream segments of the Rivière Richelieu, Rivière Maskinongé and Rivière des Prairies. The second is composed of sections of the Rivière Yamaska and Rivière Noire.

Since 1942, all specimens have been caught in the Maskinongé, Mille Îles, Noire, Rivière Richelieu and Rivière Yamaska and in a few localized sites in the St. Lawrence River, namely the fast-flowing Sainte-Anne-de-Bellevue and Vaudreuil channels, the Lavaltrie-Contrecœur sector and Lake Saint-Pierre.

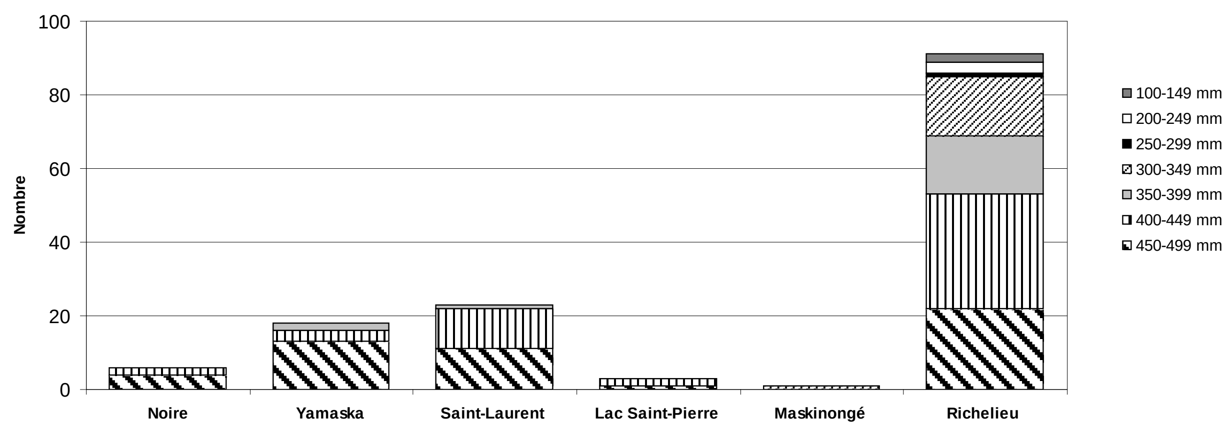
However, the picture revealed by the telemetry studies conducted on adults in 2004, 2007 and 2008 differs significantly from that developed based on sampling carried out with conventional fishing gear. These studies confirmed the presence of the species in virtually all of this territory as well as in three new tributaries, namely the downstream portions of the Rivière L'Acadie (tributary of the Rivière Richelieu), Saint-François River (near its mouth in Lake Saint-Pierre) and Rivière des Prairies. These studies also demonstrated that the species is still present in the Rivière des Mille Îles and the entire fluvial section from the channels at the head of Lake Saint-Louis to Lake Saint-Pierre (Gariépy 2008; Hatin *et al.* 2009, 2010 and unpubl. data) (Figure 5). In light of the most recent knowledge about the Copper Redhorse and in accordance with the definitions provided in the COSEWIC (2011) and IUCN (2011) documents, the species' range can be subdivided into two locations which represent ecologically and geographically distinct areas in which a single threatening event can rapidly affect all individuals of the taxon present. The first is the St. Lawrence River system and its main tributaries including the Rivière Richelieu, and the second is the Yamaska-Noire rivers system.

In short, the species' range has remained essentially unchanged since its rediscovery in 1942 (Gariépy 2008) with the exception of the Rivière Yamaska and Rivière Noire, where its persistence is increasingly less probable. In all likelihood, the species is extirpated from these two rivers as a result of habitat fragmentation and the significant degradation of the aquatic environments and water quality. The last record of the Copper Redhorse in the Rivière Yamaska was 20 years ago (in 1992) and nearly 50 years ago (in 1964) in the Noire River. This location is considered historical. Search efforts focusing specifically on these rivers would make it possible to determine the actual status. See also the Search Effort section.

[2] As defined by COSEWIC (2007).

Finally, following the commencement of artificial reproduction and stocking activities, a limited number of individuals in the larval and juvenile stages have been stocked annually outside the species' known range, i.e., several kilometres upstream of the Chambly dam (Rivière Richelieu). This sector has both fast-flowing and calm water habitats in which the species could potentially become established (Vachon 2010a and unpubl. data). In view of the fact that the Copper Redhorse's presence is the result of a reintroduction and that its persistence in this sector of the Rivière Richelieu is not yet confirmed, these areas will not be considered in calculating the species' extent of occurrence and area of occupancy (see below).

The Rivière Richelieu is still the only known site where the Copper Redhorse reproduces naturally. This river is strategic to its life cycle, particularly since it is the only site where young-of-the-year and individuals less than 300 mm (TL) have been captured because the species' discovery and that 64% of records of sub-adults (TL < 500 mm) come from this river (Figure 6). The Rivière Richelieu therefore provides spawning, nursery and growth habitats and is also a migration corridor for the Copper Redhorse. It is also a feeding ground for some adults who make their home range there and reside there year-round (Gariépy 2008; Hatin *et al.* 2009, 2010 and unpubl. data; DFO 2011; Vachon 2007b, 2009, 2010abc).



English Translation:
Nombre = Number
Saint-Laurent = St. Lawrence
Lac Saint-Pierre = Lake Saint-Pierre

Figure 6. Distribution of all of the records of capture of natural-origin sub-adult Copper Redhorse (n=142), by size class (TL), in the range from 1944 to 2011.

The current state of knowledge indicates that the St. Lawrence River and its main tributaries (Rivière des Prairies and Rivière des Mille Îles) are used by the species primarily as an adult feeding ground (especially the Montréal-Sorel section), congregation area and migration corridor (Gariépy 2008; Hatin *et al.* 2009, 2010 and unpubl. data; DFO 2011). Historical data also indicate the presence of several sub-adult (300 mm ≤ TL ≤ 499 mm) concentration areas in the St. Lawrence River particularly in the Lavaltrie-Contrecœur sector. Nearly 19% of sub-adult records are from the St. Lawrence River (Vachon 2009, 2010b).

Extent of Occurrence and Area of Occupancy

The estimates of the extent of occurrence and area of occupancy differ from those provided in the previous status report (COSEWIC 2004) because of new available information and changes in calculation methods. The new estimates show that the extent of occurrence of the Copper Redhorse, which includes the Rivière Yamaska and Rivière Noire (historical extent of occurrence), is 4,891 km^2, while the current extent of occurrence[3] is estimated at 3,471 km^2. The current extent of occurrence has apparently declined nearly 30% since the rediscovery of the species.

The species' current areas of occupancy, estimated using 1 km X 1 km and 2 km X 2 km grids, are 115.9 km^2 and 168.5 km^2, respectively. The Rivière Richelieu, the Montréal-Sorel section of the St. Lawrence River as well as the downstream section of the Rivière des Mille Îles are the sectors where the historical and recent locations and records of the species are the most abundant and concentrated.

Search Effort

The Copper Redhorse in the St. Lawrence River

The presence of the Copper Redhorse was reported in the St. Lawrence River from 1942 to 1973. The species was not found in any subsequent survey during 25 years after (Table 1). The most recent Copper Redhorse records in the St. Lawrence River are from the late 1990s and the 2000s and come from validated reports from a commercial fisher working in the Lavaltrie-Contrecœur sector as well as telemetric monitoring studies (see details below).

Samplings conducted in the St. Lawrence River in the context of impact studies or other specific or university projects have never led to the detection of the species. (Sirois pers. comm. 2012). No specimens of Copper Redhorse were captured in Lake Saint-Pierre or its archipelago (between 1995 and 2011) and in Lake Saint-Louis (between 1988 and 2011) or in other sectors of the St. Lawrence River covered by the Réseau de suivi ichtyologique (RSI) fish surveys using experimental nets and beach seines (Dumont 1996; Fournier *et al.* 1996, 1998ab; La Violette and Dumont 2005; La Violette *et al.* 2006; MDDEFP, unpubl. data). Four trawling campaigns in the

[3] Excluding the Rivière Yamaska and Rivière Noire. See the details and justification in the Canadian Range section.

St. Lawrence River between 2007 and 2009 by the *Lampsilis*, a research vessel owned by the Université du Québec à Trois-Rivières, also failed to find any specimens of Copper Redhorse. Although the spatial coverage of the trawl effort was not systematic or uniform, these campaigns did cover a large area extending from upstream of Rigaud (Lac des Deux Montagnes) and Saint-Zotique (Lake Saint-François) to Deschambault–Grondines, i.e., approximately 60 km downstream of Trois-Rivières. A total of 148 tows, covering a distance 130 km, were carried out in habitats of different depth classes including littoral zones (2 m ≤ Z ≤ 5 m), natural trenches (4 m ≤ Z ≤ 23 m), the edge of the channel (3 m ≤ Z ≤ 12 m) and the navigation channel (8 m ≤ Z ≤ 17 m) (MDDEFP, 2014; Paradis pers. comm. 2012). However, in 1942, four specimens were captured in the Sainte-Anne-de-Bellevue and Vaudreuil channels at the head of Lake Saint-Louis (Ottawa River) by Legendre (1942), and one by Vladykov in Lake Saint-Pierre. Six others have been found in Lake Saint-Pierre, including two in 1944 (Cuerrier *et al.* 1946), one in 1947 as well as three in 1971 in its archipelago (Sorel and Berthier channels) (Massé and Mongeau 1974) (Table 1).

Table 1. Records of capture of Copper Redhorse, main sampling programs and fieldwork in the sector of the St. Lawrence River in which the species is known to be present.

	Record of capture		Systematic or large-scale sampling / fieldwork		
	first	**last**	**Year**[1]	**Brief description**	**Reference**
West of the Island of Montréal Sainte-Anne-de-Bellevue and Vaudreuil channels at the head of Lake Saint-Louis Lake Saint-Louis Laprairie Basin	1942	2004	1965 to 1968 1975-1976 1988 to 1990 1997, 2005, 2009, 2011 2004, 2007-2008 2009	Seine and net Net RSI and RSIa (seine and net) Telemetry tracking Trawling campaign with the *Lampsilis*	Mongeau and Massé 1976 Sloterdijk 1977 Dumont 1996 Fournier *et al.* 1998b; La Violette *et al.,* 2006; MDDEFP, unpubl. data (RSI) Gariépy 2008; Hatin *et al.,* 2009 and unpubl. data MDDEFP, 2014
South and east of the Island of Montréal From the Mercier Bridge to Sorel	1973	2008	1973, 1977 1975-1976 1991 to 1993 2001, 2010 1998 to 2006 2004, 2007-2008 2009	RSI (seine and net) Captures by commercial fisher Telemetry tracking Trawling campaign with the *Lampsilis*	Mongeau and Massé 1976; Massé and Mongeau 1976; Mongeau *et al.,* 1980 Sloterdijk 1977 Nilo, 1996 MDDEFP, unpubl. data (RSI) Vachon and Chagnon 2004; MDDEFP, unpubl. data Chagnon 2003a,b; Vachon and Chagnon 2004; Chagnon 2004, 2005 Gariépy 2008, Hatin *et al.,* 2009 and unpubl. data MDDEFP, 2014
Lake Saint-Pierre and its archipelago	1944	2008	1971-1972 1975-1976 1995, 1997 2002, 2003, 2007, 2009, 2010, 2011 2004, 2007-2008 2005 to 2012 2007 to 2009	Seine and net RSI (seine and net) RSI and RSIa (seine and net) RSI and RSIa (seine and net) Telemetry tracking Monitoring of yellow perch recruitment (seine) Trawling campaign with the *Lampsilis*	Massé and Mongeau 1974 Sloterdijk 1977 Fournier *et al.,* 1996, 1998a MDDEFP, unpubl. data (RSI) MDDEFP, unpubl. data (RSI) Gariépy 2008; Hatin *et al.,* 2009 and unpubl. data Brodeur, pers. comm. 2012 MDDEFP, 2014

[1] The years in bold are the years in which systematic or large-scale sampling was conducted

[2] RSI: Réseau de Suivi Ichtyologique

In the Montréal-Sorel section of the St. Lawrence River, the only records of the species date back to 1973, when four specimens were captured between Verchères and Contrecoeur (Massé and Mongeau 1976). It should be noted that, despite fairly exhaustive coverage of the sector by fishing efforts carried out in the summer and fall at some 97 sites from 1991 to 1993 (Nilo 1996) and systematic sampling of the Montréal-Sorel section in 2001 and in 2010 during a fish monitoring study (RSI) (MDDEFP, unpubl. data), no specimens of Copper Redhorse were captured (Table 1). The presence of the species in this part of the St. Lawrence River (Montréal-Sorel section) was recorded in 1998 in the Lavaltrie-Contrecœur sector and nearly every year thereafter, in spring and fall, thanks to the collaboration of a commercial fisher using hoop nets and gill nets. Since 2006, no specimens of the species have been reported in the fishing gear of the commercial fisher, who likely avoids the sites where it would most likely be found. Since the start of a monitoring in collaboration with the commercial fisher, recaptures have been reported every year and the number of new individuals recorded annually has continued to decline since then, from 115 and 86, respectively, in 1999 and 2000, to between 21 and 46 during the 2001-2004 period, to only four in 2005 (Chagnon 2003a,b; Vachon and Chagnon 2004; Chagnon 2004, 2005; Côté pers. comm. 2012). Although the results can be affected by various factors, including hydrological conditions as well as variable fishing effort (which, however, has remained almost comparable from year to year), these results point to a decline in the adult population, particularly because the specimens captured by the commercial fisher have always been large adult specimens.

These observations undoubtedly reflect the extreme rarity of the species, which complicates its detection, since the most recent telemetry studies have revealed a different picture compared to historical captures and more recent sampling programs carried out in the species' range. Indeed, despite a relatively low number of tagged individuals, these studies succeeded in confirming the presence of the species in all of these sectors of the St. Lawrence River and its main tributaries (Gariépy 2008; Hatin *et al.* 2009 and unpubl. data), which constituted the species' historical range except for the Rivière Yamaska and Rivière Noire (COSEWIC 2004). Search effort involving telemetry studies is described in the **Dispersal and Migration** section

Tributaries

<u>Rivière des Mille Îles and Rivière des Prairies</u>

The picture is similar in the Rivière des Mille Îles. Since the capture of 12 specimens in 1971 and 1973 (Mongeau and Massé 1976) in the entire Rivière des Mille Îles, only three other individuals have been collected there, including one at the head of the river (Grand-Moulin rapids) in 1980 (Massé *et al.* 1981) and two in 1996 near the confluence with Rivière des Prairies, downstream from the dam near Île du Moulin at Terrebonne (MDDEFP, unpubl. data). The beach seine surveys conducted by Éco-Nature in the Rivière des Mille Îles during the summers of 2002, 2003 and 2006 and in the fall of 2008 failed to find any specimens of Copper Redhorse (Bisson *et al.* 2002;

Bisson and Gauvin 2007; Boutin *et al.* 2009) (Table 2). However, telemetry studies again confirmed the presence of the species in the Rivière des Mille Îles and detected the species for the first time in the Rivière des Prairies (Gariépy 2008; Hatin *et al.* 2009, 2010 and unpubl. data).

Table 2. Records of capture of Copper Redhorse, main sampling programs and fieldwork in the tributaries in which the species is known to be present.

	Record of capture		Systematic or large-scale sampling / fieldwork		
	first	**last**	**Year[1]**	**Brief description**	**Reference**
Rivière des Mille Îles	1971	2008	1971, 1973 1975-1976 1980 1996 2004, 2007-2008 2002, 2003, 2006, 2008	Community sampling (net and seine) Telemetry tracking Search for young-of-the-year (seine)	Mongeau and Massé 1976 Sloterdijk 1977 Massé *et al.,* 1981 MDDEFP, unpubl. data Gariépy 2008; Hatin *et al*., 2009 and unpubl. data Bisson *et al*., 2002; Bisson and Gauvin 2007; Boutin *et al.,* 2009.
Rivière des Prairies	2004	2008	1971, 1972 1975-1976 1982 to 1988 1995 to 1999 2004, 2007-2008	Community sampling (net and seine) Net Telemetry tracking	Mongeau and Massé 1976 Sloterdijk 1977 Provost *et al.,* 1982; Provost and Fortin 1984; Gendron 1986, 1987, 1988 Fortin *et al*., 2002 (Rivière des Prairies hydroelectric generating station) Gariépy 2008; Hatin *et al.* 2009 and unpubl. data
Rivière Maskinongé	1971	1971	1963 to 1974	Community sampling (net and seine)	Mongeau *et al.,* 1981
Rivière Saint-François	2007	2007	1965 and 1974 2004, 2007-2008	Community sampling (net and seine) Telemetry tracking	Mongeau and Legendre 1976 Gariépy 2008; Hatin *et al.,* 2009 and unpubl. data
Rivière Richelieu (From Chambly dam to the mouth)	1965	2013	1968 to 1970 and 1995 1984, 1985, 1990 to 1994, 1996, 1997 1997 to 1999, 2001, 2003, 2004, 2006 to 2012 2001 to 2005, 2007, 2008 2004, 2007-2008 2004 to 2013	Community sampling (net and seine) Targeted studies on the Copper Redhorse (species biology, search for spawning areas: trap nets, hoop nets, beach seines, electrofishing. Targeted studies on the Copper Redhorse (biology of juveniles, recruitment and population monitoring, search for sub-adults and artificial reproduction: beach seines, gill nets, trawls, purse seines) Monitoring of the Vianney-Legendre fish ladder at Saint-Ours: Operation of the cage and gill net in the entrance basin of the fish ladder Telemetry tracking Artificial reproduction (net in the entrance basin of the fish ladder, operation of the cage of the fish ladder, net at the tailrace of the dam and purse seine)	Mongeau 1979a; Saint-Jacques 1998 Work at Chambly, Saint-Ours and Saint-Charles-sur-Richelieu Branchaud and Fortin 1998, Branchaud and Gendron 1993; Branchaud *et al*., 1993, 1995; Boulet *et al.,* 1995, 1996; Dumont *et al.,* 1997; La Haye *et al.,* 1992, 1993; La Haye and Clermont 1997; Mongeau *et al.,* 1986, 1992 Vachon 1999ab, 2002, 2007b, 2010a (juveniles), 2014 and unpubl. data Groupe conseil GENIVAR, 2002; Fleury and Desrochers 2003, 2004, 2005, 2006; Leclerc and Vachon 2008; Desrochers 2009 Gariépy 2008; Hatin *et al.,* 2009 and unpubl. data Vachon 2010a, 2014 and unpubl. data
Rivière L'Acadie	2008	2008	1968 to 1970 2004, 2007-2008	Community sampling (net and seine) Telemetry tracking	Mongeau 1979a Gariépy 2008; Hatin *et al*., 2009 and unpubl. data
Rivière Yamaska	1948	1992	1963-1975 1976 to 1978	Community sampling (net and seine)	Mongeau 1979b Buth 1978; Harvey 1979

	Record of capture		Systematic or large-scale sampling / fieldwork		
	first	last	Year[1]	Brief description	Reference
Rivière Noire	1963	1964	1985 1987 1991 1992 1995 2012	Seine sampling in a part of the sectors historically inhabited by the species	Mongeau *et al.,* 1986 MDDEFP, unpubl. data La Violette 1996 Boulet *et al.,* 1995 La Violette 1999 N. Vachon; MDDEFP, unpubl. data.

[1] The years in bold are the years in which systematic or large-scale sampling was conducted.

[2] RSI: Réseau de Suivi Ichtyologique

Rivière Richelieu

Since the capture of the first individuals in the Rivière Richelieu in 1965, the presence of the species has been regularly recorded, given the fact that most of the recovery and search efforts requiring the capture and handling of specimens have been carried out in this river. The species was found at 30 stations distributed throughout the river from the Chambly Basin as far as the river mouth (Sorel) during a systematic sampling program carried out from 1968 to 1970 (Mongeau 1979a). In 1995, systematic sampling of the Rivière Richelieu, although less intensive than the previous program, resulted in the capture of a single specimen (Saint-Jacques 1998). However, numerous local studies have succeeded in capturing spawners and fry at Chambly and at Saint-Ours (Branchaud and Fortin 1998; Branchaud and Gendron 1993; Branchaud *et al.* 1993, 1995; Boulet *et al.* 1995, 1996; Dumont *et al.* 1997; La Haye *et al.* 1992, 1993; La Haye and Clermont 1997; Mongeau *et al.* 1986, 1992) and young-of-the-year as well as a few age 1+ and 2+ juveniles, especially in the Saint-Charles-sur-le-Richelieu sector (Boulet *et al.* 1995, 1996; Vachon 1999ab, 2002, 2007b, 2010a and unpubl. data) (Table 2). The most recent telemetry studies on adults have provided more detailed data on the functions that this river plays in the species' life cycle (Gariépy 2008; Hatin *et al.* 2009, 2010 and unpubl. data).

Rivière Yamaska and Rivière Noire

The Copper Redhorse was first recorded in the Rivière Yamaska by Vladykov in the 1940s. Parts of a specimen, captured by Vladykov on June 19, 1948, near Saint-Césaire, are currently in the Cornell University collection (CU 25512) (Jenkins pers. comm. 2003). The species was subsequently found in abundance in the 1960s in the Yamaska (upstream of the Saint-Hyacinthe dam) and Noire rivers (Mongeau 1979b; Mongeau *et al.* 1986, 1992). At that time, these rivers ranked, respectively, second and third in terms of the number of specimens collected (Mongeau *et al.* 1986). Despite visits made to the sector from 1976 to 1978 (Buth 1978; Harvey 1979), in 1985 (Mongeau *et al.* 1986), in 1991 (La Violette 1996), in 1992 (Boulet *et al.* 1995) and in 1995 (La Violette 1999), the presence of the species was reported only once in 1992 in the Rivière Yamaska (Boulet *et al.* 1995). Beach seine sampling in the fall of 2012 covering some 30 stations in the Rivière Yamaska and Rivière Noire in the sectors historically inhabited by the Copper Redhorse did not detect the species, at least no young-of-the-year or juveniles (N. Vachon, MDDEFP, unpubl. data) (Table 2). Given the fragmentation and degradation of the habitats in these rivers, the populations there are most likely extirpated. Targeted studies on the species are required in order to draw more definitive conclusions.

Other Tributaries

Despite large-scale systematic surveys carried out mainly during the 1960s and 1970s in the Saint-François River, Rivière des Prairies and Rivière L'Acadie (Mongeau and Legendre 1976; Mongeau and Massé 1976; Mongeau 1979a; Sloterdijk 1977; Fortin *et al.* 2002), the Copper Redhorse was first reported in these rivers in the 2000s by telemetric monitoring (Gariépy 2008; Hatin *et al.* 2009 and unpubl. data) (Table 2).

Surveys in the Areas Bordering the Species' Range

Areas bordering the range were also covered by large-scale systematic surveys. No Copper Redhorse have ever been found in the Ottawa River or Lac des Deux Montagnes. Other surveys carried out since the late 1990s in the Ottawa River and some of its tributaries in connection with studies on the River Redhorse and other species at risk or on fish communities produced the same results. The species was not among the experimental net captures in Lac des Deux Montagnes in 2010. The Copper Redhorse has never been reported in Lake Saint-François, upstream of Lake Saint-Pierre (St. Lawrence River) or in the upstream section of the Chambly dam (Rivière Richelieu) (Table 3).

