REPORT

Identification guide and key for juvenile redhorse (genus *Moxostoma*) from Québec

Direction de l'aménagement de la faune de Montréal, de Laval et de la Montérégie

Société de la faune et des parcs du Québec

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Identification guide and key for juvenile redhorse (genus *Moxostoma*) from Québec

by

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To Norianne, Simon and Helen….

«L'essentiel est invisible aux yeux… »

Le petit Prince de Saint-Exupéry

ABSTRACT

Research on the early life history is essential to the understanding of the biology of a species. In Québec, five redhorse species (Catostomid family; *Moxostoma* genus) cohabit in the southern part of the territory: the silver (*M. anisurum*), shorthead (*M. macrolepidotum*), greater (*M. valenciennesi*), river (*M. carinatum*) and copper (*M. hubbsi*) redhorse. Some studies were realised on the biology of these five species, mainly in an attempt to increase the knowledge on the copper redhorse, a threatened species only present in Québec. However, none of these studies lead to the design of an identification key to their juvenile stage. This situation is not only for the copper redhorse, but also for the river redhorse, considered a special concern species by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and the greater redhorse to whom this status can be eventually attributed. This study follows the recommendations of the Intervention Plan for the restoration of the copper redhorse (1999-2003) that gave priority to the realisation of an identification key to the Québec juvenile redhorse (action 3.6). More than 6000 young-of-the year and yearlings redhorse were examined. Most of them were seined in the Richelieu River from August to October 1997 to 2001. Some specimens collected during other fish surveys in the Richelieu and St. Lawrence River and a sub sample (n=64) of artificially reared copper redhorse were also used. Technical drawings were made using a Leica MZ8 binocular microscope. Meristic criteria (number of scales rows around the caudal peduncle; number of rays on the dorsal fin), external morphological descriptors (shape of the supraorbital canal, the body, the mouth and the dorsal fin), pigmentation (of the operculum, snout, behind the supratemporal canal (occiput) and general pattern) and the morphology of pharyngeal arch and teeth are included in a dichotomous key. These criteria can be used with confidence to identify fish at least 35 mm long (total length). Three criteria (the chromatophores distribution on the body, the occipital pigmentation and the shape of the supraorbital canal) can be used for field identification of at least three species: shorthead, silver and river redhorse. Young greater and copper redhorse can also be distinguished by the operculum and body pigmentation. For the copper redhorse, dissection of the pharyngeal arch is still the best way to confirm the identification. Body and fins pigmentation of wild and artificially reared copper redhorse is different. This key is not yet exhaustive, but it is a good tool for the study of early life history of the five local redhorse species.