Table 3. Main sampling programs and fieldwork in the sectors bordering the range of the Copper Redhorse.

	Systematic or large-scale sampling / fieldwork		
	Year[1]	**Brief description**	**Reference**
SECTORS UPSTREAM OF THE RANGE: St. Lawrence River system and Ottawa River			
Ottawa River and tributaries	1965 1995-1996 1998-1999 1999 2009	Community sampling (net and seine) Community sampling (seine) in 11 tributaries on the north shore Targeted studies on the River Redhorse (various types of nets) Electrofishing Targeted studies on the channel darter: electrofishing and seines	Mongeau 1965 Dubuc 1999 Campbell 2001 Comtois *et al.,* 2004 Pariseau *et al*., 2009
Lac des Deux Montagnes	1964 to 1966-1968 1975-1976 2009 2010	Community sampling (net and seine) Trawling campaign with the Lampsilis RSIa (net)	Mongeau and Massé 1976; Mongeau *et al*., 1982 Sloterdijk 1977 MDDEFP, 2014 MDDEFP, unpubl. data (RSI)2

	Systematic or large-scale sampling / fieldwork		
	Year[1]	**Brief description**	**Reference**
Lake Saint-François	1968	Community sampling (net and seine)	Mongeau 1979c
	1996-2004-2009	RSI (seine and net)	Fournier *et al*., 1997a; Laviolette and Dumont 2005; Vachon *et al*., 2013b
	2009	Trawling campaign with the Lampsilis	MDDEFP, 2014
SECTORS DOWNSTREAM OF THE RANGE: St. Lawrence River			
Bécancour–Batiscan section	1996-2001-2008-2012	RSI (seine and net)	Fournier *et al.,* 1997b; MDDEFP, unpubl. data
Grondines–Saint-Nicolas section	1997- 2006	RSI (seine and net)	Fournier 1998; MDDEFP, unpubl. data
	2007-2008	Trawling campaign with the Lampsilis	MDDEFP, 2014
SECTORS UPSTREAM OF THE RIVIÈRE RICHELIEU: upstream of the Chambly dam			
Upper Richelieu	1968 to 1970	Community sampling (net and seine)	Mongeau 1979a
	2012	RSI (seine and net)	RSI, MDDEFP, unpubl. data
Missisquoi Bay	1965	Community sampling (net and seine)	Mongeau 1979a
	2003	RSI (seine and net)	Bilodeau *et al.,* 2004
	2012	RSI (seine and net)	RSI, MDDEFP, unpubl. data

[1] The years in bold are the years in which systematic or large-scale sampling was conducted

[2] RSI: Réseau de Suivi Ichtyologique

HABITAT

Habitat Requirements

The rivers frequented by the Copper Redhorse are located in a region of Québec of very limited area characterized by a growing season of at least 1,790 degree-days above 5.6ºC and where the summer water temperature exceeds 20ºC. Although the current is slow, usually less than 0.3 m/s, certain segments have short stretches of fast-flowing water where the species finds conditions favourable to spawn. Adults are absent from areas where the water is heavily polluted and turbid (Mongeau *et al.* 1986, 1988, 1992).

Outside the spawning period, adult Copper Redhorse mainly frequent shallow areas (Z ≤ 4 m) with a slow current (≤ 0.5 m/s). Adult summer feeding habitats consist of aquatic grass beds of medium to high density composed primarily of *Vallisneria americana* and *Potamogeton* sp. The abundance of gastropods, fine particle size distribution of the substrate, low current velocity and abundance of dreissenids, in that order, are the variables that determine habitat selection in summer and early fall. The archipelagos of the Boucherville and Lavaltrie-Contrecœur islands in the St. Lawrence River as well as the section of the Rivière Richelieu between Chambly and Saint-Ours are sectors used extensively for feeding by adults during the summer. The average size of the home ranges varies depending on the season and is approximately 0.29 km^2 in summer (n=16), 2.31 km^2 (n=17) in fall and 0.65 km^2 (n=11) in winter. However, there are a few seasonal variations in habitat selection (Gariépy 2008; Hatin *et al.* 2009, 2010 and unpubl. data).

There are currently two known Copper Redhorse spawning sites, namely the archipelago of the Chambly rapids and the tailrace of the Saint-Ours dam (Figure 5). These spawning grounds are in riffle areas, with a moderate to slow current and depths ranging from 0.75 to 2 m. The heterogeneous substrate is composed of fine to coarse gravel, rocks and sometimes even fragments of bedrock partly submerged in the clay (Boulet *et al.* 1995, 1996; Dumont *et al.* 1997; La Haye *et al.* 1992; La Haye and Clermont 1997; Mongeau *et al.* 1986, 1992). Telemetry studies have confirmed the use of these two spawning grounds in places where the substrate is composed of various gravel-cobble-pebble combinations in 95% of cases. These studies have also demonstrated that the species may spawn at greater depths and at higher current velocities. In fact, during the spawning period, 77% of the locations were in areas with a depth ≤ 4.0 m, including 42% in depths ranging from 2.1 to 4 m. Use of areas with a depth of 8 m or more was also demonstrated in the tailrace of the Saint-Ours dam. A large proportion (65%) of the locations used during the spawning period were in areas where the current velocity was ≤ 0.75 m/s, including 55% in areas with a current ranging from 0.25 to 0.75 m/s, while 18% were in areas where the current velocity was ≥ 1.0 m/s (Gariépy 2008; Hatin *et al.* 2009 and unpubl. data). Based on current knowledge about the species' behaviour and a review of the literature, a maximum surface of 1 m^2 (considered conservative) per trio, composed of one female and two males, is required to perform a spawning act (Vachon 2010c).

The first few individuals observed at the head of Lake Saint-Louis were mature and likely in the process of spawning (Legendre 1942). Other sites in the St. Lawrence River, such as the Grand-Moulin rapids in Rivière des Mille Îles, the Dorion and Saint-Anne-de-Bellevue channels at the head of Lake Saint-Louis could potentially meet the spawning requirements of the Copper Redhorse, but the presence of a spawning area there has never been confirmed (Jenkins 1970; Massé *et al.* 1981; Vachon and Chagnon 2004).

Like their congeners, young-of-the-year Copper Redhorse frequent shallow littoral areas during their first growing season. These areas are ≤ 1.5 m deep, gently sloped (≤ 20º) and vegetated. The current is very slow and the substrate is relatively fine (mix of clay-silt and sand) (Vachon 1999a). The section of the Rivière Richelieu that includes Jeannotte Island and aux Cerfs Island at Saint-Marc-sur-Richelieu is an important nursery area for juvenile redhorse, especially the Copper Redhorse, since several wild specimens have been captured there (Vachon 1999ab, 2002, 2007b, 2010a).

The sectors of the Rivière Richelieu where juvenile redhorse have been captured are also frequented by several other species at risk (Massé and Bilodeau 2003; Vachon 1999ab, 2002, 2007b, 2010a) designated by COSEWIC. They include the River Redhorse, considered a species of special concern (COSEWIC 2006) and two threatened species, the Channel Darter (*Percina copelandi*) (COSEWIC 2002) and the Eastern Sand Darter (*Ammocrypta pellucida*) (COSEWIC 2009). These three species are also listed under the federal *Species at Risk Act*, as recommended by COSEWIC. The River Redhorse and the Channel Darter have been designated vulnerable and the Eastern Sand Darter has been designated threatened under the Québec "*Loi sur les espèces menacées ou vulnérables"* (RLRQ, c E-12.01) (LEMV) *(Act respecting threatened or vulnerable species)* (CQLR, c E-12.01).

Habitat Trends

High-quality Copper Redhorse habitats are in decline throughout much of its range. Moreover, its presumed extirpation from the Rivière Yamaska and Rivière Noire is closely linked to environmental degradation. These rivers are located in the most heavily agricultural region of Québec. Agricultural pressures in this region are increasing. The intensification of agricultural activities and urbanization often has a detrimental impact on forested areas. The negative impact of deforestation on aquatic ecosystems is well known. In Montérégie, this phenomenon is worrisome. Wooded areas covered approximately 26% of the territory of Montérégie in 2002. Compared to 1999, this represents a loss of 4% or 12,511 ha. Most of the major tree-cutting has been carried out for agricultural purposes (Soucy-Gonthier *et al.* 2003). The intensification of agricultural activities has counteracted some of the efforts that have been made to clean up discharges of industrial and household waste.

Although the construction of the Vianney-Legendre fish ladder is helping to restore free passage of the Copper Redhorse in the Rivière Richelieu and efforts have been made to clean up municipal discharges, habitat degradation in the Richelieu is worrisome. A large proportion of its watershed is occupied by intensive agricultural activities and urban development is increasing. The river is also used extensively by pleasure craft. These factors are contributing to the degradation of water quality, shoreline alteration and the degradation or destruction of grass beds near the shore in this river, which plays a crucial role in the life cycle of the Copper Redhorse for reproduction and rearing (see details in the Threats and Limiting Factors section).

Located in the most densely populated area of Québec, the St. Lawrence River and its main tributaries face a wide variety of pressures that have significantly modified the habitats over the last 150 years. The sector of the St. Lawrence River currently frequented by the Copper Redhorse is still relatively unfragmented. Depending on the sector, urban and industrial development and even agricultural activities are factors contributing to habitat degradation.

Rivière Yamaska and Rivière Noire

In 1996, 43% (207,041 ha) of the total area of the Rivière Yamaska watershed was under cultivation. In 2006, the figure was 47% (224,894 ha). Since 1976, wide-row crops, which are more polluting, have been increasing and accounted for 66% of crops in 2006, occupying 31% of the area. The trends in the number of livestock units are similar. In 2006, the number of livestock units was 317,892, composed mainly of hogs (57%) and cattle (29%), compared to 233,104 units in 1976 (Berryman 2008; Primeau *et al.* 1999).

Despite the efforts made to improve urban wastewater treatment, which have helped improve water quality, particularly in terms of phosphorus and fecal coliforms, since the 1980s, the Rivière Yamaska is one of the rivers most in need of further clean-up efforts in order to comply with the phosphorus concentration criterion for preventing eutrophication. From 1998 to 2005, the median phosphorus concentration at the mouth of the Yamaska was estimated at 99 µg/L, which is a clear improvement over the levels recorded between 1979 and 1987 (220 µg/L), but still remains three times higher than the criterion for protection against eutrophication (30 µg/L). The average annual total phosphorus load transported by the Rivière Yamaska between 2001 and 2003 (310 tonnes/year) exceeds largely the total maximum allowable load, which is estimated to be 65.2 tonnes annually. Phosphorus inputs of agricultural origin account for 67%, while nearly 25% are of urban origin (point source and nonpoint source). The estimated total nitrogen loads between 2001 and 2003 (7,854 tonnes/year) also exceed the maximum levels permitted by water quality guidelines (2,174 tonnes/year) (Berryman 2008; Gangbazo and Le Page 2005; Gangbazo *et al.* 2005).

In several sectors of the Rivière Yamaska, the situation in terms of contamination by toxic substances during the 1990s was considered worrisome (Berryman and Nadeau 1998, 1999). The median concentrations of PCBs, chlorinated dioxins and furans, and PAHs measured in the Rivière Yamaska at Saint-Hyacinthe between 2001 and 2003 met drinking water standards but exceeded established water quality guidelines for the protection of aquatic life. The concentrations of nonylphenol ethoxylates, recognized endocrine disruptors, were also high and occasionally exceeded standards, especially in winter (Berryman 2008).

In the Rivière Yamaska, the lowest ratings (fair and poor) of the indices, which describe the integrity of the benthic (IBGN) and fish (IBI) communities, were obtained in the section historically inhabited by the Copper Redhorse. The situation is slightly better in the Noire River, where ecosystem integrity, as shown by these two indices, is rated fair to excellent in the sector where the species has previously been found (La Violette 1999; Saint-Onge 1999). Based on the Québec water quality index, the Index of Bacteriological and Physicochemical Quality (IQBP), and the Eastern Canadian Diatom Index (IDEC) as measured in these sectors of the Rivière Yamaska and Rivière Noire between 2001 and 2003, water quality is rated as poor or very poor (Berryman 2008).

Rivière Richelieu and its tributaries

In the Rivière Richelieu watershed, the area of cultivated land increased by 10% from 1979 to 1991. During that period, major changes occurred in the composition of livestock and poultry, including a decline in the number of cattle and an increase in the number of hogs and poultry. These changes had an impact on crop type at the watershed scale: the area devoted to wide-row direct-seeded crops (mainly corn) increased by 150%, whereas the area devoted to other grain crops and forages fell by 28% and 38%, respectively (Simoneau 1993). In 1995, the total area under cultivation was 141,176 ha (Piché and Simoneau 1998), while in 2006, agricultural activities occupied 167,630 ha, or nearly 70% of the watershed. Wide-row crops (corn), which require significant amounts of pesticides and fertilizers, now account for 78% of the area under cultivation. Despite a slight decrease in the number of farms, there was a 23% increase in the number of livestock units, primarily hogs, between 2001 and 2006; the number of livestock units was estimated at 84,383: approximately 49% cattle, 39% hogs and nearly 10% poultry (Simoneau and Thibault 2009).

According to the phosphorus data recorded between 2001 and 2003, the average annual total phosphorus load transported by the Rivière Richelieu (391 tonnes/year) exceeds the total maximum allowable load to prevent eutrophication (346 tonnes/year) (Gangbazo and Le Page 2005; Gangbazo *et al.* 2005). Simoneau and Thibault (2009) estimate that 50% of inputs are of agricultural origin. The assessment of ecosystem integrity based on the composition of benthic (IBGN) and fish (IBI) communities shows that the Rivière Richelieu is rated fair or poor over nearly three-quarters of its length. A significant reduction in the IBGN as well as a notable decline in pollution-sensitive benthic species have been recorded at the outlet of the Chambly Basin downstream of the Rivière des Hurons and the Rivière L'Acadie (agricultural tributaries). The IBI shows that the sector between Saint-Marc-sur-Richelieu and Saint-Ours is one of the most degraded of the whole river, owing to the increase in urban, industrial and agricultural pressures (Piché 1998; Saint-Jacques 1998).

The assessments based on the Bacteriological and Physicochemical water Quality Index (IQBP) and the Eastern Canadian Diatom Index (IDEC) carried out between 2001 and 2003 also indicate that the state of the aquatic ecosystems within the Rivière Richelieu watershed is still quite precarious, despite the efforts made to clean up agricultural pollution (Simoneau and Thibault 2009). Poor ratings were obtained for the IDEC at Saint-Charles-sur-Richelieu and at Sorel, while ratings obtained for the IQBP were satisfactory or borderline between 2001 and 2003, and borderline to poor between 2005 and 2007, respectively, in the same municipalities. According to Simoneau and Thibault (2009), the more positive water quality assessments obtained with the IQBP index compared to the IDEC index can be explained by the fact that the former does not consider certain pesticides and other toxic substances likely to adversely affect organisms and modify biological communities.

In the Rivière Richelieu, as in several sectors of the Rivière Yamaska, the situation in terms of contamination by toxic substances is considered worrisome (Berryman and Nadeau 1998, 1999). A number (approximately 10) of pesticides were detected in the main channel of the Rivière Richelieu in 1998 and 1999, including atrazine and metolachlor. Even though the water quality guidelines were not exceeded in most cases, their simultaneous presence is considered worrisome. Estimated concentrations of certain toxic substances of urban and industrial origin between 2001 and 2003 in surface water at the mouth of the Rivière Richelieu show that the median concentrations of PCBs and chlorinated dioxins and furans exceeded the water quality guidelines for the protection of piscivorous terrestrial wildlife and for the prevention of contamination of water and aquatic organisms, while the PAH levels recorded met standards. With the exception of aluminum, the median concentration values of some 20 metals measured at the mouth of the Rivière Richelieu in 2004 and 2005 met surface water quality criteria (Simoneau and Thibault 2009).

The Rivière des Hurons and the Rivière L'Acadie are the two main tributaries of the Rivière Richelieu. The first empties into the Chambly Basin, near the Copper Redhorse spawning ground, and the second flows directly into the mouth of the Chambly Basin. These two rivers drain heavily agricultural areas and have severe low-water problems in summer. Regardless of the index used (IQBP or IDEC), the water quality ratings of these rivers obtained since the late 1990s are very poor and the most recent data show no improvement. Both the number and concentrations of pesticides recorded in the water at the mouth of the Rivière des Hurons and the Rivière L'Acadie are higher than in the main channel of the Rivière Richelieu. As many as 29 pesticides were detected in the Rivière des Hurons between 2002 and 2004, including atrazine, metolachlor, bentazon and dicamba. Although the concentrations of some of these pesticides, including atrazine, and a few insecticides exceeded water quality guidelines in the Rivière des Hurons, they were lower than in previous years. The same substances were detected in the Rivière L'Acadie, but no concentrations exceeding the guidelines were recorded (Giroux *et al.* 2006; Simoneau and Thibault 2009). During the 2008-2010 period, the number of pesticides detected in the Rivière des Hurons was similar and there was no improvement in levels of contamination by toxic substances compared to the preceding reference period (2005-2007). Metolachlor, atrazine and bentazon were again among the most frequently detected substances, as well as a few other herbicides, including glyphosate, imazethapyr and flumetsulam. The frequency of detection of a number of herbicides increased. From 2008 to 2010, 10% to 19% of the samples exceeded water quality guidelines (chronic aquatic life toxicity criterion–CVAC). The substances that exceeded the guidelines were atrazine and the insecticides chlorpyrifos, carbaryl, carbofuran, diazinon and azinphos-methyl (Giroux and Pelletier 2012).

St. Lawrence River

In the St. Lawrence River, agricultural pressures, although present, are less significant. However, urbanization and related activities, as well as industrial activities are having adverse impacts on the ecosystems of the St. Lawrence. In Québec, urban sprawl has been continuing for several decades and the Great Lakes–St. Lawrence Lowlands region is the most industrialized in the country (Bernier *et al.* 1998). Major clean-up efforts have been undertaken since the 1970s. These measures, aimed at both municipal and industrial activities, have helped to improve water quality in the St. Lawrence River by reducing contamination of bacteriological origin as well as discharges of organic matter and suspended solids (Hébert and Belley 2005). The bacteriological and physicochemical quality index (IQBP) showed that the percentage of stations where water quality was good or satisfactory was always higher than 65% from 1995 to 2002, but was less than 33% between 2003 and 2005. These changes are apparently related to the generalized increase in turbidity in the St. Lawrence River as well as an increase in the concentrations of suspended solids and phosphorus in the sectors downstream of Lake Saint-Pierre. They are believed to be the result of changes in the flow regime of the St. Lawrence River as well as an increase in erosion processes (Hébert 2006).

An initial assessment of the biotic integrity of the St. Lawrence River based on the IBI shows that the ecosystem is fairly degraded (La Violette *et al.* 2003). The values, estimated from the first two cycles of the RSI fish survey, show that the state of health of fish communities in the St. Lawrence River is poor to fair (Mingelbier *et al.* 2008).

Declining St. Lawrence River water levels, as well as the acceleration of shoreline erosion by wave action from passing vessels, resulting from increased traffic by commercial ships and pleasure craft, are also disturbing aquatic ecosystems. Over the past 20 years, the water levels of the St. Lawrence River have been falling and low-water problems are becoming increasingly severe. For many species, including the Copper Redhorse, this represents losses in both the quantity and quality of habitat (spawning, feeding and nursery). Several biological processes depend on subtle synchronisms between water levels, temperature and flow (Robichaud and Drolet 1998). The impacts of these changes on the Copper Redhorse are not known.

BIOLOGY

Despite the fact that the Copper Redhorse is an extremely rare species, a lot of critical knowledge has been acquired over the last decades. Much of this information comes from technical reports, some of which are the result of recovery activities. A few articles have also been published in scientific journals, in particular on the biology, artificial reproduction, genetic characterization and ecotoxicology of the species.

Life Cycle and Reproduction

Reproduction in the natural environment

The Copper Redhorse lives for at least 30 years (de Lafontaine *et al.* 2002a) and reaches a considerable size. The size (total length) of spawners is generally greater than 500 mm (Mongeau *et al.* 1986, 1992), although according to Jenkins (1970), males can reproduce once they reach 475 mm. Both sexes reach sexual maturity at the beginning of the 10th year; hence the reproductive lifespan appears to be at least 20 years. The duration of natural generation of the species appears to be about 20 years. However, based on recent observations, particularly during artificial reproduction activities, which clearly indicate an aging of the population, the average age of spawners is currently likely to be around 25 years (see also the Artificial Reproduction, Rearing and Stocking section).

In 12 females captured in 1984 in the Chambly Basin that varied from 547 to 690 mm in total length (TL), fecundity ranged from 34,900 to 111,860 eggs. The fecundity of a 2 kg female is approximately 32,750 eggs (Mongeau *et al.* 1986, 1992). Similar results were obtained in 32 female spawners used during artificial reproduction activities in 2008 and 2009. In these females, which ranged in size (TL) from 551 to 711 mm and weight from 2.4 to 5.8 kg, fecundity was estimated at around 20,000 eggs per kilogram. In total, they produced between 24,500 and 197,200 eggs (N. Vachon, MDDEFP, unpubl. data). The number of eggs produced and the diameter of the eggs released correlate positively with the weight of female spawners (Branchaud and Gendron 1993; Branchaud *et al.* 1995; Mongeau *et al.* 1986, 1992). Generally, a sex ratio in favour of males is observed at reproduction sites, which suggests that they travel to the spawning areas before the females or that they are more active (Branchaud *et al.* 1993, 1995). However, the artificial reproduction activities carried out since 2004 do not indicate a clear trend in this regard (N. Vachon, MDDEFP, unpubl. data; Leclerc and Vachon 2008). As reported in other *Moxostoma*, Copper Redhorse leap out of the water during the reproduction period. This behaviour has been observed at or near spawning sites and is used as an indicator of reproduction activity (Dumont *et al.* 1997; Vachon and Chagnon 2004).

Spawning begins around the last week of June and can continue until the first week of July, at which time the water temperature ranges from 18 to 26ºC. Although some studies suggest that spawning may occur at night, it appears that the level of activity of spawners declines from late evening until sunrise (Boulet *et al.* 1995; Dumont *et al.* 1997; La Haye *et al.* 1992; Mongeau *et al.* 1986, 1992). The artificial reproduction activities (see the details in the Physiology and Adaptability section) confirm that spawners are also active during the day, particularly in the afternoon, when the largest proportion of spawner captures occurs and when a few females in full ovulation have been captured. During the 2004-2012 period, artificial reproduction activities took place between June 10 and 29, when the water temperature ranged from 19.2 to 23.3ºC (N. Vachon, MDDEFP, unpubl. data).

The eggs, which range in diameter from 2.81 to 3.42 mm, are non-adhesive and orangey-yellow in colour. At a constant temperature of 20ºC, hatching occurs after 89 to 127 degree-days, peaking at around 108 to 110 degree-days, which represents 4.5 to 6.5 days of incubation. At hatching, the yolk sac larvae measure 9.09 mm on average. At the start of exogenous feeding, at which time resorption of the yolk sac is practically completed, the average size of the larvae is 13.11 mm. This important stage generally occurs 15 days after fertilization. Emergence of the larvae (beginning of swimming behaviour) has been observed 12 to 16 days after fertilization, with peak activity after 15 days (Branchaud and Gendron 1993; Branchaud *et al.* 1993, 1995).

Growth

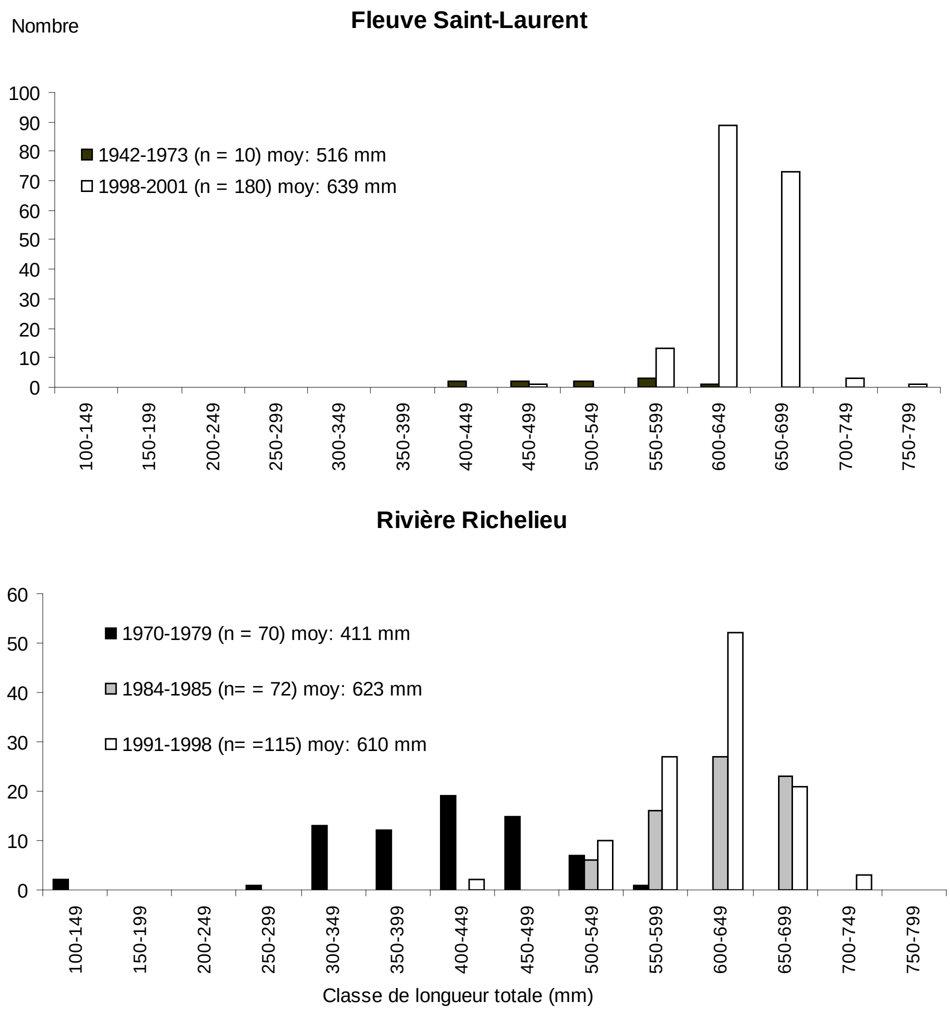
In the Copper Redhorse, the growth rate in length and weight is generally higher than its congeners. No difference in growth has been observed between the sexes. The females are generally more corpulent than the males. On the basis of the results obtained by back calculation, a Copper Redhorse measures on average 370, 550 and 670 mm respectively at 5, 10 and 20 years (Mongeau *et al.* 1986, 1992). To date, the largest specimen captured measured 780 mm (Vachon and Chagnon 2004). The heaviest individual was a 711 mm female weighing 6.14 kg captured in June 2005 in the Rivière Richelieu (N. Vachon, MDDEFP, unpubl. data).

In fall, the average size of young-of-the-year redhorse in the Rivière Richelieu reflects the temporal sequence of spawning of the different species. The size of young-of-the-year is closely linked to the cumulative number of degree-days above 10ºC during the growing season, which ends at the latest around the end of September, even if fall is late. The average total length of natural-origin young-of-the-year redhorse captured from September to November ranged from 37.5 to 48.5 mm (average of 41.6 mm). These juveniles are more vulnerable than their congeners to winter mortality because they are smaller. At the same period in 1999 and 2001, the average size of young-of-the-year in the other four redhorse species was greater than 57 mm. Young-of-the-year Shorthead and Silver Redhorse measured on average between 72 and 83 mm (Vachon 1999ab, 2002). The hypothesis of a greater impact on Copper Redhorse of selective winter mortality according to size has never been proven, but cannot be ruled out (Vachon 1999a).

Survival

The Copper Redhorse population is aging, which appears to be attributable to recruitment problems stemming from low reproductive success (Branchaud *et al.* 1993, 1995; Boulet *et al.* 1995, 1996; La Haye *et al.* 1992; Vachon and Chagnon 2004). The shift in size distribution profiles toward higher values, between 1942 and 2001, is obvious and statistically significant (Figure 7). Other examples also indicate the presence of a high proportion of old individuals in the population and a very low level of natural recruitment (see also the Artificial Reproduction, Rearing and Stocking section). In the spring of 2003, the average size of Copper Redhorse captured in the Lavaltrie-Contrecœur sector was 646 mm; 90% of the specimens measured 620 mm or more

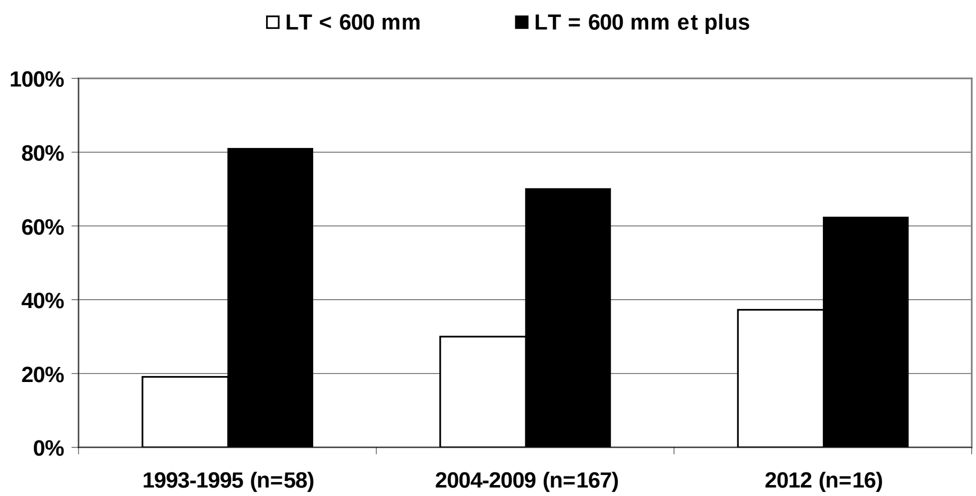
(Chagnon 2003). The individuals captured in the fish ladder (Rivière Richelieu) in 2002 and in 2003 were over 600 mm in length (Fleury and Desrochers 2003, 2004). Of the 36 individuals that were part of the telemetry studies in 2004 and 2007 (Gariépy 2008; Hatin *et al.* 2009), only one measured less than 500 mm, 8% measured between 500 mm and 599 mm, and 89% measured 600 mm or more.



English Translation:
Fleuve Saint-Laurent St= Rivière Richelieu / Lawrence River = Rivière Richelieu
Nombre = Classes de longueur totale (mm) / Number = Total length class (mm)
Moyenne = average / moy = average

Figure 7. Size frequency distribution of Copper Redhorse in the St. Lawrence River and the Rivière Richelieu from 1942 to 2001 (adapted from Vachon and Chagnon 2004).

It is also evident from the handling of specimens during artificial reproduction activities that the specimens are old. As was the case between 1993 and 1995, when the first artificial reproduction experiments were conducted (see the details in the Physiology and Adaptability section), the largest proportion of individuals captured (60% to 80%), whether or not they were used in the artificial reproduction program, was composed of specimens measuring 600 mm or more. Comparisons among the three artificial reproduction periods, interrupted in 2010 and 2011, show a slight decrease in the proportion of individuals 600 mm or more, which can be considered encouraging (Figure 8).



English Translation:
LT= 600 mm et plus / TL = 600 mm and longer

Figure 8. Proportion (%), by size class, of Copper Redhorse handled during the years when artificial reproduction activities were carried out.

The number of immature Copper Redhorse (TL < 500 mm) specimens captured remains marginal. Only five individuals in the 400 to 499 mm size range were captured during artificial reproduction activities, including one in 1994 and four between 2004 and 2011. Other indicators also reflect the precarious situation of the population and stock of spawners. A report issued after six years of artificial reproduction activities (2004 to 2008) as well as an analysis of 2009 data reveal a relatively high rate of recapture of spawners (male and female), i.e., 10.7% in 2005, 8.3% in 2007, 25% in 2008 and 11.4% in 2009.

Furthermore, there have been virtually no captures of juveniles longer than 100 mm for 40 years (Vachon and Chagnon 2004 and MDDEFP, unpubl. data). The only two feral specimens in the 100 to 150 mm size range (age 1+) were captured in 1974 in the Rivière Richelieu (Mongeau *et al.* 1986). In 2004, one natural-origin Copper Redhorse (TL = 244 mm, age 2+) was captured in the Rivière Richelieu (Vachon 2007b). The only two other records of specimens in this size range date back to 1970 in the Rivière Richelieu (Mongeau *et al.* 1979a). No specimens of Copper Redhorse in the 150 to 199 mm size class have ever been caught. These data show mainly the very low reproduction success of the Copper Redhorse as other redhorse species in the same size range can be captured using similar techniques and fishing gear.

Physiology and Adaptability

Artificial reproduction, rearing and stocking

The first Copper Redhorse artificial reproduction and rearing experiments were conducted in the early 1990s. Efforts to reproduce the species artificially have been successful, but hormonal induction had to be used (Branchaud and Gendron 1993; Branchaud *et al.* 1993, 1995). In these studies, spawners were held for several days in tanks. A few adult specimens were also held for several months or even a few years in aquariums. However, spawners must be handled very carefully because they exhibit severe stress reactions when captured (Branchaud and Gendron 1993). Holding adults in long-term captivity has, however, proven difficult. Most of the specimens die (Dumont *et al.* 1997; Dumont pers. comm. 2003).

In 1994, juveniles were reared in a semi-closed system at the Tadoussac hatchery as well as in a small experimental pond (Branchaud *et al.* 1995; Turgeon 1995). The survival rate of the larvae was approximately 23% in the fertilized pond and 87% at the Tadoussac hatchery. The larvae and juveniles feed on both artificial and natural foods (Branchaud and Gendron 1993; Branchaud *et al.* 1993, 1995; Turgeon 1995). Although the rearing experiments in 1994 were encouraging, some adjustments had to be made given the low growth rate (average length of 22.8 mm after 91 days of rearing) and the high prevalence of scoliosis observed in the individuals produced in the semi-closed system at Tadoussac. In 1995 and 1996, rearing in fertilized ponds at the Baldwin Mills hatchery was recommended. The improvement of rearing techniques made it possible to produce larger advanced fry in fall (average size 42 mm) and the deformation problems were corrected (Branchaud and Fortin 1998; Dumont *et al.* 1997; Dumont pers. comm. 2003).

Following these studies, some 100,000 fry were stocked, on an experimental basis, in the Rivière Richelieu during the falls of 1994, 1995 and 1996. The survival of the specimens stocked in the fall of 1994 is very improbable because they were very small in size (average: 22.8 mm) and in poor condition (thin). In 1995, some 40,000 fertilized eggs were released in the Chambly rapids, 35,000 unfed fry were raised at Baldwin Mills and approximately 21,000 larger advanced fry (average: 42 mm) were stocked in the Rivière Richelieu in fall (Branchaud *et al.* 1995; Branchaud and Fortin 1998; Dumont *et al.* 1997; Dumont pers. comm. 2003). With the exception of one specimen captured in 1997, the origin of which is unknown (Vachon 1999a), no Copper Redhorse likely to have been stocked has been found (Boulet *et al.* 1995). However, this absence of recaptures cannot be interpreted as a failure because it is often difficult to monitor small fish returned to their natural environment. In fact, their dispersal greatly reduces the chances of recapture (Boulet *et al.* 1995).

Studies on young-of-the-year and subsequent monitoring of the recruitment of young-of-the-year carried out in September 1998, 1999 and 2001 in the Rivière Richelieu (Saint-Marc-sur-Richelieu sector) showed that the relative abundance of the Copper Redhorse compared to its congeners was ≤ 0.35%. Between 1998 and 2001, a single young-of-the-year Copper Redhorse was captured each year; however, none were captured during similar attempts in 2003 (Vachon 1999ab, 2002, 2007b). In 1997, despite much more intensive fishing efforts, which covered a larger sector of the Rivière Richelieu, the results were scarcely any better; the relative abundance of young-of-the-year Copper Redhorse was 0.63% (Vachon 1999a). Given the very low natural reproductive success observed in the Copper Redhorse, it became obvious that the recruitment rate was insufficient to offset natural mortality. Because these observations, combined with the findings on the aging of the population (see above), were very worrisome, facilities were developed specifically for rearing Copper Redhorse and an artificial reproduction plan was quickly developed before the capture of spawners becomes a major obstacle to implementation of the plan.

Beginning in 2004, an artificial reproduction and stocking program was implemented, with the aim of rebuilding the spawning stock. The goal of this program, based on factorial matings involving 10 males and 10 females annually, is to produce and stock, each year, 500,000 larvae and 15,000 fry belonging to 100 families. The program will have a minimum duration of 10 consecutive years, i.e., the period required to attain the objective of maintaining 90% of the genetic diversity of the existing population over a period of 100 years (Bernatchez 2004; Lippé *et al*. 2006). Nine ponds were constructed at the Baldwin-Coaticook hatchery and are reserved for the rearing of Copper Redhorse. This program has been one of the priority actions of the Copper Redhorse recovery strategies since 2004 (Équipe de rétablissement du chevalier cuivré du Québec 2005, 2012; DFO 2012).

Conditions were favourable for carrying out these activities from 2004 to 2009 and in 2012. The spawners are kept in captivity for three to nine days during these operations before being released back into the capture site. Owing to the extreme weather and hydrological conditions in 2010 (warm, early spring and low water levels) and 2011 (historical flooding in the Rivière Richelieu), it was not possible to capture a sufficient number of spawners to enable the program to be carried out (N. Vachon, MDDEFP, unpubl. data). From 2004 to 2012, nearly 3,300,000 larvae, 168,400 fall fry and 86 age 1+ juveniles belonging to 541 families were stocked in the Rivière Richelieu. The success of the operations varies from year to year depending on the number of spawners, the quality of the gametes and the rate of survival in the ponds, which is dependent on the prevailing summer weather conditions (N. Vachon, MDDEFP, unpubl. data).

Because breeding males were becoming increasingly rare (higher recapture rate since 2007 and declining abundance) and because significant asynchrony between males and females captured was limiting the performance of the artificial breedong program, development of semen cryopreservation protocols were initiated. The first trials were conducted in 2012 and the results are encouraging. About 3,550 fingerlings produced by cryopreserved milt were stocked in the Rivière Richelieu in September 2013 (Vachon 2010a; 2014 Vachon *et al*., 2013a, 2014).

The monitoring of redhorse recruitment in the Rivière Richelieu is the main approach chosen for measuring achievement of the species protection and recovery objectives. This sampling, using beach seine nets, has been carried out annually since 1999 (with few exceptions) in the Saint-Marc-sur-Richelieu sector (near Jeannotte Island and aux Cerf Island) and in the section of the Rivière Richelieu between Saint-Ours and Sorel since 2008.

Since 2006, this monitoring has been supplemented by genetic analyses to determine the origin (natural or artificial) of the juvenile redhorse and to evaluate the genetic diversity of the progeny. The relative abundance of young-of-the-year redhorse compared to their congeners recorded during monitoring of recruitment in the Saint-Marc-sur-Richelieu sector was 7.7%, 27.6%, 2.7%, 25.4% and 2.4%, respectively, in 2004 and from 2006 to 2009. No specimens of Copper Redhorse were captured in this sector in 2010 or 2011 (Vachon 2007b, 2010a and unpubl. data). In 2004, because of the preservation method used, it was not possible to determine the origin of the specimens through genetic analyses. However, subsequent analyses show that most of the individuals originate from artificial reproduction (Côté *et al.* 2007 and 2010). Despite the stocking of larvae and juveniles in the sector downstream from the Saint-Ours dam since 2009 and the resumption of monitoring of recruitment in this section of the river in 2008, no young-of-the-year Copper Redhorse have been captured there, except in 2011, when one natural-origin individual (TL = 35 mm) was among the 194 young-of-the-year redhorse, all species combined, found in the sector (N. Vachon, MDDEFP, unpubl. data).

Natural reproduction of Copper Redhorse in the Rivière Richelieu was confirmed in 2006, 2008, 2009 by the capture of young-of-the-year. However, the level remains extremely low. Of all the young-of-the-year Copper Redhorse captured from 2007 to 2009, the ratio of specimens originating from artificial reproduction relative to natural reproduction was around 9:1 on average. Of the nine natural-origin young-of-the-year captured during this period, only three were from two parents that were not listed in the genetic database. These results show that spawners, both male and female, survive the handling during artificial reproduction activities well and are able to reproduce naturally even several years after an initial capture. However, these results are also worrisome because they confirm that the pool of spawners in the current population is very small (Côté *et al.* 2007, 2010; Vachon 2007b, 2010a and unpubl. data). The monitoring of redhorse recruitment in the Rivière Richelieu in 2010 and 2011, years in which it was impossible to carry out artificial reproduction, once again demonstrates the very low rate of natural reproduction of Copper Redhorse. This monitoring led to the capture of a single natural-origin young-of-the-year in the downstream sector of the Saint-Ours dam in 2011 (N. Vachon, MDDEFP, unpubl. data).

The rate of survival of stocked young-of-the-year to a more advanced age is not known, but the monitoring carried out provides several observations of interest. To date, the survival of stocked juveniles has been demonstrated up to the second year with the capture of an age-1+ specimen in 2006 that was produced artificially in 2005 as well as the capture, in 2009, of an age-1+ juvenile (TL= 120 mm) stocked the previous year and another age-2 specimen (TL= 243 mm, weight = 300 g) that was stocked in 2007 (Côté *et al.* 2007, 2010; Vachon 2007b, 2010a). The survival of young stocked at the larval stage was also demonstrated in 2007 when the larvae and young fry were marked with oxytetracycline (Beaulieu 1996) differently before being stocked. Of the 13 young-of-the-year captured in the fall of 2007, all originated from artificial reproduction, three of which were stocked at the larval stage (Brassard 2008; Vachon 2010a). Genetic analyses show that heterozygosity as well as allelic richness are comparable between spawners and juveniles, but a slight loss of allelic diversity was detected (Côté *et al.* 2010). These results are encouraging, but the survival of stocked specimens beyond two years remains to be demonstrated. As in the past, the capture of sub-adults, particularly individuals aged 2 to 10 years, is infrequent and more targeted efforts in 2010 were not successful (N. Vachon, MDDEFP, unpubl. data).

Based on a literature review, it is shown that several catostomids have a certain degree of spawning site fidelity (Vachon 2010c). Current knowledge, as well as the observations made during artificial reproduction operations, also suggests that Copper Redhorse have a similar behaviour and it is possible that stocked individuals exhibit the same behaviour (Vachon 2010a). Modde *et al.* (2005) also documented this spawning site fidelity behaviour in another species in the same family, *Xyrauchen texanus*, through a telemetry study on stocked natural-origin and artificially produced individuals. Artificial reproduction activities and population monitoring in the coming years will be decisive in demonstrating this behaviour. More concrete results are expected within five to ten years (Vachon 2010a,c).

Ecotoxicology

A study of the contamination profiles of seven Copper Redhorse aged 9 to 33 that died accidentally in the tailrace of the Saint-Ours dam reveals that the level of contamination of the liver, gonads and muscle tissue by bioaccumulative substances (mercury, trace metals, PCB congeners, dioxins and furans) is comparable or sometimes even lower than that recorded in other younger catostomids of the Yamaska and Rivière Richelieu basins. The concentrations found are lower than those recognized as harmful to reproduction or as affecting egg and fry survival (de Lafontaine *et al.* 2002a).

However, these results do not rule out the possibility that other contaminants, which do not accumulate in the organism, such as certain pesticides, are disrupting reproductive processes. On the basis of the observations made during artificial reproduction experiments, it appears that, even if the growth and initial development of the gonads take place normally, difficulties arise, particularly in the females, during the later stages of maturation as well as when the gametes are released. None of the females captured at the peak reproductive period released eggs under gentle abdominal pressure and only very few males expressed milt (Branchaud and Gendron 1993; Branchaud *et al.* 1993, 1995). However, during the artificial reproduction activities carried out since 2004, a few females in full ovulation and a few milting males were captured (N. Vachon, MDDEFP, unpubl. data). The hypothesis that physiological disorders impairing final gamete maturation are of toxicological origin was the subject of an extensive review of the literature by Gendron and Branchaud (1997). These authors concluded that it is probable that metabolites of alkylphenol polyethoxylates (APEs) impair final gamete maturation in the Copper Redhorse (endocrine disruptors), while atrazine as well as other pesticides (e.g., diazinon and carbofuran) may confuse the olfactory system of spawners, which would affect the perception of pheromones, substances that help synchronize gamete maturation as well as spawning behaviour in both sexes. Given the presence of these contaminants in the Rivière Richelieu, particularly during the Copper Redhorse reproduction period, the hypothesis is plausible (Gendron and Branchaud 1997).

More recently, studies were conducted at the Maurice Lamontagne Institute (MLI) aimed at verifying certain aspects of the endocrine disrupter hypothesis and developing expertise in and techniques for measuring vitellogenin levels in plasma and mucus in catostomids. Experiments were conducted on Shorthead Redhorse and a few Copper Redhorse originating from the initial artificial reproduction experiments and kept in captivity at the Montréal Biodôme. The results proved to be very promising, particularly with respect to the measurement of vitellogenin levels in mucus, a non-invasive method (Maltais and Roy 2007, 2009; Maltais *et al.* 2010). Since 2010, samples have been taken from spawners obtained from the natural environment, including Silver Redhorse and Copper Redhorse, as well as during Copper Redhorse artificial reproduction activities. The measurement of vitellogenin levels in mucus samples from Copper and Silver Redhorse spawners is currently being carried out and this work is supplemented by the histological examination of gonads from Silver Redhorse (MLI and MDDEFP, studies under way).

Dispersal and Migration

The first telemetric study on adult Copper Redhorse was conducted in 2004 when 20 specimens (11 males and nine females) were captured in the St. Lawrence River (Lavaltrie-Contrecoeur sector) and in the Vianney-Legendre fish ladder (Rivière Richelieu) from April to June and fitted with internal or external transmitters. Monitoring was carried out from April 27 to November 26, 2004, by boat and occasionally by plane as well as using a fixed station set up in the Vianney-Legendre dam. In total, 618 telemetry locations were recorded (Gariépy 2008). A second study was conducted in 2007 and 2008 in order to supplement the information on the species' movements and habitat use, including during the winter season, a period not covered by the previous study. Sixteen specimens (seven males, eight females and one of indeterminate sex) captured in the Vianney-Legendre fish ladder in the spring of 2007 were fitted with an internal emitter. Satisfactory monitoring results were obtained for eleven specimens from October 2007 to August 2008. These studies generated 803 telemetry locations, including 174 in fall, 230 in winter and 191 in spring (Hatin *et al.* 2009, 2010 and unpubl. data). In order to conduct an analysis of habitat selection, 12 habitat characterization parameters were evaluated at all the telemetry location sites as well as at several randomly selected unused stations, i.e., 278 in 2004 and 283 in 2007 and 2008.

The Copper Redhorse is a migratory species. During pre- and post-spawning movements, which take place mainly from April to June, individuals can cover distances of 43 to 138 km. The average daily distance travelled is higher in spring (0.93 km/day), compared to 0.13, 0.55 and 0.17 km/day, respectively, in the summer, fall and winter (Gariépy 2008; Hatin *et al.* 2009, 2010 and unpubl. data).

The juveniles are dispersed by drifting of the larvae after hatching. The larvae are distributed along the river. Unfed fry and juveniles subsequently remain associated with the grass beds near the shore during their first growing season and at least at the beginning of the second. In fall, particularly when the water temperature is less than 12ºC, the young-of-the-year move away from the shores and head toward deeper water (Vachon 1999a). These observations support those obtained during experiments on the behaviour of juvenile stages of redhorse conducted in 1996, which show that at fall temperatures (7.5ºC), young-of-the-year Copper Redhorse exhibit a clear preference for coarser substrates, while such behaviour was not observed at temperatures of 21ºC (Branchaud and Fortin 1998).

Diet and Interspecific Interactions

The diet of adult Copper Redhorse is specialized and consists almost exclusively of molluscs (more than 90% by number). In the rivers and streams of the St. Lawrence Plain, several other species feed on molluscs, including the River Redhorse, but not so exclusively (Mongeau *et al.* 1986, 1992). Indeed, the particular configuration of the Copper Redhorse's pharyngeal apparatus is well adapted to crushing (Eastman 1977; Jenkins 1970; Mongeau *et al.* 1986). There is very little overlap between the diet of the Copper Redhorse and that of the other species. The taxa most frequently found in the digestive tracts of Copper Redhorse are Unionidae, Sphaeriidae and Amnicolidae, in its entire range. An examination of non-animal substances found in the digestive tracts of redhorse suggests that there is a spatial segregation between the species when they feed (Mongeau *et al.* 1986, 1992). Telemetry studies have demonstrated the importance of gastropod-rich aquatic grass beds as feeding habitat for adults during the summer period (Gariépy 2008; Hatin *et al.* 2009; DFO 2011). The species most associated with the Copper Redhorse are the carp (*Cyprinus carpio*), the River Redhorse and the Silver Redhorse (Mongeau *et al.* 1992).

Conversely, in the young-of-the-year and age-1 individuals captured in spring, there was little difference in diet between the species, despite the fact that at this period of ontogenesis, the morphology of the Copper Redhorse's pharyngeal apparatus is already distinctive and can be used to distinguish it from its congeners. In juvenile Copper Redhorse, whose total length ranges from 36.0 to 53.5 mm, more than 50% (by number) of prey are microcrustaceans (Cladocera: Chydoridae; Copepoda: Harpacticoida). Worms (Nematoda) and algae (Desmidiae) also occupy an important place and chironomid larvae are also frequently ingested (Vachon 1999a). In rearing ponds, chironomid larvae and pupae as well as cyclopoid copepods were the main organisms consumed by very early juvenile stages of Copper Redhorse (TL=13.0 to 22.1 mm) (Branchaud *et al.* 1995). In the laboratory, older Copper Redhorse juveniles (average size 108.4 mm) fed on zebra mussels (*Dreissena polymorpha*) less than 8 mm (Branchaud and Gendron 1993).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

The fact that the species is extremely rare and displays migratory patterns makes it very difficult to estimate population abundance and monitor trends. Given the diversity of fishing gear, level of effort and periods covered by the various sampling, recovery and monitoring activities over the years, spatial comparisons cannot be made. Many individuals have been tagged, but the number of recaptures is very low. The estimates of abundance and fluctuations in the size of the population are based mainly on inferences made from information from various sources as well as on comparisons of the relative abundance of Copper Redhorse with its congeners.

Although activities to reintroduce the species within its natural range have been carried out since 2004 by stocking larvae and young-of-the-year produced artificially from wild spawners, and although monitoring of recruitment shows a significant contribution of these individuals to young-of-the-year, it is still too early to draw any definitive conclusions concerning their net contribution to the abundance of the current adult population. In fact, the detection of sub-adults is still too marginal and their participation in natural recruitment has still not been demonstrated since they do not reach sexual maturity until around the age of 10 years. The contribution of the stocked specimens is therefore not considered in the assessment of population size and trends, because the eligibility criteria set out in the COSEWIC Guidelines on Manipulated Populations (COSEWIC 2010) have not been met.

Abundance

Despite the marking of numerous specimens with spaghetti tags or microchips in the Rivière Richelieu in the 1990s, none has ever been recaptured. It is therefore impossible to estimate the number of individuals. Since the discovery of the species, approximately 1,000 natural-origin Copper Redhorse of all ages have been captured. Currently, the only estimate available was produced in the fall of 2000, based on information (capture-tagging-recapture) obtained from the commercial fisher in Lavaltrie-Contrecœur. At that time, at most a few hundred individuals (generally fewer than 500) were circulating in the sector. The limits of the confidence interval at 95% of these estimates, which are based on only a few recaptures, vary, depending on the method used, from about 40 to fewer than 1,650 individuals in almost all cases (Vachon and Chagnon 2004).

The studies carried out over the last few years also demonstrate that the number of mature individuals is still extremely low. For example, compared to the first few years of artificial reproduction, there are fewer spawners, greater effort is required to capture them and the recapture rate is high in some years, the proportion of spawners greater than 600 mm in length is still high and captures of immature individuals, particularly sub-adults in the 100 to 499 mm size class, are still extremely low (Vachon 2010a and unpubl. data; see also details in the preceding sections). Other factors may partially explain these observations, such as specific hydrological and climatic conditions which can influence pre-spawning migration, behaviour during the reproduction period as well as the spawning periodicity, which may not be annual. The fact remains that based on these results, there is still no evidence of an increase in the pool of spawners.

These observations are strongly supported by the results obtained during monitoring of the Copper Redhorse recruitment and population, which show that the level of natural reproduction is very low, that the contribution of stocked young-of-the-year relative to wild individuals is quite significant (9:1), and that in nearly 50% of cases, one or both parents of young-of-the-year redhorse from natural reproduction are known in our databases (Côté *et al.* 2007, 2010; Vachon 2007b, 2010a and unpubl. data; see also details in the preceding sections).

Fluctuations and Trends

The Copper Redhorse was formerly more abundant in various periods of history and prehistory. Archeological digs at the site of Mandeville, on the west shore of the Rivière Richelieu (Iroquois occupation between 1450 and 1550 AD), and the site of the Jacob Wirtele inn at Place Royale in Old Montréal (early 19th century) show that Copper Redhorse represented respectively 16.7% and 9.1% of the identified redhorse species (Courtemanche and Elliott 1985; Ostéothèque de Montréal Inc. 1984; Courtemanche pers. comm. 2003). These results are significantly higher than the proportions of 2% to 3% reported during the fish surveys of waters in the Montréal area between 1963 and 1985 (Mongeau *et al.* 1986), and higher than the figure of 0.04% recorded at the fish ladder in the spring of 2003 (Fleury and Desrochers 2004). Copper Redhorse bones have also been found at other locations, including Laprairie (BiFi-23), dating back to the French occupation of the area in the late 17th and early 18th centuries, Place Jacques-Cartier in Montréal (BjFj-44) (Courtemanche pers. comm. 2003) and the archeological site at Station 4 at Pointe-du-Buisson (BhFl-1, 920-940 AD) located on the south shore of the St. Lawrence River, at its mouth in Lake Saint-Louis (Courtemanche 2003). From 1997 to 2003 as well as in 2010 and 2011 (years in which there was no stocking), the relative abundance of wild young-of-the-year compared to its congeners always ranged between 0% and 0.5%. Recaptures of spawners are frequent, virtually annual, and sometimes reach significant proportions during artificial reproduction activities, which, since 2008 has prompted minor changes in the artificial reproduction protocol in order to fully exploit the potential, particularly from a genetic perspective, of the last old spawners (Vachon 1999ab, 2007b and 2010a and unpubl. data). These findings are also indicators of the very low abundance of spawners even today.

Rescue Effect

No rescue is possible.

THREATS AND LIMITING FACTORS

Generalities

Because the rivers and streams inhabited by the Copper Redhorse are located in the most densely populated areas of Québec, anthropogenic factors are undoubtedly endangering the species. However, the causes of its decline cannot be determined with certainty. The species appears most likely to be the victim of a combination of factors. The threats affecting habitat quality are the most widespread, take different forms, and their occurrence is high in the species' range (DFO 2007a). Habitat degradation and fragmentation, as well as low reproductive success, appear to be the main factors in explaining its decline (Gendron and Branchaud 1997; Mongeau *et al.* 1986, 1988, 1992; Scott and Crossman 1973, Vachon 2003b). Given its sensitivity to pollution and siltation, the fact that individuals congregate at certain times of the year, its extremely small range and that there are only two known reproduction sites, the species is particularly vulnerable to any natural disasters that could affect its habitat in any way.

Changes in the hydrological regimes, industrialization, urbanization, shoreline alteration, agricultural pressures, shipping and commercial fishing are the six major pressures to which the St. Lawrence River has been exposed in the last 150 years (Mingelbier *et al.* 2012). These pressures have undoubtedly had an adverse effect on the Copper Redhorse over time and many are still very present. The level of contamination and turbidity of the water, bank erosion and the biotic integrity of the freshwater fish communities are still a concern (State of the St. Lawrence Monitoring Committee, 2008). The St. Lawrence River, where important adult feeding areas are located, remains an important waterway and is not protected from oil spills and future development of port infrastructure. Finally, the St. Lawrence River is attractive for the development and exploitation of new forms of renewable energy and some infrastructures (hydrokinetic electricity-producing turbines) are being tested.

In the Rivière Richelieu, the alteration of riparian environments, the loss of shallow littoral zones through encroachment and the degradation of aquatic grass beds in nursery areas are also worrisome and increasing, and are the result of urban development and increased recreational boating. Shoreline erosion is obvious and pervasive in the Rivière Richelieu and threatens the stability of roads along the river. In recent years, urgent bank stabilizations have been achieved in some places. A stabilization plan, scheduled over a period of ten years, is in its final stages of preparation. Stabilization works involve, in the vast majority of cases, the use of mechanical stabilization techniques and sometimes the use of counter-weighting methods. These infrastructures lead to the destruction, degradation and disruption of shallow littoral areas and aquatic vegetation which are known to be nursery and growth habitat for young Copper Redhorse and which are unique to the Rivière Richelieu. In this river, as well as in the Rivières Yamaska and Noire, water quality degradation resulting from agriculture activities is also a major concern.

The introduction of exotic and invasive species and pathogens is likely to be an additional limiting factor for the Copper Redhorse, particularly in the St. Lawrence River and the Rivière Richelieu. Finally, climate change (global warming, extreme climate and weather events) may also contribute to exacerbating certain threats and limiting factors, and their long-term effects are still difficult to determine. For example, suboptimal temperatures during the spawning season and growth of larvae and young-of-the-year (early warming in spring, cool summer) are likely to affect the reproductive success of the species as well as survival of juveniles in the first year.

Biological Characteristics

Several characteristics of Copper Redhorse biology, such as late maturity (around 10 years), its specialized diet and its late spawning season, which contribute to increasing the risks of exposure to contaminants and to producing young-of-the-year that are smaller in fall than those of its congeners, constitute factors which increase its vulnerability. Furthermore, according to Parent and Schmirl (1995), the biological characteristics of the Copper Redhorse are similar to the general profile of the species most at risk of extinction, identified on the basis of 51 characteristics of threatened (n=29) or non-threatened species (n=88).

Habitat Fragmentation (see also biology and habitat trends sections)

The species' range is very limited and is currently restricted to the St. Lawrence River system and its main tributaries. In light of the most recent studies, particularly on the genetic characterization of the species, which confirms that there is only a single population (Lippé *et al.* 2004, 2006), as well as the telemetry studies and population monitoring, which demonstrate that the Copper Redhorse is a migratory species dependent for completion of its life cycle on both the St. Lawrence River and the Rivière Richelieu (Gariépy 2008; Hatin *et al.* 2009, 2010; Vachon 2007b, 2010a and unpubl. data), it is clear that maintaining the connectivity and free passage between these two systems is a key factor for survival of the species.

Hydrological Regime Modifications

Changes in the management of water levels in the St. Lawrence River as well as flow patterns near the spawning grounds in the Rivière Richelieu could degrade feeding habitats and spawning areas and be harmful for the species.

More frequent and prolonged periods of low water flows in the St. Lawrence River (Croley 2003; Verhaar 2010) may pose an additional threat to the species by making potential spawning areas inaccessible and by limiting the size of feeding grounds (Hatin *et al.,* 2010). This trend, which first became evident about 10 years ago and is currently raising serious concerns not only for the Copper Redhorse, but also for all fish communities, is the subject of numerous studies and consultations. Dredging activities in the St. Lawrence River for navigation purposes or for maintenance of port infrastructure could intensify with the lower St. Lawrence River water levels (Lambert

2011). This represents a threat, the scope of which remains to be determined precisely. Added to this are the greater variations in both the frequency and amplitude of hydrological and climatic conditions, particularly in spring (Boyer *et al.* 2010), which likely have an impact on the recruitment success of redhorse in the Rivière Richelieu (N. Vachon, unpubl. data), although the overall long-term impact on the Copper Redhorse is still difficult to assess. Low water levels are likely to limit the availability / quality of habitats particularly nursery and spawning areas in the Rivière Richelieu (especially at the Chambly spawning ground). Extreme flood events during the spawning season are potentially also harmful to the reproductive success.

Pollution and Habitat Degradation Related to Urban and Industrial Development (see also Habitat Trends section)

The increase in urban and industrial development is an additional factor contributing to habitat degradation because it causes degradation of shorelines, littoral environments (including aquatic grass beds) as well as encroachments and emissions of various pollutants.

Toxicants from urban and industrial sources

Wastewater discharges in the St. Lawrence River (~100 m^3/s at Montréal) contain numerous pharmaceutical products that are still active, antidepressants and some of their metabolites, as well as estrogenic substances. These substances are known to have the effect of feminizing and reducing the reproductive capabilities of the males of some fish species living in the wastewater plume from the Communauté métropolitaine de Montréal (Aravindakshan *et al.* 2004). Antidepressants affect the brain activity and sexual attraction of fish (Lajeunesse *et al.* 2011). Together, Montréal, Laval, Québec City, Longueuil, Trois-Rivières and Salaberry-de-Valleyfield account for ~60% of the total wastewater flow of the province (Mingelbier *et al.* 2012). Numerous contaminants from urban and industrial source have been detected in the St. Lawrence River, especially in sediments (State of the St. Lawrence Monitoring Committee, 2008). The Copper Redhorse is exposed to these toxicants because some of its habitats are located in the effluent of the treatment plants of the cities of Montréal, Longueuil and Laval (Équipe de rétablissement du chevalier cuivré du Québec, 2012).

Development and Production/Exploitation of Renewable and Non-renewable Energy

The development and production of new forms of energy is booming and southern Québec is not an exception. Currently, it is difficult or impossible for most of them to assess the scope of their long-term impacts on the survival and the recovery of the Copper Redhorse. Some forms of energy, activities or infrastructures to promote the exploitation and transport which are in development or have been the subject of preliminary projects could potentially have a negative impact on the species and its habitats. For example, few hydrokinetic electricity-producing turbines are already in the St. Lawrence River near Montréal. In the range of the Copper Redhorse, installation of turbines on existing dams has been considered as well as the construction of new dams for power generation. Finally, the exploration of shale gas is beginning in Québec and is currently under a moratorium (MDDEFP, unpubl. data). The impact of their large-scale extraction are under evaluation.

Pollution and Habitat Degradation Related to Agricultural Activities (see also Habitat Trends section)

Toxicants from agricultural sources

As mentioned above, the serious difficulties experienced by the Copper Redhorse in reproducing in the natural environment are also quite likely associated with toxicological factors which hinder the final maturation of gametes and affect the olfactory abilities of spawners (Gendron and Branchaud 1997). Water contamination by the widespread use of pesticides therefore constitutes an important limiting factor to consider. Because it spawns later (late June/early July) than its congeners, the Copper Redhorse appears to be more exposed to contaminants since this period corresponds to the peak periods of fertilizer application as well as reduced river flows. The 1998 and 1999 surveys show that atrazine is omnipresent in the Rivière Richelieu and that the highest levels generally coincide with the period when spawners congregate or during the Copper Redhorse spawning period. Some ten other types of pesticides (metolachlor, 2,4-D, bentazone, etc.) have been detected in the main channel of the Rivière Richelieu during the Copper Redhorse spawning period. Little is known about the effects of such a combination of contaminants on aquatic organisms (Gendron and Branchaud 1997; Giroux 2000). Inputs of toxic substances near the Chambly spawning ground, via the Rivière des Hurons, continue to be a source of concern, because the concentrations of atrazine and many other pesticides, some of which are believed to be endocrine disrupters, remain high (Giroux *et al.* 2006; Giroux and Pelletier 2012; Simoneau and Thibault 2009). Pesticides have various adverse effects on the aquatic environment, which are documented in an increasing diversity of organisms, including algae, diatoms, aquatic plants, amphibians and fish (Giroux and Pelletier 2012).

Toxic substances are also likely to affect molluscs on which the Copper Redhorse feeds exclusively. In the basins of the Rivière Richelieu and Rivière Yamaska, the integrity of the benthic communities is considered fair or poor over at least half of their length. This deterioration of integrity is also directly linked to agricultural, urban and industrial pressures (Piché 1998; Saint-Onge 1999). The negative impact of current agricultural practices on habitats and wildlife, including the Copper Redhorse, is increasingly recognized (Société de la faune et des parcs du Québec 2002).

Acceleration of Erosion Processes and Excessive Sediment Input

The acceleration of erosion and increased turbidity (siltation) resulting from agricultural activities, deforestation and urbanization also appears to affect the Copper Redhorse. These processes are threatening the integrity of aquatic ecosystems by degrading the habitat and disturbing the entire food chain, including molluscs, an essential food source for the Copper Redhorse. The central and lower portions of the Rivière Yamaska are particularly affected by siltation and the increase in turbidity. In the basins of the Rivière Richelieu and Rivière Yamaska, certain maxima recorded (turbidity and suspended solids) are sufficient to adversely affect populations of aquatic invertebrates, particularly if these conditions persist (Vachon 2003b). Most fish in the family Catostomidae, specifically those in the genus *Moxostoma*, are extremely sensitive to high levels of pollution, siltation and turbidity (Vachon 2003b). Moreover, in Karr's index of biotic integrity (IBI) (1981), the number and species composition of individuals belonging to the family Catostomidae is one of the 12 descriptors used. More recent studies show that changes in the structure of the Catostomidae community reflect the biological integrity of the ecosystem (Emery *et al.* 1999). In several cases, the history of the constriction of the range of several members of this family since the beginning of the century has coincided with the deterioration of biotic integrity (Jenkins and Burkhead 1994; Scott and Crossman 1973; Trautman 1981). The Copper Redhorse exhibits biological characteristics and ecological requirements (reproduction and feeding patterns) similar to those of other species known to be most affected by habitat degradation, caused by siltation and increased turbidity (Vachon 2003b).

Eutrophication of Aquatic Habitats

The eutrophication of rivers and streams negatively impacts the Copper Redhorse and could favour certain co-occurring species, such as carp (*Cyprinus carpio*) and Tench (*Tinca tinca*), that are potential competitors of the Catostomidae (Mongeau *et al.* 1986, 1992; Dumont *et al.* 2002) because of their greater ability to survive in nutrient-enriched and less oxygenated environments. The effects of the eutrophication of aquatic environments such as Lake Saint-Pierre that have large shallow littoral zones, where different water masses meet but do not mix, can significantly change habitats and the food chain. In fact, more recently, the proliferation of very dense aquatic grass beds has been observed near the mouth of the tributaries on the south shore of Lake Saint-Pierre, attributable to high inputs of nutrients combined with the decrease in water levels and an increase in water temperature. These studies also demonstrated that the percolation of water through these vast grass beds has resulted in oxygen-depleted areas in the aquatic environment downstream, the effects of which were evident over the entire food chain, including the fish community, and that these areas were now colonized by a benthic cyanobacterium (*Lyngbya wollei*) (Hudon and Carignan 2008; Hudon *et al.* 2011). This habitat degradation, attributable in part to nutrient loads from agricultural activities, appears to be one of the factors explaining the problems with Yellow Perch (*Perca flavescens*), recruitment in Lake Saint-Pierre and the collapse of the population despite many significant changes in sport and commercial fishing regulations in the last 15 years (Magnan *et al., in preparation*).

Invasive Non-Native / Alien Species and Pathogens

Invasive alien species pose a threat to the Copper Redhorse. Since the 1990s, two new alien fish species have been detected and have spread in the Copper Redhorse's range. The Tench (*Tinca tinca*) was introduced in the Upper Richelieu in the early 1990s and is now very well established and abundant in the sector upstream of the Chambly Basin. Given its high fecundity and its ability to adapt to various environmental conditions, even the most adverse, the Tench could represent an additional threat to the Copper Redhorse, but its impact is still unpredictable (Dumont *et al.* 2002; Vachon and Dumont 2000). The Tench could compete with the Copper Redhorse for food resources at various stages in its life cycle. This fish is a generalist and opportunistic benthivore. Insect larvae, molluscs and benthic crustaceans are part of its diet (Cudmore and Mandrak 2011). Molluscs (gastropods), various crustaceans and insect larvae have been found in the stomachs of a few adult individuals from the Rivière Richelieu (Guibert 2000). The Tench has since progressed slowly in the Rivière Richelieu. Since 2010, low numbers of adults, juveniles and young-of-the-year have been captured in the Saint-Marc-sur-Richelieu sector (important nursery area) where the species likely finds conditions for reproduction. The Tench is now also present in the St. Lawrence River, where it was first observed in 2006. Since 2011, a year marked by historical flooding in the Rivière Richelieu, the Tench has progressed rapidly in the St. Lawrence River and records are increasing. In the fall of 2011, the species was detected for the first time in the fish weir of the Aquarium du Québec in Québec City, which has been in operation since 1964 (Masson *et al.* 2013; Pelletier *et al.* 2012).

The case of the Round Goby (*Neogobius melastonomus*) is also very worrisome. The species was first detected in the waters of the St. Lawrence River in 1997, in the fish weir of the Aquarium du Québec. The RSI fish surveys of the St. Lawrence River have documented its very rapid progression in terms of expansion of area and abundance throughout the St. Lawrence River and its presence is now documented as far as the Ouelle River area (Pelletier *et al.* 2012). In 2009, the Round Goby was the third most abundant species in the littoral zones of Lake Saint-François. The species is very abundant in certain sectors of Lake Saint-Louis and the Montréal-Sorel section and its abundance is increasing. The Round Goby is also well established in Lake Saint-Pierre but, to date, is less abundant than in Lake Saint-François. Changes in fish communities are evident in a few sectors of the St. Lawrence River and, in some cases, are most likely related to the arrival and progression of Round Goby populations (Reyol *et al.* 2010; Brodeur *et al.* 2011; Vachon *et al.,* 2013b). The Round Goby was first detected in the Rivière Richelieu in 2011 with the capture of a specimen at the river mouth during redhorse recruitment monitoring activities (Vachon, 2014). To date, there have been no other confirmed records in the Rivière Richelieu, but the risk of spread of the species is high given that fishers tend to use them as bait despite the fact that this is prohibited (Fortin pers. comm. 2012). The Round Goby can reach far higher densities than native benthic fish species. It can become a fierce competitor of redhorse for food resources. In fact, like certain redhorse species, its diet includes molluscs and it is capable of crushing them with its pharyngeal teeth. It also feeds on zooplankton, chironomid larvae, small fish species, and the eggs and larvae of larger fish (Poos *et al.* 2010; Kornis *et al.* 2012).

The arrival of alien fish species remains a concern in the St. Lawrence River and its major tributaries and in the Rivière Richelieu not only for the Copper Redhorse, but also for all fish fauna, particularly in a context of climate change. The release of alien fish into the water during religious ceremonies was already reported in the Montréal region a few years ago. Other species, presumably released by aquarists, have also been recently reported in the St. Lawrence River and its tributaries (Brodeur pers. comm. 2012).

In view of the fact that the Copper Redhorse's diet is based almost exclusively on molluscs, any disturbances that would have an impact on this group of invertebrates could also adversely affect the Copper Redhorse. The zebra mussel (*Dreissena polymorpha*) is well established in the St. Lawrence River. Studies show that the species is also on the rise in the Rivière Richelieu. Little is known about the potential impact of this species on the ecosystem of the river, but it is likely to be significant (Cusson and de Lafontaine 1997; de Lafontaine *et al.* 2002b). The adverse effects of the introduction of zebra mussel on native species of molluscs are well known. Some groups, on which the Copper Redhorse feeds almost exclusively, specifically pelecypods and gastropods, could be affected (Dermott and Kerec 1997; Stewart and Haynes 1994). Moreover, because zebra mussels have a great ability to concentrate contaminants (Bruner *et al.* 1994), the effects of contaminant bioconcentration will have to be studied if the mussels are ingested in large numbers by the Copper Redhorse. In the laboratory, juvenile Copper Redhorse have been observed to feed on zebra mussels (Branchaud and Gendron 1993). The evolution of the benthic communities of the Rivière Richelieu in the presence of these mussels is very important given that any change in these communities could adversely affect the Copper Redhorse (de Lafontaine *et al.* 2002b; Vachon 2003b).

Finally, given the high vulnerability of the Copper Redhorse, mass mortalities associated with viral hemorrhagic septicemia (VHS), or other invasive pathogens, could significantly affect the survival and recovery of the species (Équipe de rétablissement du chevalier cuivré du Québec, 2012).

Sportfishing and Commercial Harvest

By-catches pose a non-negligible threat to the status of the population. The studies by Branchaud and Jenkins (1999) concluded that the species may have been severely impacted by overfishing during the 19th century. At the time, the Copper Redhorse was prized as a food fish and hence there was strong market demand for it. Although commercial fishing of Copper and River Redhorse has been banned for nearly 20 years, the harvesting of other redhorse species is still permitted, including the Greater Redhorse (*Moxostoma valenciennesi*), a congener that can easily be confused with the Copper Redhorse by less experienced persons. Given the significant efforts being made to rebuild the spawning stock, by-catches of sub-adults and adults could increase in the coming years as well as the risks of mortality from commercial fishing under the current regulatory context. The sport fishing regulations are more restrictive and prohibit the capture and possession of all species of sucker and redhorse in virtually the entire range. It has been demonstrated that catches of Copper Redhorse by sport fishers pose a genuine threat and this activity is being more closely monitored. These monitoring activities have shown that members of certain ethnic communities (Asians and Eastern Europeans) seek out and use the redhorse as a food fish (Fortin pers. comm. 2012).

Pleasure Craft Activities

Finally, pleasure craft traffic in the reproduction areas in the Chambly rapids during the Copper Redhorse spawning and egg incubation period is another factor contributing to endangering the species (Gendron and Branchaud 1997, 2001). The "*Règlement sur le refuge faunique Pierre-Étienne-Fortin"* (RLRQ C-61.1, r.46) (*Regulation respecting the Pierre-Étienne-Fortin Wildlife Preserve*) (CQLR,c. C-61.1, r.46) de la *"Loi sur la conservation et la mise en valeur de la faune"* (RLRQ, c. C-61.1) from the (*Act respecting the conservation and development of wildlife*) (CQLR, c. C-61.1), adopted in November 2003, has improved the protection of this important spawning ground and limited the disturbance of spawners and the trampling of eggs. However, the management and monitoring of the wildlife preserve over the last 10 years as well as the telemetry studies show that raising awareness of wildlife preserve users and visitors is an important aspect and that certain regulatory amendments and restrictions are required in order to improve protection of the spawning sites. Monitoring activities also show that pleasure craft activities are clearly increasing in the Richelieu River, especially in Saint-Marc-sur-Richelieu area where there is a very productive nursery area for the species, and that these activities contribute to riverbank erosion and aquatic vegetation deterioration.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

As is the case of other fish species, the Copper Redhorse and its habitat receive a level of protection under two Québec laws, namely the *"Loi sur la conservation et la mise en valeur de la faune"* (RLRQ, c. C- 61.1) (LCMVF) *(Act respecting the conservation and development of wildlife)* (CQLR, c. C-61.1) and the *"Loi sur la qualité de l'environnement*" (RLRQ, c. Q-2) *(Environment Quality Act)* (CQLR, c. Q-2).

The Copper Redhorse (*Moxostoma hubbsi*) was designated threatened in 1987 by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (Mongeau *et al.* 1988). The situation described in La Haye and Huot (1995) and numerous initiatives by members of the environmental community led to the designation of the Copper Redhorse as a threatened species in April 1999 under the Québec *"Loi sur les espèces menacées ou vulnérables"* (RLRQ, c E-12.01) (LEMV) (*Act respecting threatened or vulnerable species*) (CQLR, c E-12.01). This status is the highest level of protection that can be granted to a species in Québec and is applied when the loss of the species is feared. The Copper Redhorse is the first species to have been so designated under this act. However, this designation does not provide any special protection for Copper Redhorse habitats. These habitats are and remain protected by the "*Règlement sur les habitats fauniques"* (RLRQ, c. C-61.1, r.18) (*Regulation respecting wildlife habitats*) (CQRL c. C-61.1, r.18) made pursuant to the *"Loi sur la conservation et la mise en valeur de la faune"* (RLRQ, c. C- 61.1) (LCMVF) (*Act respecting the conservation and development of wildlife*) (CQLR, c. C-61.1).

Following the issuing of the updated status report (COSEWIC 2004), the Copper Redhorse was designated Endangered by COSEWIC. The species was officially designated Endangered in December 2007 under the *Species at Risk Act* (S.C. 2002, c. 29) and listed in Schedule 1 of SARA after the public consultations (DFO 2005) and the socio-economic analysis of the Copper Redhorse listing (DFO 2007b) were finalized, as required under this act. Recovery potential assessment has also been done (DFO 2007a). Listing in Schedule 1 of the *Species at Risk Act* provides legal protection of the species because it prohibits the killing, harming, harassing, capturing or taking of species at risk and/or the destruction of critical habitat of species at risk. As required under section 37 of the *Species at Risk Act*, an initial recovery strategy was developed, which includes a description of the characteristics of the species' critical habitats at various stages in its life cycle as well as mapping of the areas designated to date in its range (DFO 2012). This description and this mapping are based on a detailed analysis (DFO 2009, 2011) of observations made at the spawning areas and young-of-the-year nursery areas, historical records of capture as well as results of studies on habit selection by adults obtained during telemetry monitoring in 2004, 2007 and 2008 (Gariépy 2008; Hatin *et al.* 2009, 2010 and unpubl. data).

The Copper Redhorse is also protected by several other regulatory measures. In fact, use of redhorse (all species) as bait-fish has been banned since the 1980s and commercial fishing of Copper and River Redhorse has been prohibited since 1995. Sport fishing capture and possession of all redhorse and sucker species in the Rivières Richelieu, Yamaska and Noire has been banned since 1998. In 2009, these regulations were amended and now cover the species' entire known range, with the exception of Lake Saint-Pierre and its archipelago (*Québec Fishery Regulations*) (SOR/90-214 and SOR/2008-322). A ban on commercial bait fishing has been in place since April 1, 2008, in the Rivière Richelieu, from downstream of the Chambly dam to the St. Lawrence River.

Three provincial recovery plans (1995-1999, 1999-2003 and 2004-2008) have been implemented since 1995 (Comité d'intervention 1995, 1999; Équipe de rétablissement du chevalier cuivré, 2005). The recovery and protection activities set out in these plans fall under three major headings: 1–Conservation (23%), 2–Awareness-raising and communication (15%), and 3–Knowledge acquisition and monitoring (62%). A large proportion of the 107 activities have been (51%) or are currently in the process of being carried out (25%) (Équipe de rétablissement du chevalier cuivré du Québec, 2014, *in press*).

A fourth provincial recovery plan (2012-2017) was prepared jointly with the first recovery strategy under the *Species at Risk Act*. The recovery goal presented in these documents is to attain a self-perpetuating population of 4,000 mature individuals within 20 years while maintaining 90% genetic diversity (Équipe de rétablissement du chevalier cuivré du Québec, 2012; DFO 2012).

The protection and recovery of the Copper Redhorse are also based on education, preventive and enforcement actions carried out by wildlife protection officers to ensure compliance with the various acts and regulations. As is the case for many other species at risk, an initial provincial protection plan for the Copper Redhorse was prepared in 2011 by the Direction de la protection de la Faune de L'Estrie-Montréal-Montérégie. A report on the activities carried out was produced at the end of the first year of the intervention plan (Direction générale de la protection de la faune, 2011ab).

Non-Legal Status and Ranks

The World Conservation Union (IUCN) has considered it vulnerable since 1996 (Gimenez 1996). The species is considered critically imperilled at the provincial (rank S1), national (rank N1 since December 5, 1996) and global scale (rank G1 since September 19, 1996). The American Fisheries Society assigned the Copper Redhorse the status of endangered species in 2008 (NatureServe 2012).

Habitat Protection and Ownership

The habitats of the Copper Redhorse are mainly under public ownership. However, some small tributaries may be privately owned. The territory of the Pierre-Étienne-Fortin Wildlife Preserve is the subject of special protection measures (Figure 5). This wildlife preserve, which covers an area of 63 ha, is partly under private ownership. The river bed is owned by the Nature Conservancy of Canada (NCC) and certain islands (Saint-Jean archipelago) are owned by the municipality of Richelieu.

Because the littoral habitats surrounding the shorelines of Jeannotte Island and aux Cerfs Island (Saint-Marc-sur-Richelieu sector) are recognized as strategic nursery habitats for the Copper Redhorse, these islands now receive some degree of protection. The Nature Conservancy of Canada acquired Jeannotte Island (13.68 ha) in 2006 and aux Cerfs Island (17.16 ha) in 2009. Ownership of aux Cerfs Island has since passed to the Government of Québec and a conservation easement is maintained there by NCC. A proposal to create a wildlife preserve is currently being prepared. Since 2010, awareness-raising activities aimed at area users have been carried out by NCC and the watershed organization Comité de concertation et de valorisation du bassin de la rivière Richelieu (COVABAR). The aquatic grass beds around the islands have been marked by some 46 buoys in an effort to encourage recreational boaters to slow down, and two docks with awareness posters have been installed. Elsewhere, the Îles de Contrecoeur National Wildlife Area, the Parc des Îles-de-Boucherville and the Rivière-des-Mille-Îles Wildlife Preserve also provide some degree of protection to a few Copper Redhorse habitats (DFO 2011).

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INFORMATION SOURCES

Aravindakshan, J., V. Paquet, M. Gregory, J. Dufresne, M. Fournier, D.J. Marcogliese, and D. Cyr. 2004. Consequences of xenoestrogen exposure on male reproductive function in spottail shiners *(Notropis hudsonius).* Toxicol. Sci. 77:156-165.

Beauchard, O. 1998. Morphologie comparée des arcs branchial et pharyngien des cinq espèces de chevalier : *Moxostoma anisurum, Moxostoma carinatum, Moxostoma hubbsi, Moxostoma macrolepidotum et Moxostoma valenciennesi*, rapport présenté dans le cadre du cours d'initiation à la recherche, Montréal, Université du Québec à Montréal, 20 p.

Beaulieu, A. 1996. Évaluation de la rémanence de marques fluorescentes sur des suceurs cuivrés juvéniles (*Moxostoma hubbsi*) 18 mois après une première exposition à l'oxytétracycline, Québec, ministère de l'Environnement et de la Faune, Direction de la faune et des habitats, Québec, 10 p.

Bernatchez, L. 2004. Considérations génétiques et protocole de reproduction relatifs au plan de rétablissement du chevalier cuivré (*Moxostoma hubbsi*), document présenté à la Société de la faune et des parcs du Québec et à Pêches et Océans Canada, 43 p.

Bernier, L., P. Lachance, L. Quilliam et D. Gingras. 1998. Rapport sur l'état du Saint-Laurent – La contribution des activités urbaines à la détérioration du Saint- Laurent, Équipe conjointe bilan, composée de représentants d'environnement Canada, de Pêches et Océans Canada et du ministère de l'Environnement et de la Faune du Québec, Sainte-Foy. Rapport technique.

Berryman, D., et A. Nadeau. 1998. Le bassin de la rivière Richelieu : contamination de l'eau par les métaux et certaines substances organiques toxiques, *in* Le bassin versant de la rivière Richelieu : l'état de l'écosystème aquatique–1995, ministère de l'Environnement et de la Faune (éd.), Direction des écosystèmes aquatiques, Québec, envirodoq n° EN980604, rapport n° EA-13, section 2.

Berryman, D., et A. Nadeau. 1999. Le bassin de la rivière Yamaska : contamination de l'eau par les métaux et certaines substances organiques toxiques, *in* Le bassin versant de la rivière Yamaska : l'état de l'écosystème aquatique—1998, ministère de l'Environnement et de la faune (éd), Direction des écosystèmes aquatiques, Québec, envirodoq nº EN990224, rapport nº EA-14, section 3.

Berryman, D., 2008. État de l'écosystème aquatique du bassin versant de la rivière Yamaska : faits saillants 2004-2006, Québec, ministère du Développement durable, de l'Environnement et des Parcs, Direction du suivi de l'état de l'environnement, ISBN 978-2-550-53592-8 (PDF), 22 p.

Bilodeau, P., Dumas, B. et H. Massé. 2004. Composition et état de santé de la communauté des poissons de la baie Missisquoi, lac Champlain, été 2003. Ministère des Ressources naturelles, de la Faune et des Parcs, Direction de l'aménagement de la faune de Montréal, de Laval et de la Montérégie, Longueuil, Rapport technique 16-23, xii + 43 p. + annexes.

Bisson, R, G. Dufour et I. Mathieu. 2002. Inventaire du chevalier cuivré sur la rivière des Mille Îles, secteur de Lachenaie et Saint-François (Laval). Éco-Nature, Parc de la Rivière-des-Mille-Iles, Laval, 15 p.

Bisson, R. et V. Gauvin. 2007. Rapport sur les actions de rétablissement du chevalier cuivré (*Moxostoma hubbsi*) sur la rivière des Mille Îles, été automne 2006. Éco-Nature, Parc de la Rivière-des-Mille-Iles, Laval, iv+49p.

Blaquière, J., et A. Auclair. 1974. Chambly, Information Chambly enr., 170 p.

Boulet, M., J. Leclerc et P. Dumont. 1995. Programme triennal d'étude sur le suceur cuivré, rapport d'étape, Québec, ministère de l'Environnement et de la Faune, Direction régionale de Montréal, Laval, Lanaudière, Laurentides, Montérégie, Service de l'aménagement et de l'exploitation de la faune, Montréal, 61 p.

Boulet, M., Y. Chagnon et J. Leclerc. 1996. Recherche et caractérisation des aires de fraye des suceurs cuivré et ballot au bief d'aval du barrage de Saint-Ours (rivière Richelieu) en 1992, Québec, ministère de l'Environnement et de la Faune, Direction régionale de la Montérégie, Service de l'aménagement et de l'exploitation de la faune, Longueuil, Rapport de travaux. 06-38, xi + 37 p.

Boutin, A., G. Lepage et R. Bisson. 2009. Rapport sur les actions de rétablissement réalisées pour le dard de sable (*Ammocrypta pellucida*) à la rivière des Mille Îles en 2008-09. Éco-Nature, Parc de la Rivière-des-Mille-Îles, Laval, iii+15 p.

Boyer, C., D. Chaumont, I. Chartier and. A.G. Roy. 2010 Impact of climate change on the hydrology of St. Lawrence tributaries. Journal of Hydrology. 384 : 65–83.

Branchaud, A., and A.D. Gendron. 1993. Artificial spawning and rearing of the Copper Redhorse, *Moxostoma hubbsi* (Teleostei: Catostomidae). Can. Field. Nat. 107:279-282.

Branchaud, A., M. Boulet, S. Pépin et R. Fortin. 1993. Essais de reproduction artificielle du suceur cuivré entrepris au cours de l'été 1993, Québec, ministère du Loisir, de la Chasse et de la Pêche, Service de l'aménagement et de l'exploitation de la faune, Rapport de travaux 06 - 34. 34 p.

Branchaud, A., D. Hatin, P. Cayer, L. Côté, P. Dumont et R. Fortin. 1995. Reproduction artificielle et élevage du suceur cuivré, Québec, ministère de l'Environnement et de la Faune, Direction régionale de Montréal, Laval, Lanaudière, Laurentides, Montérégie, Service de l'aménagement et de l'exploitation de la faune, Montréal, Rapport de travaux 06 - 34. 49 p.

Branchaud, A., L. Bernatchez, J. Leclerc et R. Fortin. 1996. Identification des larves et des œufs des suceurs, *Moxostoma*, par analyse de l'ADN mitochondrial, Québec, ministère de l'Environnement et de la Faune, Direction de la faune et des habitats, rapport technique, 18 p.

Branchaud, A., A. D. Gendron, J. F. Bergeron et P. Dumont. 1998. Proposition de changement du nom français du suceur cuivré, lettre adressée à Monsieur Gilles Harvey et datée du 21 janvier 1998, ministère de l'Environnement et de la Faune du Québec, Direction régionale de la Montérégie, 6 p.

Branchaud, A., et R. Fortin. 1998. Reproduction artificielle, élevage et comportement des jeunes stades du chevalier cuivré (*Moxostoma hubbsi*), rapport préparé pour le Fonds pour le Rétablissement des Espèces Canadiennes en Péril, Université du Québec à Montréal, Montréal, 27 p.

Branchaud, A., et R. E. Jenkins. 1999. Pierre Fortin (1823–1888) et la première description scientifique du chevalier cuivré, *Moxostoma hubbsi*, *Can. Field. Nat.* 113 : 345 – 358.

Brassard, J. 2008. Contribution des ensemencements de larves et de juvéniles dans le rétablissement d'une espèce menacée, le chevalier cuivré. Rapport final présenté à monsieur Pascal Sirois et monsieur Daniel Lord comme exigence partielle du cours 1GBI126. Diffusion des résultats de recherche du programme de baccalauréat en biologie. Université du Québec à Chicoutimi. vii + 23 pages.

Brodeur, P., Y. Reyjol, M. Mingelbier, T. Rivière et P. Dumont. 2011 Prédation du gobie à taches noires par les poissons du Saint-Laurent : contrôle potentiel d'une espèce exotique ? Le naturaliste canadien, 135 : 4 – 11.

Brodeur, P., pers. comm. 2012. *Email correspondence to N. Vachon*. October 2012. Biologist, Ministère du Développement durable, de l'Environnement, de la Faune et des Parcs du Québec.

Buth, D.G. 1978. Biochemical systematics of the *Moxostomatini* (Cypriniformes, Catostomidae). PhD thesis, University of Illinois at Urbana-Champaign. 191 pp.

Campbell, B.G. 2001. A study of the river redhorse, *Moxostoma carinatum* (Pisces: *Catostomidae*), in the tributaries of the Ottawa River, near Canada's National Capital and in a tributary of Lake Ontario, the Grand River, near Cayuga, Ontario. Thesis submitted to the School of Graduate Studies and Research, University of Ottawa.

Centre d'expertise hydrique du Québec (CEHQ). 2012. Répertoire des barrages. http://www.cehq.gouv.qc.ca/Barrages/Default.asp#Nouvelle. Consulté en août 2012.

Chagnon, Y. 2003a. Étude du chevalier cuivré du fleuve Saint-Laurent, Société de la faune et des parcs du Québec, Direction de l'aménagement de la faune de Lanaudière, Repentigny, rapport manuscrit des données de 2002 et du printemps 2003.

Chagnon, Y. 2003b. Pêche du chevalier cuivré du fleuve Saint-Laurent secteur Lavaltrie–Contrecœur. Direction de l'aménagement de la faune de Lanaudière, Repentigny. Rapport manuscrit des données de 2003.

Chagnon, Y. 2004. Pêche du chevalier cuivré du fleuve Saint-Laurent secteur Lavaltrie–Contrecœur. Direction de l'aménagement de la faune de Lanaudière, Repentigny. Rapport manuscrit des données de 2004.

Chagnon, Y. 2005. Pêche du chevalier cuivré du fleuve Saint-Laurent secteur Lavaltrie–Contrecœur. Direction de l'aménagement de la faune de Lanaudière, Repentigny. Rapport manuscrit des données de 2005.

Clapin-Pépin, D. 1997. Au moins 25 millions de dollars pour le suceur cuivré, *Le naturaliste canadien* 121 : 26-34.

Comité d'intervention. 1995. Plan d'intervention pour la survie du suceur cuivré (*Moxostoma hubbsi*), Québec, ministère de l'Environnement et de la Faune, Direction de la faune et des habitats, 40 p.

Comité d'intervention. 1999. Plan d'intervention pour la survie du chevalier cuivré (*Moxostoma hubbsi*), Québec, Société de la faune et des parcs du Québec, Direction de la faune et des habitats, 55 p.

Comtois, A., F. Chapleau, C.B. Renaud, H. Fournier, B. Campbell et R. Pariseau. 2004. Inventaire printanier d'une frayère multispécifique : l'ichtyofaune des rapides de la rivière Gatineau, Québec. Canadian-Field-Naturalist 118 : 521–529.

COSEWIC. 2002. COSEWIC assessment and update status report on the Channel Darter *Percina copelandi* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 21 pp.

COSEWIC. 2004. COSEWIC assessment and update status report on the Copper Redhorse *Moxostoma hubbsi* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 38 pp. http://www.sararegistry.gc.ca/sar/assessment/status_e.cfm

COSEWIC. 2006. COSEWIC assessment and update status report on the River Redhorse *Moxostoma carinatum* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 31 pp. http://www.sararegistry.gc.ca/sar/assessment/status_e.cfm

COSEWIC. 2007. COSEWIC National Freshwater Biogeographic Zones. http://www.cosewic.gc.ca/images/Fig2-FreshwaterBiogeographicZones_Eng.jpg

COSEWIC. 2009. COSEWIC assessment and status report on the Eastern Sand Darter *Ammocrypta pellucida*, Ontario populations and Quebec populations, in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 49 pp. http://www.sararegistry.gc.ca/sar/assessment/status_e.cfm

COSEWIC 2011. Definitions and Abbreviations. http://www.cosewic.gc.ca/eng/sct2/sct2_6_e.cfm

COSEWIC 2010. COSEWIC Guidelines on Manipulated Populations. Approved by COSEWIC in April 2010. http://www.cosepac.gc.ca/eng/sct2/sct2_8_e.cfm

Côté, C., pers. comm. 2012. *Email correspondence to N. Vachon*. September 18, 2012. Biologist, Ministère du Développement durable, de l'Environnement, de la Faune et des Parcs du Québec.

Côté, G., Albert, V. et L. Bernatchez. 2007. Caractérisation génétique de chevaliers cuivrés (*Moxostoma hubbsi*) reproducteurs de 2005-2006 et de leurs juvéniles ensemencés en 2006 dans la rivière Richelieu. Rapport final présenté par l'Université Laval à Pêches et Océans Canada. 22 p. et 5 annexes.

Côté, G., N. Vachon et L. Bernatchez. 2010. Caractérisation génétique de chevaliers cuivrés (*Moxostoma hubbsi*) reproducteurs de 2007-2008-2009 et de leurs juvéniles ensemencés en 2007-2008-2009 dans la rivière Richelieu. Rapport final présenté par l'Université Laval (Institut de Biologie Intégrative et des Systèmes) à Pêches et Océans Canada.

Courtemanche, M., et V. Elliott. 1985. Identification des os de poissons provenant du site de Mandeville (CaFg–1), Ostéothèque de Montréal, Inc., Université du Québec à Montréal, Dactylogramme, 4 p.

Courtemanche, M. 2003. Pratiques halieutiques au site 4 de la Pointe-du-Buisson (BhFl-1) au sylvicole Moyen tardif (920-940 AD), mémoire présenté à la Faculté des études supérieures en vue de l'obtention du grade de Maître ès sciences (M. Sc.) en anthropologie, Université de Montréal, Département d'anthropologie, Faculté des arts et des sciences, xviii + 325 p.

Courtemanche, M., pers. comm. 2003. *Verbal communications during the writing of the 2004 COSEWIC report*. Ostéothèque de Montréal. Département d'anthropologie. Université de Montréal.

Croley T. E., II. 2003. Great Lakes climate change hydrologic impact assessment: I.J.C. Lake Ontario-St. Lawrence River regulation study. Technical memorandum glerl-126, National Oceanic and Atmospheric Administration, Ann Arbor, Michigan.

Cudmore, B., and N.E. Mandrak. 2011. Biological synopsis of Tench (*Tinca tinca*). Can. MS Rpt. Fish. Aquat. Sci. 2948: v + 20 pp.

Cuerrier, J. P., F. E. J. Fry et G. Préfontaine. 1946. Liste préliminaire des poissons de la région de Montréal et du lac Saint-Pierre, *Naturaliste Can.* 73 : 17-32.

Cusson, B., et de Lafontaine. 1997. Présence et abondance des larves de moules zébrées dans la rivière Richelieu et le Saint-Laurent en 1996, Environnement Canada – Région du Québec, Conservation de l'environnement, Centre Saint-Laurent, Rapport scientifique et technique ST-143, 58 p.

de Lafontaine, Y., N.L. Gilbert, F. Dumouchel, C. Brochu, S. Moore, E. Pelletier, P. Dumont, and A. Branchaud. 2002a. Is chemical contamination responsible for the decline of the Copper Redhorse (*Moxostoma hubbsi*), an endangered fish species, in Canada? The Science of the Total Environment 298:25-44.

de Lafontaine, Y., G. Costan, B. Cusson, and D. Labonté. 2002b. Zebra Mussel colonization and growth in the Richelieu River between 1997 and 2000. Environment Canada – Quebec Region, Environmental Conservation, St. Lawrence Centre. Scientific and Technical Report ST-223E. 43 pp.

Dermott, R., and D. Kerec. 1997. Changes in the deepwater benthos of eastern Lake Erie since the invasion of *Dreissena*: 1979-1993. Canadian Field-Naturalist 102:81-86.

Desrochers, D. 2009. Validation de l'efficacité de la passe multiespèces Vianney-Legendre au Lieu historique national du Canal-de-Saint-Ours – saison 2008. Rapport préparé par Milieu inc., pour Parcs Canada, Québec, 66 p + annexes.

DFO (Department of Fisheries and Oceans Canada). 2005. Consultation workbook regarding the addition of the Copper Redhorse to the List of Wildlife Species at Risk under the *Species at Risk Act*. 18 pp. http://www.registrelep.gc.ca/virtual_sara/files/public/cd_copper_redhorse_1105_e.pdf

DFO (Department of Fisheries and Oceans Canada). 2007a. Recovery potential assessment report of Copper Redhorse *(Moxostoma hubbsi)*. Canadian Science Advisory Secretariat. Ottawa. Science Advisory Report 2007/043. 18 pp.

DFO (Department of Fisheries and Oceans Canada). 2007b. Socio-economic analysis of listing the Copper Redhorse in Schedule 1 of the *Species at Risk Act*. Regional Policy and Economics Branch. Fisheries and Oceans. 24 pp.

DFO (Department of Fisheries and Oceans Canada). 2009. Habitat use of Copper Redhorse and quantifying habitat quality – Part 1; March 17-18, 2009. DFO Can. Sci. Advis. Sec., Proceedings 2009/030.

DFO (Department of Fisheries and Oceans Canada). 2011. Advice relevant to the identification of critical habitat for Copper Redhorse (*Moxostoma hubbsi*). Canadian Science Advisory Secretariat, Science Advisory Report 2010/072.

DFO (Department of Fisheries and Oceans Canada). 2012. Recovery strategy for the Copper Redhorse (*Moxostoma hubbsi*) in Canada. *Species at Risk* Act Recovery Strategy Series, Fisheries and Oceans Canada. Ottawa. xi + 60 pp. http://www.registrelep-sararegistry.gc.ca/document/default_e.cfm?documentID=1565

Direction générale de la protection de la faune. 2011a. Chevalier cuivré : Plan de protection provincial 2010-2013. Protection de la faune de l'Estrie-Montréal-Montérégie. 20 pages.

Direction générale de la protection de la faune. 2011b. Chevalier cuivré : Bilan du plan de protection provincial 2010-2011. 6 pages.

Dubuc, N. 1999. Composition des communautés de poisons et relations espèces-habitat dans 11 tributaires de la rive nord de la rivière des Outaouais. Rapport de recherche présenté à l'Université du Québec à Montréal comme exigence partielle de la maîtrise en science de l'environnement. 137 p. + annexes.

Dumont, P. 1996. Comparaison de la dynamique des populations de perchaudes (*Perca flavescens*) soumises à des niveaux différents de stress anthropique, thèse présentée à l'Université du Québec à Montréal comme exigence partielle au doctorat en sciences de l'environnement, Québec, ministère de l'Environnement et de la Faune, Service de l'aménagement et de l'exploitation de la faune, Montréal, Rapp. Tech. 06 – 46, xxvi + 286 p.

Dumont, P., J. Leclerc, J.-D. Allard et S. Paradis. 1997. Libre passage des poissons au barrage de Saint-Ours, rivière Richelieu, Québec, ministère de l'Environnement et de la Faune, Direction régionale de la Montérégie, Service de l'aménagement et de l'exploitation de la faune et Direction des ressources matérielles et des immobilisations, Québec, et ministère du Patrimoine canadien (Parcs Canada), xiii + 88 p.

Dumont, P., N. Vachon, J. Leclerc, and A. Guibert. 2002. Intentional introduction of Tench into southern Quebec. Pp.169-178, *in* R. Claudi, P. Nantel and E. Muckle-Jeffs (eds.). Alien Invaders in Canada's Waters, Wetlands, and Forests, Canadian Forest Service, Natural Resources Canada.

Dumont, P., pers. comm. 2003. *Verbal communications during writing of the 2004 COSEWIC report.* Biologist, Société de la faune et des Parcs du Québec.

Eastman, J. T. 1977. The pharyngeal bones and teeth of Catostomid fishes. American Midland Naturalist 97:68-87.

Emery, E.B., T.P. Simon, and R. Vies. 1999. Influence of the family Catostomidae on the metrics developed for a great river index of biotic integrity. Pp. 203-224, *in* T.P. Simon (ed.). Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities, CRC Press, Washington DC, New York.

Équipe de rétablissement du chevalier cuivré. 2005. Plan de rétablissement pour la survie du chevalier cuivré (*Moxostoma hubbsi*) 2004-2008. Ministère des Ressources naturelles, de la Faune et des Parcs, Direction du développement de la faune. Québec. 77 pages.

Équipe de rétablissement du chevalier cuivré du Québec. 2012. Plan de rétablissement du chevalier cuivré (*Moxostoma hubbsi*) au Québec – 2012-2017. Ministère des Ressources naturelles et de la Faune du Québec, Faune Québec. 55 pages.

Équipe de rétablissement du chevalier cuivré du Québec. 2014. *in press*. Bilan du rétablissement du chevalier cuivré (*Moxostoma hubbsi*) pour la période 1992-2012. Ministère des Ressources naturelles et de la Faune, Faune Québec.

Fleury, C. et D. Desrochers. 2003. Validation de l'efficacité des passes à poissons au lieu historique du Canal-de-Saint-Ours – saison 2002. Rapport préparé par Milieu inc., pour Parcs Canada, Québec, 69 p + annexes.

Fleury, C. et D. Desrochers. 2004. Validation de l'efficacité des passes à poissons au lieu historique du Canal-de-Saint-Ours – saison 2003. par Milieu inc., pour Parcs Canada, Québec, 79 p. + annexes.

Fleury, C. et D. Desrochers. 2005. Validation de l’efficacité des passes à poissons au lieu historique national du Canal-de-Saint-Ours – saison 2004 par Milieu inc., pour Parcs Canada. Québec, 116 p. + annexes.

Fleury, C. et D. Desrochers. 2006. Validation de l’efficacité de la passe multiespèces Vianney-Legendre au Lieu historique national du Canal-de-Saint-Ours – saison 2005 par Milieu inc., pour Parcs Canada. Québec, 80 p. + annexes.

Fortin, R., J. D’Amours et S. Thibodeau. 2002. Effets de l’aménagement d’un nouveau secteur de frayère sur l’utilisation du milieu en période de fraie et sur le succès de reproduction de l’esturgeon jaune (*Acipenser fulvescens*) à la frayère de la rivière des Prairies, rapport synthèse 1995-1999, pour l’Unité Hydraulique et Environnement, Hydro-Québec et la Société de la faune et des parcs du Québec, Direction de l’aménagement de la faune de Montréal, Laval et de la Montérégie, Département des Sciences biologiques, Université du Québec à Montréal.

Fortin, P., pers. comm. 2012. *Verbal communications during meeting of the "Équipe de rétablissement du chevalier cuivré du Québec" on October 25, 2012.* Lieutenant à la Direction de la protection de la Faune, Ministère du Développement durable, de l'Environnement, de la Faune et des Parcs du Québec.

Fournier, D., F. Cotton, Y. Mailhot, D. Bourdeau, J. Leclerc et P. Dumont. 1996. Rapport d’opération du réseau de suivi ichtyologique du fleuve Saint-Laurent : Échantillonnage des communautés ichtyologiques des habitats lentiques du lac Saint-Pierre et de son archipel en 1995, ministère de l’Environnement et de la Faune, Direction régionale de la Mauricie – Bois-Francs, Direction régionale de la Montérégie, 59 p.

Fournier, D., J. Leclerc, P. Dumont et B. Bélanger. 1997a. Rapport d’opération du réseau de suivi ichtyologique du fleuve Saint-Laurent : Échantillonnage des communautés ichtyologiques du lac Saint-François en 1996, Ministère de l’Environnement et de la Faune, Direction de la faune et des habitats, Direction régionale de la Montérégie, Québec. Nº Cat 3642-97-08, 62 p.

Fournier, D., Y. Mailhot et D. Bourbeau. 1997b. Rapport d'opération du réseau de suivi ichtyologique du fleuve Saint-Laurent : Échantillonnage des communautés ichtyologiques du tronçon Gentilly-Batiscan en 1996. Ministère de l'Environnement et de la Faune, Direction de la faune et des habitats, Direction générale de la Mauricie - Bois-Francs, Québec. 61 p.

Fournier, D. 1998. Rapport d'opération du réseau de suivi ichtyologique du fleuve Saint-Laurent : Échantillonnage des communautés ichtyologiques du tronçon Grondines - Saint-Nicolas en 1997. Ministère de l'Environnement et de la Faune, Direction de la faune et des habitats, Québec. 72 p.

Fournier, D., Y. Mailhot et D. Bourdeau. 1998a. Rapport d’opération du réseau de suivi ichtyologique du fleuve Saint-Laurent : Échantillonnage des communautés ichtyologiques des habitats lotiques du lac Saint-Pierre en 1997, ministère de l’Environnement et de la Faune, Direction de la faune et des habitats, Direction régionale Mauricie – Bois-Francs, 47 p.

Fournier, D., J. Leclerc, P. Dumont et B. Bélanger. 1998b. Rapport d’opération du réseau de suivi ichtyologique du fleuve Saint-Laurent : Échantillonnage des communautés ichtyologiques du lac Saint-Louis en 1997, ministère de l’Environnement et de la Faune, Direction de la faune et des habitats, Direction régionale de la Montérégie, 91 p.

Gangbazo, G. et A. Le Page. 2005. Détermination des objectifs relatifs à la réduction des charges d’azote, de phosphore et de matières en suspension dans les bassins versants prioritaires. Ministère du Développement durable, de l’Environnement et des Parcs. Direction des politiques de l’eau. Québec. Envirodoq : ENV/2005/ 96. 28 p.

Gangbazo, G., J. Roy et A. Le Page. 2005. Capacité de support des activités agricoles par les rivières : cas du phosphore total. Ministère du Développement durable, de l’Environnement et des Parcs. Direction des politiques en milieu terrestre. Québec. Envirodoq Nº ENV/2005/0215. 31 p.

Gariépy, S. 2008. Déplacements, domaines vitaux, sélection et caractérisation des habitats des chevaliers cuivrés adultes dans le système du fleuve Saint-Laurent, Québec, Canada. Mémoire présenté à L'Université du Québec à Rimouski comme exigence partielle du programme de Maîtrise en Gestion de la faune et de ses habitats. X + 167 pages.

Gendron, A., et A. Branchaud. 1991. Identification des oeufs de Catostomidés récoltés au bassin de Chambly en juillet 1991, Québec, ministère du Loisir, de la Chasse et de la Pêche, Service de l'aménagement et de l'exploitation de la faune, Rapport de travaux 06 - 18, 11 p. + 2 annexes.

Gendron, A. D., et A. Branchaud. 1997. Impact potentiel de la contamination du milieu aquatique sur la reproduction du suceur cuivré (*Moxostoma hubbsi*) : Synthèse des connaissances, Québec, ministère de l'Environnement et de la Faune, Service de l'aménagement et de l'exploitation de la faune, Longueuil, Rapport technique 16 – 02, xvi + 160 p.

Gendron, A. D. et A. Branchaud. 2001. Dossier de présentation du refuge faunique des rapides de Chambly pour la protection du chevalier cuivré. Québec, Faune et Parcs. Direction régionale de la Montérégie, Longueuil et Direction de la faune et des habitats. vi + 46 p.

Gendron, M. 1986. Rivière-des-Prairies, suivi de l'aménagement du haut-fond, printemps 1986, Le groupe de recherche SEEEQ Ltée, pour la Direction Environnement, Hydro-Québec.

Gendron, M. 1987. Rivière-des-Prairies, suivi de l'aménagement du haut-fond, printemps 1987, Le groupe de recherche SEEEQ Ltée, pour la Direction Environnement, Hydro-Québec.

Gendron, M. 1988. Rivière-des-Prairies, suivi de l'aménagement du haut-fond, synthèse 1982-1988, Le groupe de recherche SEEEQ Ltée, pour le service de Recherches en Environnement et santé publique, vice-présidence Environnement, Hydro-Québec.

Gimenez Dixon, M. 1996. *Moxostoma hubbsi*. *in*: IUCN 2012. IUCN Red List of Threatened Species. Version 2012.1. Website: www.iucnredlist.org. [accessed on August 14, 2012].

Giroux, I. 2000. Suivi des pesticides dans la rivière Richelieu près des sites de fraie du Chevalier cuivré, ministère de l'Environnement, Direction du suivi de l'état de l'environnement, Québec, 9 p., 2 annexes.

Giroux, I., C. Robert et N. Dassylva. 2006. Présence de pesticides dans l'eau au Québec : bilan dans des cours de zones en culture de maïs et de soya en 2002, 2003 et 2004, et dans les réseaux de distribution d'eau potable, ministère du Développement durable, de l'Environnement et des Parcs, Direction du suivi de l'état de l'environnement, Direction des politiques de l'eau et Centre d'expertise en analyse environnementale du Québec. 57 p. et 5 annexes.

Giroux, I. et L. Pelletier. 2012. Présence de pesticides dans l'eau au Québec : bilan dans quatre cours d'eau de zones en culture de maïs et de soya en 2008, 2009 et 2010, Québec, ministère du Développement durable, de l'Environnement et des Parcs, Direction du suivi de l'état de l'environnement. 46 p. et 3 annexes.

Gravel, Y., et J. Dubé. 1980. Le barrage de l'île du Moulin et la circulation des poissons, en particulier de l'alose savoureuse *Alosa sapidissima* (Wilson), dans les cours d'eau de l'archipel de Montréal, ministère du Loisir, de la Chasse et de la Pêche, Direction de la recherche faunique, Service de la faune aquatique, v + 42 p.

Groupe conseil GENIVAR. 2002. Validation de l'efficacité des passes à poissons au lieu historique national du Canal-de-Saint-Ours, rapport préparé par le Groupe conseil GENIVAR pour Parcs Canada, Québec, 45 p.

Grünbaum, T., R. Cloutier, and P. Dumont. 2003. Congruence between chondrification and ossification sequences during caudal skeleton development: a Moxostomatini case study. H. Browman and A.B. Skiftesvik (ed.). The Big Fish Bang: Proceedings of the 26th Annual Larval Fish Conference, Bergen, July 2002.

Guibert, A. 2000. La tanche (*Tinca tinca*) dans le Haut-Richelieu : État des connaissances et perspectives. Rapport de stage de Maîtrise des Sciences et Techniques en Ingénierie des Milieux Aquatiques et Corridors Fluviaux, Université de Tours (France).

Harris, P.M., R.L. Mayden, H.S. Espinosa Pérez, and F. Garcia De Leons. 2002. Phylogenetic relationships of *Moxostoma* and *Scartomyzon* (Catostomidae) based on mitochondrial cytochrome *b* sequence data. Journal of Fish Biology 61:1433-1452.

Harvey, G. 1979. Les métaux lourds et les composés organochlorés dans la chair des poissons du bassin versant de la Yamaska, Québec, ministère du Loisir, de la Chasse et de la Pêche, Service de l'aménagement de la faune, Rapport technique No 06-30, 80 p.

Hatin, D., S. Gariépy, P. Dumont, R. Dumas, Y. Bilodeau, M. Mingelbier, J. Morin, C. Côté, S. Desloges, Y. Chagnon, J. Leclerc et J. Novotni. 2009. Habitats des chevaliers cuivrés adultes. Communication scientifique présentée à l'atelier de travail sur l'utilisation de l'habitat par le chevalier cuivré pour la définition des habitats essentiels de l'espèce en vertu de la *Loi sur les espèces en péril*. 17 et 18 mars 2009.

Hatin, D., J. Morin, S. Martin et P. Dumont. 2010. Modélisation de l'habitat printanier et automnal des chevaliers cuivrés adultes. Communication scientifique présentée à l'atelier de travail sur l'utilisation de l'habitat par le chevalier cuivré pour la définition des habitats essentiels de l'espèce en vertu de la *Loi sur les espèces en péril*. 18 mars 2010.

Hébert, S. et J. Belley. 2005. Le Saint-Laurent – La qualité des eaux du fleuve 1990-2003. Québec, ministère de l'Environnement, Direction du suivi de l'état de l'environnement. Envirodoq nº ENV/2005/0095, collection nº QE/156, 25 p. et 3 annexes.

Hébert, S. 2006. Water quality in the fluvial section. Physicochemical and bacteriological parameters. Monitoring the State of the St. Lawrence River. 4 p. http://planstlaurent.qc.ca/fileadmin/site_documents/documents/SESL/Qualite_eau_parametre_2006_e.pdf

Hudon, C., and R. Carignan. 2008. Cumulative impacts of hydrology and human activities on water quality in the St. Lawrence River (Lake Saint-Pierre, Quebec, Canada). Can. J. Fish. Aquat. Sci. 65:1165-1180.

Hudon, C., A. Cattaneo, A.-M. Tourville Poirier, P. Brodeur, P. Dumont, Y. Mailhot, J.-P. Amyot, S.-P. Despatie, and Y. de Lafontaine. 2011. Oligotrophication from wetland epuration alters the riverine trophic network and carrying capacity for fish. Aquatic Sciences – Research Across Boundaries. Pp. 1-17.

IUCN Standards and Petitions Subcommittee. 2011. Guidelines for Using the IUCN Red List Categories and Criteria. Version 9.0. Prepared by the Standards and Petitions Subcommittee. Downloadable from http://www.iucnredlist.org/documents/RedListGuidelines.pdf

Jenkins, R.E. 1970. Systematic studies of the Catostomid fish tribe *Moxostomatini*. PhD thesis, Cornell University, Ithaca, New York, 800 pp.

Jenkins, R.E., and N.M. Burkhead. 1994. Freshwater Fishes of Virginia. American Fisheries Society, Bethesda, Maryland. 1079 pp.

Jenkins, R.E., pers. comm. 2003. *Verbal communication during the writing of the 2004 COSEWIC report*. Professor, Roanoke College, Virginia.

Jenkins, R.E. pers. comm. 2012. *Email correspondence to N. Vachon*. August 30, 2012. Retired Professor, Roanoke College, Virginia.

Jones, N., pers. comm. 2012. *Email correspondence to N. Vachon*. September 9, 2012. Scientific Project Officer and ATK Coordinator, COSEWIC Secretariat.

Karr, J.R. 1981. Assessment of biotic integrity using fish communities. Fisheries 6(6):21-27.

Kornis, M.S., N. Mercado-Silva, and M.J. Vander Zanden. 2012. Twenty years of invasion: a review of Round Goby *Neogobius melanostomus* biology, spread and ecological implications. Journal of Fish Biology 80:235–285.

La Haye, M., C. Bélanger, J. Leclerc et P. Dumont. 1992. Observations sur la reproduction du suceur cuivré (*Moxostoma hubbsi*) dans le Bassin de Chambly en 1991, Québec, ministère du Loisir, de la Chasse et de la Pêche, Service de l’aménagement et de l’exploitation de la faune, Montréal, Rapport de travaux 06- 19, 39 p.

La Haye, M., S. Desloges, Y. Chagnon, J. Leclerc et M. Boulet. 1993. Mise au point de la méthode de localisation des aires de reproduction du suceur cuivré (*Moxostoma hubbsi*) et du suceur ballot (*Moxostoma carinatum*) dans les rapides de Chambly (rivière Richelieu) par radio-télémétrie, Québec, ministère du Loisir, de la Chasse et de la Pêche, Service de l’aménagement et de l’exploitation de la faune, Montréal, Rapport de travaux 06 - 25, 39 p. 151 p.

La Haye, M., et M. Huot. 1995. Situation du suceur cuivré (*Moxostoma hubbsi*) au Québec : espèce susceptible d'être désignée menacée ou vulnérable, Québec, Le groupe de recherche SEEEQ ltée pour le ministère de l'Environnement et de la Faune, Direction de la faune et des habitats, 50 p.

La Haye, M., et S. Clermont. 1997. Libre passage des poissons au barrage de Saint-Ours, rivière Richelieu, étude des concentrations de poissons en aval du barrage, rapport technique, réalisé par Enviro-Science inc. pour Parcs Canada, 15 p. + annexes.

Lajeunesse, A., C. Gagnon, F. Gagné, S. Louis, P. Čejka, and S. Sauvé. 2011. Distribution of antidepressants and their metabolites in brook trout exposed to municipal wastewaters before and after ozone treatment – Evidence of biological effects. Chemosphere DOI:10.1016/j.chemosphere.2010.12.02.

Lambert, S. 2011. Impacts des changements climatiques sur la disponibilité de l'eau dans le sud du Québec. Essai présenté au Centre Universitaire de Formation en Environnement en vue de l'obtention du grade de maître en environnement. niversité de Sherbrooke. 58 p.

La Violette, N. 1996. A comparison of past and present fish associations in the Yamaska River, Quebec: a search for ecological responses to sewage treatment. Master's thesis, Department of Zoology and Institute for Environmental Studies, University of Toronto, Toronto, Ontario, 89 pp.

La Violette, N. 1999. Le bassin de la rivière Yamaska : les communautés ichtyologiques et l'intégrité biotique du milieu, *in* Le bassin versant de la rivière Yamaska : l'état de l'écosystème aquatique—1998, ministère de l'Environnement et de la faune (éd.), Direction des écosystèmes aquatiques, Québec, envirodoq nº EN990224, rapport nº EA-14, section 6.

La Violette, N., D. Fournier, P. Dumont et Y. Mailhot. 2003. Caractérisation des communautés de poissons et développement d'un indice d'intégrité biotique pour le fleuve Saint-Laurent, 1995-1997, Société de la faune et des parcs du Québec, Direction de la recherche sur la faune, 237 p.

La Violette N. et P. Dumont. 2005. Rapport d'opération du suivi ichtyologique du fleuve Saint-Laurent : Lac Saint-François 2004. Ministère des Ressources naturelles et de la Faune, Secteur Faune Québec, Direction de la recherche sur la faune, Québec, 17 p.

La Violette N., P. Dumont et I. Koukouchkine. 2006. Rapport d'opération du suivi ichtyologique du fleuve Saint-Laurent : Lac Saint-Louis 2005. Ministère des Ressources naturelles et de la Faune, Secteur Faune Québec, Direction de la recherche sur la faune, Québec, 24 p.

Leclerc, J et N. Vachon. 2008. Migration des poissons et captures de chevaliers cuivrés dans la passe Vianney-Legendre en 2007 (rivière Richelieu). Ministère des Ressources naturelles et de la Faune, Direction de l'aménagement de la faune de l'Estrie, de Montréal et de la Montérégie, Longueuil, Rapp. Tech. 16-40, vi + 20 pages + 2 annexes.

Legendre, V. 1942. Redécouverte après un siècle et reclassification d'une espèce de Catostomidé, *Naturaliste Canadien* 69 : 227 - 233.

Legendre, V. 1943. Un nouveau poisson pour la province de Québec, *Rev. Canad.Biol.* 2 : 105-107.

Legendre, V. 1954. The Freshwater Fishes, Volume 1, Key to game and commercial fishes of the Province of Quebec. Soc. Canad. d'Écologie, Montreal. The Biological Bureau, Game and Fisheries Department, Province of Quebec. **180 pp.**

Legendre, V. 1964. Les vivants du Québec; les découvertes récentes, ministère du Tourisme, Chasse et Pêche, Service de la Faune, Québec, Rap. No 3 : 170-186.

Lippé C, P. Dumont, and L. Bernatchez. 2004. Isolation and identification of 21 microsatellite loci in the Copper Redhorse (*Moxostoma hubbsi*; Catostomidae) and their variability in other catostomids. Molecular Biology Notes 4:638–641.

Lippé, C., P. Dumont, and L. Bernatchez. 2006. High genetic diversity and no inbreeding in the endangered Copper Redhorse, *Moxostoma hubbsi* (Catostomidae, Pisces): the positive sides of a long generation time. Molecular Ecology 15:1769–1780.

Magnan, P., P. Brodeur, N. Vachon, Y. Mailhot, P. Dumont et Y. Paradis. *in preperation*. État du stock de perchaude du lac Saint-Pierre en 2011 et bilan du plan de gestion de 2008. Comité aviseur scientifique sur la gestion de la perchaude du lac Saint-Pierre, Université du Québec à Trois-Rivières et ministère du Développement durable, de l'Environnement, de la Faune et des Parcs.

Maltais, D., and R.L. Roy. 2007. A lateral flow immunoassay for rapid evaluation of vitellogenin levels in plasma and surface mucus of the Copper Redhorse (*Moxostoma hubbsi*). Environ. Toxicol. Chem. 26:1672-1676.

Maltais, D., and R.L. Roy. 2009. Purification and partial characterization of vitellogenin from shorthead redhorse (*Moxostoma macrolepidotum*) and Copper Redhorse (*Moxostoma hubbsi*) and detection in plasma and mucus with a heterologous antibody. Fish Physiol. Biochem. 35:241-254.

Maltais, D., R.L. Roy, and C.M. Couillard. 2010. Hybrid ELISAs for vitellogenins of the endangered Copper Redhorse *Moxostoma hubbsi* and the shorthead redhorse *Moxostoma macrolepidotum* (Cypriniformes, Catostomidae). Ecotoxicol. Environ. Safety 73(5):883-892.

Massé, G., et J.-R. Mongeau. 1974. Répartition géographique des poissons, leur abondance relative et bathymétrie de la région du lac Saint-Pierre, Québec, ministère du Tourisme, de la Chasse et de la Pêche, Service de l'aménagement de la faune, Rapp. Tech. 06–01.

Massé, G., et J.-R. Mongeau. 1976. Influence de la navigation maritime sur la répartition géographique et l'abondance des poisons du fleuve Saint-Laurent entre Longueuil et Sorel, Québec, ministère du Tourisme, de la Chasse et de la Pêche, Service de l'aménagement de la faune, Rapp. Tech. 06–10.

Massé, G, J. Leclerc, P. Levesque et L. Saulnier. 1981. Les frayères du rapide du Grand-Moulin, rivière des Mille-Îles, ministère du Loisir, de la Chasse et de la Pêche du Québec, Service de l'aménagement et de l'exploitation de la faune, Direction régionale de Montréal.

Massé, H., et P. Bilodeau. 2003. Vérification de l'identification des dards en collection et mise à jour de la liste des mentions de fouille-roche gris (*Percina copelandi*), Société de la faune et des parcs du Québec, Direction de l'aménagement de la faune de Montréal, de Laval et de la Montérégie, Longueuil, Rapport technique 16-12, v + 11p. et annexes.

Massé, H. et J. Leclerc. 2008. Guide révisé d'identification des Catostomidés du Québec. Ministère des Ressources naturelles et de la Faune, Direction de l'aménagement de la faune de l'Estrie, de Montréal et de la Montérégie, Longueuil – Rapport technique 16-38 vi + 20 pages + annexes.

Masson, S , Y. de Lafontaine, A.-M. Pelletier, G. Verreault, P. Brodeur, N. Vachon et H. Massé. 2013. Dispersion récente de la tanche (*Tinca tinca*) au Québec. Le Naturaliste canadien. 137 (2) : 55-61.

MDDEFP (Ministère du Développement durable, de l'Environnement, de la Faune et des Parcs). 2014. Données MDDEFP-UQTR-Lampsilis-Poissons d'eau douce. Observatoire global du Saint-Laurent [http://OGSL.ca]. Consulté le 2014-02-13.

Mingelbier, M., Y Reyjol, P. Dumont, Y. Mailhot, P. Brodeur, D. Deschamps, and C. Côté. 2008. St. Lawrence Freshwater Fish Communities. Monitoring the State of the St. Lawrence River. 8 pp. http://planstlaurent.qc.ca/fileadmin/site_documents/documents/SESL/Communautes_poissons_2008_e.pdf

Mingelbier, M. Y. Reyjol, P. Brodeur, C. Côté, P. Dumont, F. Lecomte, Y. Mailhot, Y. Paradis, G. Richard et N. Vachon. 2012. Un géant sous-pression! Cartographie des principales pressions du Saint-Laurent en 2012. Affiche présentée au Atelier sur la faune aquatique en 2012. Québec.

Modde, T., Z.H. Bowen, and D.C. Kitcheyan. 2005. Spatial and temporal use of a spawning site in the Middle Green River by wild and hatchery-reared razorback suckers. Trans. Amer. Fish. Soc. 134:937–944.

Mongeau, J.-R. 1965. Inventaire ichtyologique de la rivière des Outaouais de Greece's Point à l'embouchure de la rivière du Nord, été 1965., ministère du Tourisme, de la Chasse et de la Pêche. Service de l'aménagement de la faune. 11 p.

Mongeau, J.-R. et G. Massé. 1976. Les poissons de la région de Montréal, la pêche sportive et commerciale, les ensemencements, les frayères, la contamination par le mercure et les PCB, ministère du Tourisme, de la Chasse et de la Pêche, Service de l'aménagement et de l'exploitation de la faune, Région administrative de Montréal, Rapport technique 06-13, 286 p.

Mongeau, J.-R. et V. Legendre. 1976. Les ressources fauniques du bassin inférieur de la rivière Saint-François : évolution des populations en dix ans, 1965–974. Ministère du Tourisme, de la Chasse et de la Pêche, Service de l'aménagement de la faune et Service de la recherche biologique. Direction régionale de Montréal. Rapport technique 06-14, 126 p.

Mongeau, J.-R. 1979a. Dossiers des poissons du bassin versant de la Baie Missisquoi et de la rivière Richelieu, 1954 à 1977, Québec, ministère du Tourisme, de la Chasse et de la Pêche, Service de l'aménagement et de l'exploitation de la faune, Région administrative de Montréal, Rapport technique 06-24, 251 p.

Mongeau, J.-R. 1979b. Les poissons du bassin de drainage de la rivière Yamaska, 1963 à 1975, Québec, ministère du Tourisme, de la Chasse et de la Pêche, Service de l'aménagement et de l'exploitation de la faune, Région administrative de Montréal, Rapport technique 06 - 22. 191 p.

Mongeau, J.-R. 1979c. Recensement des poissons du lac Saint-François comtés de Huntingdon et Vaudreuil-Soulanges, pêche sportive et commerciale, ensemencements de maskinongés, 1963 à 1967, ministère du Tourisme, de la Chasse et de la Pêche, Service de l'aménagement et de l'exploitation de la faune, Région administrative de Montréal, Rapport technique 06-25, 125 p.

Mongeau, J-R., L. Leclerc et J. Brisebois. 1980. La répartition géographique des poissons, les ensemencements, la pêche sportive et commerciale, les frayères et la bathymétrie du fleuve Saint-Laurent dans le bassin de La Prairie et les rapides de Lachine, ministère du Loisir, de la Chasse et de la Pêche du Québec, Service de l'aménagement et de l'exploitation de la faune, Direction régionale de Montréal, Rapport technique Nº 06-29.

Mongeau, J-R., L. Leclerc et J. Brisebois. 1981. Les poissons du bassin de drainage de la rivière Maskinongé, la bathymétrie, la répartition et l'abondance relative des espèces, la croissance du maskinongé, les ensemencements, les frayères et la pêche sportive, ministère du Loisir, de la Chasse et de la Pêche du Québec, Service de l'aménagement et de l'exploitation de la faune, Direction régionale de Montréal, Rapport technique Nº 06-31.

Mongeau, J-R., L. Leclerc et J. Brisebois. 1982. La dynamique de la reconstitution des populations de l'esturgeon jaune *Acipenser fulvescens* du lac des Deux Montagnes, province de Québec de 1964 à 1979, ministère du Loisir, de la Chasse et de la Pêche du Québec, Service de l'aménagement et de l'exploitation de la faune, Direction régionale de Montréal, Rapport technique Nº 06-33. 194 p.

Mongeau, J-R. 1984. Les suceurs, *Moxostoma*, et les meuniers, *Catostomus*, de la région de Montréal, ministère du Loisir, de la Chasse et de la Pêche du Québec, Service de l'aménagement et de l'exploitation de la faune, Direction régionale de Montréal. Tableau d'identification.

Mongeau, J.-R., P. Dumont et L. Cloutier. 1986. La biologie du suceur cuivré, *Moxostoma hubbsi*, une espèce rare et endémique à la région de Montréal, Québec, ministère du Loisir, de la Chasse et de la pêche, Service de l'aménagement et de l'exploitation de la faune, Direction régionale de Montréal, Rapport technique 06-39, 137 p.

Mongeau, J.-R., P. Dumont, L. Cloutier et A.-M. Clément. 1988. Le statut du chevalier cuivré, *Moxostoma hubbsi*, au Canada, *Can. Field. Nat.* 102 : 132 - 139.

Mongeau, J.-R., P. Dumont et L. Cloutier. 1992. La biologie du suceur cuivré (*Moxostoma hubbsi*) comparée à celle de quatre autres espèces de *Moxostoma* (*M. anisurum, M. carinatum, M. macrolepidotum, M. valenciennesi*), *Can. J. Zool.* 70 : 1354 - 1363.

NatureServe. 2012. NatureServe Explorer: An online encyclopedia of life [Web application]. Version 7.1. NatureServe, Arlington, Virginia. Website: http://www.natureserve.org/explorer [accessed August 14 and November 11, 2012].

Nilo Mellado, P. 1996. Force des classes d'âge, habitats et alimentation des esturgeons jaunes (*Acipenser fulvescens*) juvéniles du système Saint-Laurent, Université du Québec à Montréal, mémoire de maîtrise en sciences biologiques, 92 p.

Ostéothèque de Montréal, Inc. 1984. Analyse zooarchéologique des ossements provenant du site Place Royale, Montréal (BjFj–3), Ostéothèque de Montréal, Inc., Département des Sciences de la Terre, Université du Québec à Montréal, Rapport No 4, 63 p.

Paradis, Y., pers. comm. 2012. *Email correspondence to N. Vachon*. August 15, 2012. Biologiste. Direction de la faune aquatique. Ministère du Développement durable, de l'Environnement, de la Faune et des Parcs du Québec.

Parent, S., and L.M. Schriml. 1995. A model for the determination of fish species at risk based upon life-history traits and ecological data. Can. J. Fish. Aquat. Sci. 52:1768-1781.

Pariseau, R., H. Fournier, J-P. Harnois et G. Michon. 2009. Recherche de fouille-roche gris (*Percina copelandi*), et de méné d'herbe (*Notropis bifrenatus*) dans la rivière des Outaouais entre Carillon et Rapides-des-Joachims. Ministère des Ressources naturelles et de la Faune, Direction de l'expertise Faune-Forêts de l'Outaouais, Gatineau.20 p.

Pelletier, A.-M., G. Verreault et A. Simard. 2012. Le réseau de détection précoce des espèces aquatiques exotiques et envahissantes du Saint-Laurent : bilan des activités 2007-2010. Le Naturaliste canadien. 136 (3) : 73-79.

Piché, I. 1998. Le bassin de la rivière Richelieu : les communautés benthiques et l'intégrité biotique du milieu, *in* Le bassin versant de la rivière Richelieu : l'état de l'écosystème aquatique–1995, ministère de l'Environnement et de la Faune (éd.), Direction des écosystèmes aquatiques, Québec, envirodoq n° EN980604, rapport n° EA-13, section 4.

Piché, I., et M. Simoneau. 1998. Le bassin de la rivière Richelieu : profil géographique, sources de pollution, intervention d'assainissement et qualité des eaux, *in* Le bassin versant de la rivière Richelieu : l'état de l'écosystème aquatique – 1995, ministère de l'Environnement et de la Faune (éd.), Direction des écosystèmes aquatiques, Québec, envirodoq n° EN980604, rapport n° EA-13, section 1.

Poos, M., A.J. Dextrase, A.N. Schwalb, and J.D. Ackerman. 2010. Secondary invasion of the Round Goby into high diversity Great Lakes tributaries and species at risk hotspots: potential new concerns for endangered freshwater species. Biological Invasions 12:1269–1284.

Primeau, S., N. La Violette, J. Saint-Onge et D. Berryman. 1999. Le bassin de la rivière Yamaska : profil géographique, sources de pollution et interventions d'assainissement, section 1, *in* ministère de l'Environnement (éd.), Le bassin de la rivière Yamaska: état de l'écosystème aquatique, Québec, Direction des écosystèmes aquatiques, envirodoq nº EN990224, rapport nº EA-14.

Provost, J., R. Fortin, G. Patenaude, J. Picotte et P.P. Hazel. 1982. Localisation des frayères et utilisation des hauts-fonds par la faune ichtyenne, Site Rivière-des-Prairies, Projet de remplacement de l'évacuateur de crue et d'arasement d'un haut-fond, Direction de l'environnement, Hydro-Québec, Université du Québec à Montréal, Département des sciences biologiques.

Provost, J., et R. Fortin. 1984. Suivi écologique de l'ichtyofaune en période de construction, Centrale Rivière-des-Prairies, remplacement de l'évacuateur de crue, rapport préparé pour la Vice-Présidence Environnement, Hydro-Québec, Université du Québec à Montréal, Département des sciences biologiques.

Reyjol, Y., P. Brodeur, Y. Mailhot, M. Mingelbier, and P. Dumont. 2010. Do native predators feed on exotic prey? The case of Round Goby in a fluvial piscivorous fish assemblage. Journal of Great Lakes Research 36:618-624.

Robichaud, A., et R. Drolet. 1998. Rapport sur l'état du Saint-Laurent – Les fluctuations des niveaux d'eau du Saint-Laurent, Équipe conjointe bilan, composée de représentants d'environnement Canada, de Pêches et Océans Canada et du ministère de l'Environnement et de la Faune du Québec, Sainte-Foy. Rapport technique..

Robins, C.R., and E.C. Raney. 1956. Studies of the catostomid fishes of the genus *Moxostoma*, with descriptions of two new species. Cornell University Agricultural Experiment Station. Mem. 343, 1-56.

Saint-Jacques, N. 1998. Le bassin de la rivière Richelieu : les communautés ichtyologiques et l'intégrité biotique du milieu, *in* Le bassin versant de la rivière Richelieu : l'état de l'écosystème aquatique—1995, ministère de l'Environnement et de la faune (éd.), Direction des écosystèmes aquatiques, Québec, envirodoq nº EN980604, rapport nº EA-13, section 5.

Saint-Onge, J. 1999. Le bassin de la rivière Yamaska: les communautés benthiques et l'intégrité biotique du milieu, section 5, *in* ministère de l'Environnement (éd.), Le bassin de la rivière Yamaska: état de l'écosystème aquatique, Québec, Direction des écosystèmes aquatiques, envirodoq nº EN990224, rapport nº EA-14.

Scott, W.B., and E.J. Crossman. 1973. Freshwater Fishes of Canada. Fisheries Research Board of Canada, Ottawa. Bull. 184, 966 pp.

Simoneau, M. 1993. Qualité des eaux de la rivière Richelieu, 1979 à 1992, ministère de l'Environnement du Québec, Direction de la qualité des cours d'eau, envirodoq n°EN930016, rapport n° QE-83-1.

Simoneau, M. et G. Thibault. 2009. État de l'écosystème aquatique du bassin versant de la rivière Richelieu : faits saillants 2005-2007. Québec, ministère du Développement durable, de l'Environnement et des Parcs. Direction du suivi de l'état de l'environnement. ISBN 978-2-50-56454 (PDF), 23 p.

Sirois, C., pers. comm. 2012. *Email correspondence to N. Vachon*. November 19, 2012. Wildlife Technician, Ministère du Développement durable, de l'Environnement, de la Faune et des Parcs du Québec.

Sloterdijk, H. 1977. Accumulation des métaux lourds et des composés organochlorés dans la chair des poissons du fleuve Saint-Laurent, rapport soumis au Comité d'étude sur le fleuve Saint-Laurent par le ministère du Tourisme, de la Chasse et de la Pêche, Rapport technique No 7.

Société de la faune et des parcs du Québec. 2002. Rapport sur les impacts de la production porcine sur la faune et les habitats, Vice-présidence au développement et à l'aménagement de la faune, 72 p.

Soucy-Gonthier, N., D. Marceau, M. Delage, A. Cogliastro, G. Domon et A. Bouchard. 2003. Détection de l'évolution des superficies forestières en Montérégie entre juin 1999 et août 2002 à partir d'images satellitaires *LANDSAT-TM*, rapport présenté à l'Agence forestière de la Montérégie (AFM), 29 p.

State of the St. Lawrence Monitoring Committee. 2008. Overview of the State of the St.Lawrence River. St. Lawrence Plan. Environment Canada, Ministère du Développement durable, de l'Environnement et des Parcs du Québec, Ministère des Ressources naturelles et de la Faune du Québec, Fisheries and Oceans Canada, and Stratégies Saint-Laurent. 28 pp.

Stewart, T., and J.M. Haynes. 1994. Benthic macroinvertebrate communities of southwestern Lake Ontario following invasion of *Dreissena.* Journal of Great Lakes Research 20: 479-493.

Trautman, M.B. 1981. The Fishes of Ohio with Illustrated Keys, 2nd ed. Ohio State University Press, Colombus, Ohio.

Turgeon, Y. 1995. Suceur cuivré. Transport des œufs, des adultes et des alevins, incubation, élevage des larves et des embryons, stabulation des géniteurs, ministère de l'Environnement et de la Faune, Direction de la faune et des habitats.

Vachon, N. 1999a. Écologie des juvéniles 0+ et 1+ de chevalier cuivré (*Moxostoma hubbsi*), une espèce menacée, comparée à celle des quatre autres espèces de *Moxostoma* (*M. anisurum, M. carinatum, M. macrolepidotum, M. valenciennesi*) dans le système de la rivière Richelieu, mémoire présenté à l'Université du Québec à Montréal comme exigence partielle de la maîtrise en biologie, Société de la faune et des parcs du Québec, Direction de l'aménagement de la faune de la Montérégie, Longueuil, Rapport technique 16-06, xvi + 175 p.

Vachon, N. 1999b. Suivi de l'abondance relative des chevaliers 0+ dans le secteur Saint-Marc de la rivière Richelieu en septembre 1999 avec une attention particulière portée au chevalier cuivré (*Moxostoma hubbsi*), Société de la faune et des parcs du Québec, Service de l'aménagement et de l'exploitation de la faune, Longueuil, Rapport technique 16-05, vii + 25 p.

Vachon, N., et P. Dumont. 2000. Caractérisation des premières mentions de capture de la tanche (*Tinca tinca* L.) dans le Haut-Richelieu (Québec), Société de la faune et des parcs du Québec, Direction de l'aménagement de la faune de la Montérégie, Longueuil, Rapport technique 16-07, ix + 25 p.

Vachon, N. 2002. Variations interannuelles de l'abondance des chevaliers 0+ dans le secteur Saint-Marc de la rivière Richelieu de 1997 à 2001 avec une attention particulière portée au chevalier cuivré (*Moxostoma hubbsi*), Société de la faune et des parcs du Québec, Service de l'aménagement et de l'exploitation de la faune, Longueuil, Rapp. tech. 16-08.

Vachon, N. 2003a. Identification Guide and Key for Juvenile Redhorse (Genus *Moxostoma*) from Quebec. Société de la faune et des parcs du Québec, Direction de l'aménagement de la faune de Montréal, de Laval et de la Montérégie, Longueuil. Technical Report 16-14E. vi + 26 pp. and 2 appendices.

Vachon, N. 2003b. L'envasement des cours d'eau : processus, causes et effets sur les écosystèmes avec une attention particulière aux Catostomidés dont le chevalier cuivré (*Moxostoma hubbsi*), Société de la faune et des parcs du Québec, Direction de l'aménagement de la faune de Montréal, de Laval et de la Montérégie, Longueuil, Rapport technique 16-13, vi + 47 p.

Vachon, N. et Y. Chagnon. 2004. Caractérisation de la population de chevalier cuivré (*Moxostoma hubbsi*) du fleuve Saint-Laurent (secteur Lavaltrie-Contrecoeur) à partir des captures fortuites d'un pêcheur commercial en 1999, 2000 et 2001. Ministère des Ressources naturelles, de la Faune et des Parcs, Direction de l'aménagement de la faune de Montréal, de Laval et de la Montérégie, Longueuil, Rapp. tech. 16-16, ix + 74 pages + annexes.

Vachon, N. 2007a. Chevalier cuivré : bilan des activités de rétablissement. P. 1–9 *In* Fournier, D., M. Bernard et V. Cauchon (éd). 2007. Compte rendu de l'atelier sur les pêches commerciales 2007. Document de régie interne. Ministère des Ressources naturelles et de la Faune, Secteur Faune Québec, Direction du développement de la faune. Québec. 86 p. Québec (Qué.), 22–24 janvier 2007.

Vachon, N. 2007b. Bilan sommaire du suivi du recrutement des chevaliers dans le secteur Saint-Marc de la rivière Richelieu de 2003 à 2006 avec une attention particulière portée au chevalier cuivré (*Moxostoma hubbsi*). Ministère des Ressources naturelles et de la Faune, Direction de l'aménagement de la faune de l'Estrie, de Montréal et de la Montérégie. Longueuil. Rapp. Tech. 16-34, vii + 31 pages + 1 annexe.

Vachon, N. 2009. Utilisation de l'habitat par les larves, les juvéniles et subadultes de chevalier cuivré et quantification de la qualité de l'habitat. Communication scientifique présentée à l'atelier de travail sur l'utilisation de l'habitat par le chevalier cuivré pour la définition des habitats essentiels de l'espèce en vertu de la Loi sur les espèces en péril. 17 et 18 mars 2009.

Vachon, N. 2010a. Reproduction artificielle, ensemencements et suivi du recrutement du chevalier cuivré en 2009, ministère des Ressources naturelles et de la Faune, Unité de gestion des ressources naturelles et de la faune de Montréal-Montérégie, Longueuil, Rapp. tech. 16-44, vii + 28 p. + 5 annexes.

Vachon, N. 2010b. L'habitat des jeunes stades et des subadultes de chevaliers dans la rivière Richelieu et réflexions sur la désignation de l'habitat essentiel des jeunes chevaliers cuivrés dans son aire de répartition. Communication scientifique présentée à l'atelier de travail sur l'utilisation de l'habitat par le chevalier cuivré pour la définition des habitats essentiels de l'espèce en vertu de la Loi sur les espèces en péril. 18 mars 2010.

Vachon, N. 2010c. Besoins et comportements probables du chevalier cuivré pour la reproduction, la localisation et l'estimation de la superficie de frayère potentielle dans la rivière Richelieu. Communication scientifique présentée à l'atelier de travail sur l'utilisation de l'habitat par le chevalier cuivré pour la définition des habitats essentiels de l'espèce en vertu de la Loi sur les espèces en péril. 18 mars 2010. Vachon, N., S. Velásquez, P. Grondin et H. Massé. 2013a. Premiers essais de cryopréservation de la laitance du chevalier cuivré (*Moxostoma hubbsi*). Résumé de la conférence présentée à l'atelier sur la faune aquatique, Québec, 19-21 février 2013. In : Fournier, D. et V. Cauchon (éd). 2013. Compte rendu de l'atelier sur la faune aquatique 2013, Document de régie interne, ministère du Développement durable, de l'Environnement, de la Faune et des Parcs, Direction générale de l'expertise sur la faune et ses habitats, Direction de la faune aquatique, Québec, 77 p.

Vachon, N., P. Dumont, P. Brodeur, C. Côté, Y. Mailhot, M. Mingelbier et Y. Paradis. 2013b. Réseau de suivi ichtyologique : le lac Saint-François de 1996 à 2009. Ministère du Développement durable, de l'Environnement, de la Faune et des Parcs. 16 pages.

Vachon, N. 2014. *in final edition*. Reproduction artificielle, ensemencements et suivi de la population du chevalier cuivré (*Moxostoma hubbsi*) en 2013. Ministère du Développement durable, de l'Environnement, de la Faune et des Parcs. Direction régionale de l'Estrie, de Montréal et de la Montérégie, Secteur de la faune. Rapp. tech. 16-46, xii + 34 pages.

Vachon, N., S. Velásquez-Medina et P. Grondin. 2014. *in final edition*. Motilité des spermatozoïdes du chevalier cuivré dans les différents traitements de cryopréservation en 2013. Ministère du Développement durable, de l'Environnement, de la Faune et des Parcs. Direction régionale de l'Estrie, de Montréal et de la Montérégie, Secteur de la faune. xi + 31 pages.

Verdon, R., D. Desrochers, and P. Dumont. 2003. Recruitment of American eels in the Richelieu River and Lake Champlain: provision of upstream passage as a regional-scale solution to a large-scale problem. American Fisheries Symposium 33:125-138.

Verhaar, P.M. 2010. Numerical modelling of the impact of climate change on the morphology of Saint-Lawrence tributaries. Thèse présentée à la Faculté des études supérieures en vue de l'obtention du grade de Philosophiæ Doctor (Ph.D.) en géographie. Université de Montréal (Québec). xxviii + 157 p. + 4 annexes.

BIOGRAPHICAL SUMMARY OF REPORT WRITER

Nathalie Vachon is an aquatic wildlife biologist employed by the ministère du Développement durable, de l'Environnement, de la Faune et des Parcs du Québec (MDDEFP). In the course of her professional activities, she deals with a variety of topics such as species at risk, invasive and alien species, population dynamics and management, and habitat protection. Ms. Vachon first became interested in the Copper Redhorse in 1997 during her graduate studies, which dealt with the ecological aspects of the juvenile stages. She has been an active member of the Équipe de rétablissement du chevalier cuivré du Québec since 1998 and has participated in the writing of several recovery plans as well as studies leading to the description of the critical habitat for the Copper Redhorse. Since 2003, she has been in charge of various Copper Redhorse protection and recovery activities, including recruitment and population monitoring, artificial reproduction, stocking, semen cryopreservation, as well as the management and protection of the species' strategic habitats.

COLLECTIONS EXAMINED

Biological collections and databases from the ministère du Développement durable, de l'Environnement, de la Faune et des Parcs du Québec (MDDEFP).

Appendix 1. Threats Assessment Worksheet.

THREATS ASSESSMENT WORKSHEET				
Species or Ecosystem Scientific Name			*Moxostoma hubbsi*	
Element ID			**Elcode**	
Assessor(s):			Nathalie Vachon	
References:				
Overall Threat Impact Calculation Help:			**Level 1 Threat Impact Counts**	
	Threat Impact		high range	low range
	A	Very High	0	0
	B	High	2	2
	C	Medium	4	3
	D	Low	2	3
Calculated Overall Threat Impact:			Very High	Very High
Assigned Overall Threat Impact:			**A = Very High**	
Impact Adjustment Reasons:				
Overall Threat Comments			Compte tenu des données démographiques (déclin inféré de la population, faible rectutement naturel), de ses caractéristiques biologiques, de son aire de répartition très restreinte concentrée dans les régions les plus densément peuplées du Québec qui sont soumises à de fortes pressions anthropiques et que seulement deux sites de reproduction sont connus, cette évaluation traduit bien le niveau des menaces et des facteurs limitants qui pèsent actuellement et dans un horizon d'une vingtaine d'années sur l'espèce et ses habitats. Given demographic data (inferred population decline, low natural recruitment), its biological characteristics, its very restricted distribution area located in the more densely populated regions of Québec that are subject to strong anthropogenic pressures and the only two spawning sites known, this assessment reflects the level of threats and limiting factors that the species and its habitats are facing in a horizon of twenty years.	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
1	Residential & commercial development	C	Medium	Restricted (11-30%)	Serious (31-70%)	High (Continuing)	
1.1	Housing & urban areas	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	Le développement urbain entraîne très souvent l'artificialisation des milieux riverains et/ou la destruction/détérioration des bandes riveraines ce qui affecte l'intégrité des milieux aquatiques. Urban development often leads to bank artificialization and / or destruction / damage, which affects the integrity of aquatic environments.

1.2	Commercial & industrial areas	C	Medium	Restricted (11-30%)	Serious (31-70%)	Moderate (Possibly in the short term, < 10 yrs)	L'aggrandissement des infrastructures du port de Montréal dans le secteur Lavaltrie-Contrecoeur, qui abrite d'importantes aires d'alimentation des adultes, est en développement. The magnification of the infrastructures of the port of Montréal in the Lavaltrie-Contrecoeur sector, where are located important adult feeding areas, is under development.
2	Agriculture & aquaculture	B	High	Pervasive (71-100%)	Serious (31-70%)	High (Continuing)	
2.1	Annual & perennial non-timber crops	B	High	Pervasive (71-100%)	Serious (31-70%)	High (Continuing)	La rivière Richelieu et ses tributaires ainsi que les rivières Yamaska et Noire et le lac Saint-Pierre en sont particulièrement affectés. Rivière Richelieu and its tributaries as well as the Rivière Yamaska and Rivière Noire and Lake Saint-Pierre are particularly affected.
2.3	Livestock farming & ranching	D	Low	Restricted (11-30%)	Moderate (11-30%)	High (Continuing)	
3	Energy production & mining		Not Calculated (outside assessment timeframe)	Small (1-10%)	Unknown	Low (Possibly in the long term, >10 yrs)	
3.1	Oil & gas drilling		Not Calculated (outside assessment timeframe)	Unknown	Unknown	Low (Possibly in the long term, >10 yrs)	Bien qu'il existe un moratoire sur l'exploration des gaz de shistes actuellement, les forages exploratoires pourraient reprendre et une exploitation à grande échelle pourraient s'amorcer (effets sur les habitats du chevalier cuivré sont inconnus). Although there is a moratorium on shale gas exploration actually, exploratory drilling could take over and large-scale exploitation could eventually start (effects on the Copper Redhorse habitat are unknown).
3.3	Renewable energy		Unknown	Small (1-10%)	Unknown	Moderate (Possibly in the short term, < 10 yrs)	Des hydroliennes sont déjà installées dans le fleuve Saint-Laurent et cette forme d'énergie pourrait être apellée à se développer (effets inconnus). Few hydrokinetic electricity-producing turbines are already installed in the St. Lawrence River and this form of energy could grow (unknown effects).
4	Transportation & service corridors	D	Low	Restricted (11-30%)	Moderate (11-30%)	High (Continuing)	

4.1	Roads & railroads	D	Low	Restricted (11-30%)	Moderate (11-30%)	High (Continuing)	L'érosion des rives est manifeste et omniprésente dans la rivière Richelieu et menace la stabilité des routes bordant la rivière. Depuis quelques années, des travaux de stabilisation de rive d'urgence ont été réalisés. Un plan de stabilisation, prévu sur une période de 10 ans, est dans sa phase finale de préparation. Ces travaux de stabilisation impliquent, dans la très grande majorité des cas, l'usage de techniques de stabilisation mécanique et même l'usage de la méthode de contre-poids. Ces infrastructures entraînent la destruction, la détérioration et la perturbation des zones littorales peu profondes et des herbiers aquatiques qui sont connues pour être des habitats d'alevinage et de croissance des jeunes chevaliers cuivrés et qui sont uniques à la rivière Richelieu. Shoreline erosion is obvious and pervasive in the Rivière Richelieu and threatens the stability of roads along the river. In recent years, urgent riverbank stabilizations have been achieved in some places. A stabilization plan, scheduled over a period of 10 years, is in its final stages of preparation. These works involved, in the vast majority of cases, the use of mechanical stabilization techniques and sometimes the use of counter-weighting method. These infrastructures lead to the destruction, degradation and disruption of shallow littoral areas and of the aquatic vegetation which are known to be nursery and growth habitat for young Copper Redhorse and which are unique to the Rivière Richelieu.
4.3	Shipping lanes	D	Low	Restricted (11-30%)	Moderate (11-30%)	High (Continuing)	Le fleuve Saint-Laurent est une importante voie de navigation et n'est pas à l'abri de déversements d'hydrocarbures. Les dragages d'entretien de la voie maritime pourraient devenir plus fréquents en raison des changements climatiques. The St. Lawrence River is an important waterway and is not protected from oil spills. Maintenance dredgings of the waterway can become more frequent due to climate change.
5	Biological resource use	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	

5.4	Fishing & harvesting aquatic resources	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	À certains moments de l'année, notamment quand surviennent des regroupements lors de la reproduction, les captrues accidentelles sont plus susceptibles de se produire. Certaines communautés ethniques recherchent particulièrement les chevaliers de grandes tailles. At certain times of the year, especially when groupings occur during pre-sawning and spawning periods, accidental captures are more likely to occur. Some ethnic communities search particularly large sizes redhorse.
6	Human intrusions & disturbance	C	Medium	Large (31-70%)	Moderate (11-30%)	High (Continuing)	
6.1	Recreational activities	C	Medium	Large (31-70%)	Moderate (11-30%)	High (Continuing)	Particulièrement dans la rivière Richelieu, qui joue un rôle crucial dans le cycle vital du chevalier cuivré (reproduction et alevinage). Les activités nautiques (notamment les embarcations à moteurs) sont en croissance ce qui perturbe et détériore les habitats d'alevinage (érosion et remise en suspension de sédiments) . Les activités nautiques et récréatives dans le refuge faunique Pierre-Étienne-Fortin lors de la période de fraye et d'incubation des oeufs sont particulièrement néfastes pour l'espèce (dérangement des géniteurs et piétinement des œufs). Particularly in the Rivière Richelieu, which plays a crucial role in the life cycle of the Copper Redhorse (reproduction and nursery). Pleasure craft activities, which are increasing, disrupt and cause damages to the nursery habitats (erosion and resuspension of sediments). Recreational activities in the Pierre-Étienne-Fortin preserve during the spawning and incubation of eggs are particularly harmful to the species (spawners disturbance and trampling eggs).
7	Natural system modifications		Not Calculated (outside assessment timeframe)	Large (31-70%)	Serious (31-70%)	Low (Possibly in the long term, >10 yrs)	

7.2	Dams & water management/use		Not Calculated (outside assessment timeframe)	Large (31-70%)	Serious (31-70%)	Low (Possibly in the long term, >10 yrs)	Des modifications dans la gestion des niveaux d'eaux du fleuve Saint-Laurent ainsi que des patrons d'écoulement près des frayères dans la rivière Richelieu pourraient dégrader les habitats d'alimentation et de reproduction et s'avérer néfastes l'espèce. Des demandes ont déjà été faites dans le cadre d'un projet visant l'installation de turbines au barrage du lieu historique du canal-de-Saint-Ours (risques de mortalité et de modifications du régime hydrologique) ainsi que pour l'aménagement d'un barrage dans le fleuve Saint-Laurent à la hauteur de Montréal aux fins de production hydro-électrique (fragmentation supplémentaire et mortalité). Bien que ces projets n'aient pas vus le jour, ils pourraient à nouveau être présentés. Changes in the management of water levels in the St. Lawrence River as well as the flow patterns near the spawning grounds in the Rivière Richelieu could degrade feeding and spawning habitat and be harmful to the species. Projects to install turbines at the dam of the historic site of the canal de Saint-Ours (risk of mortality and changes in the hydrological regime) as well as for the development of a dam in the St. Lawrence River near Montréal for hydropower generation (further fragmentation and mortality) has been presented in the past. Although these projects have been done, they could be presented again.
8	Invasive & other problematic species & genes	CD	Medium - Low	Large - Small (1-70%)	Moderate (11-30%)	High (Continuing)	
8.1	Invasive non-native/alien species	BD	High - Low	Large - Small (1-70%)	Serious (31-70%)	High (Continuing)	La tanche et le gobie à taches noires, deux espèces très tolérantes et ubiquistes sont bien établies dans pratiquement l'ensemble de l'aire de répartition du chevalier cuivré. Bien que non encore décelée dans le fleuve Saint-Laurent, la septicémie hémorragique virale (SHV) pourrait éventuellement affecter le chevalier cuivré. Les effets d'introduction d'espèces sont mal connus. Tench and Round Goby, two very tolerant and ubiquitous species are well established in almost all the Copper Redhorse distribution area. Although not yet detected in the St. Lawrence River, viral hemorrhagic septicemia (VHS) could potentially affect the Copper Redhorse. The effects of introduced species are not well known.
9	Pollution	B	High	Large (31-70%)	Serious (31-70%)	High (Continuing)	

9.1	Household sewage & urban waste water	CD	Medium - Low	Restricted (11-30%)	Moderate - Slight (1-30%)	High (Continuing)	Le développement urbain se poursuit dans une grande partie de l'aire de répartition ce qui conduit à l'aménagement de nombreuses infrastructures de drainage. En outre, le chevalier cuivré fréquente des habitats situés dans le panache de l'effluent des usines d'épuration des villes de Montréal, de Longueuil et de Laval, et est donc exposé aux divers contaminants contenus dans ces eaux. Urban development continues in much of the range of the Copper Redhorse which leads to the development of much drainage infrastructure. Moreover, the Copper Redhorse is exposed to toxicants because some of its habitats are located in the effluent of the treatment plants of the cities of Montréal, Longueuil and Laval
9.2	Industrial & military effluents		Not Calculated (outside assessment timeframe)	Unknown	Unknown	Low (Possibly in the long term, >10 yrs)	Le dévelopement et / ou des modifications d'infrastructures pour le transport de pétrole est très probable. The developement and / or modifications of infrastructures for oil tranport is very likely.
9.3	Agricultural & forestry effluents	B	High	Large (31-70%)	Serious (31-70%)	High (Continuing)	La présence de charges excessives de nutriments, de sédiments et de substances toxiques diverses dans plusieurs cours d'eau fréquentés par le chevalier cuivré est liée aux activités agricoles et entraîne la dégradation des habitats aquatiques et de la qualité de l'eau. The presence of excessive nutrients, sediment and various toxic substances in several rivers frequented by the Copper Redhorse is linked to agricultural activities and degrades aquatic habitats and water quality.
10	Geological events		Unknown	Unknown	Unknown	Unknown	
11	Climate change & severe weather	C	Medium	Restricted (11-30%)	Serious (31-70%)	Moderate (Possibly in the short term, < 10 yrs)	Des fluctuations climatiques plus intenses ont été vécus ces dernières années au printemps et au début de l'été. Les suivis ont montré que cela avait vraisemblablement un effet négatif sur le succès de reproduction et nuisait même aux activités de reproduction artificielle, une mesure jugée prioritaire pour son rétablissement. L'impact demeure cependant difficile à quantifier à plus long terme. More extreme climatic fluctuations during the spring and early summer have been experienced in recent years. The monitorings showed that they had likely a negative effect on the reproductive success and they even interfered with the artificial breeding activities, a measure considered a priority for recovery of the species. Long-term impacts are, however, difficult to quantify.

11.2	Droughts	C	Medium	Restricted (11-30%)	Serious (31-70%)	Moderate (Possibly in the short term, < 10 yrs)	Les bas niveaux des eaux peuvent vraisemblablement limiter la disponibilité/qualité des habitats notamment de fraye (surtout sur la frayère de Chambly) et d'alevinage. Les faibles débits diminuent le potentiel de dilution des substances toxiques ce qui rend les chevaliers cuivrés plus vulnérables puisque la période de fraye est tardive et survient au moment où les épandages de pesticides sont à leur maximum. Low water levels are likely to limit the availability / quality of spawning habitats (especially at Chambly spawning ground) and nursery habitats. Low flows reduce the potential of dilution of toxic substances making the Copper Redhorse more vulnerable because its late spawning period and occurs when pesticide applications are at their maximum.
11.3	Temperature extremes	D	Low	Restricted (11-30%)	Moderate (11-30%)	Moderate (Possibly in the short term, < 10 yrs)	Des températures non optimales pendant les activités de fraye et de croissance des jeunes (réchauffement précoce au printemps, été frais) sont suceptibles de nuire au succès de reproduction de l'espèce ainsi qu'à la survie des jeunes lors de la première année. Suboptimal temperatures during spawning period and growth of young (early warming in spring, cool summer) are likely to interfere (reduce) with the reproductive success of the species and the survival of YOY during the first year.
11.4	Storms & flooding	C	Medium	Restricted (11-30%)	Serious (31-70%)	Moderate (Possibly in the short term, < 10 yrs)	Des épisodes d'innondation extrême, tel que celui vécu en 2011, sont vraisemblablement néfastes pour la reproduction de l'espèce. Extreme flooding, such as the one experienced in 2011, are likely harmful for the reproduction of the species.