KEY WORDS: *Moxostoma*, *hubbsi*, juvenile, identification, Catostomid, Québec

RÉSUMÉ

L'acquisition de connaissances sur les premiers stades de vie est essentielle à la compréhension de la biologie d'une espèce. Au Québec, cinq espèces de chevaliers (famille des Catostomidés, genre *Moxostoma*) vivent en sympatrie dans le sud du territoire : les chevaliers blanc (*M. anisurum*), rouge (*M. macrolepidotum*), jaune (*M. valenciennesi*), de rivière (*M. carinatum*) et cuivré (*M. hubbsi*). Les représentants de ce genre ont indirectement fait l'objet de quelques études dans le cadre de travaux visant à approfondir les connaissances sur le chevalier cuivré, une espèce menacée d'extinction et présente uniquement au Québec. Cependant, aucune clé d'identification des juvéniles des cinq espèces n'est encore disponible. Outre le chevalier cuivré, la situation du chevalier de rivière est considérée préoccupante au Canada par le Comité sur le statut des espèces menacées d'extinction au Canada (CSEMDC) et le chevalier jaune pourrait se voir attribuer un tel statut à court ou moyen terme. Cette étude donne suite aux recommandations qui émanent du plan d'intervention sur la survie du chevalier cuivré qui considère prioritaire l'élaboration d'une clé d'identification des jeunes chevaliers du Québec (action 3.6). Quelque six mille jeunes chevaliers de l'année et âgés de un an ont été examinés. Les spécimens ont été capturés en très grande partie à la seine de rivage dans la rivière Richelieu d'août à octobre 1997 à 2001. D'autres individus proviennent de travaux de terrain menés antérieurement dans le fleuve Saint-Laurent et la rivière Richelieu. Un sous-échantillon de chevaliers cuivrés issus de la reproduction artificielle (n=64) a également été examiné. Les illustrations ont été confectionnées sous une loupe binoculaire Leica MZ8. Des critères méristiques (rangées d'écailles autour du pédoncule caudal, rayons de la nageoire dorsale), morphologiques externes (forme et développement des canaux supraorbitaux, morphologie du corps, de la bouche et de la nageoire dorsale) et de pigmentation (de l'opercule, du museau, derrière le canal supratemporal et patron général) de même que la morphologie de l'appareil pharyngien (morphologie comparée des dents et des arcs) sont décrits sous forme d'une clé dichotomique. Ces critères sont considérés comme fiables pour des juvéniles de 35 mm et plus (longueur totale). Trois caractéristiques soit la distribution des chromatophores sur le corps, l'intensité de la pigmentation derrière le canal supratemporal (occiput) et la forme des canaux supraorbitaux, peuvent être utilisées pour distinguer au moins trois des espèces sur le terrain soit les chevaliers rouge, blanc et de rivière. Des différences de pigmentation sur l'opercule et le corps ont également été mises en évidence pour discriminer les chevaliers jaunes des cuivrés issus du milieu naturel. Cependant, en ce qui concerne cette dernière espèce, la dissection de l'appareil pharyngien demeure encore la technique de choix pour confirmer l'identification. La pigmentation du corps et des nageoires diffère entre les chevaliers cuivrés issus de la reproduction artificielle et ceux du milieu naturel. Bien que non exhaustive, cette clé constitue un outil de base efficace pour l'identification des jeunes chevaliers du Québec.

MOTS-CLÉS : *Moxostoma*, *hubbsi*, juvéniles, identification, Catostomidés, Québec

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1-INTRODUCTION

Identification of fish larvae and juveniles is sometimes difficult, particularly among members of the Catostomid family. Description and identification of the Catostomid early stages are currently based on such studies as Buynak and Mohr (1979), Fish (1932), Fuiman (1979, 1982), Hogue and Buchanan (1977), Kay *et al.* (1994), Long and Ballard (1976), McGowan (1984), Snyder (1981, 1983), Snyder and Muth (1990), Stewart (1926) etc. The white sucker (*Catostomus commersoni*) is indisputably the best described species at all its development stages. Among redhorse, particularly those found in Québec, the shorthead, silver and river redhorse are the species that are best described at their initial ontogenic stages. To this day, identification of adult redhorse of Québec (TL 25 cm and longer) is possible thanks to morphologic and meristic criteria developed by Hubbs and Lagler (1958), Jenkins (1970) and Legendre (1942, 1952) and compiled by Mongeau (1984a, b). The mitochondrial DNA analysis adapted by Branchaud *et al.* (1996) allows the distinction of the five species via two restriction enzymes (Alu I et Hpa II). Moreover, there is an identification key of 22 Catostomid species, based on the pharyngeal arch morphology and the shape and the number of teeth (Eastman 1977).

Regarding the early development stages, certain morphometric and meristic aspects, as well as pigmentation criteria have been previously described for the larvae (mesolarvae flexion) and juvenile stages of the greater, copper and river redhorse (Gendron and Branchaud 1991). According to these authors, the distinction between the greater and the copper redhorse is feasible by using pigmentation criteria, but cannot be clearly done using morphometric ones. Additional considerable efforts have been deployed to come up with an identification key based on external morphologic characters for the Québec redhorse larvae. A genetic analysis in order to confirm some of the resulting criteria showed that only 31% of the larvae had been correctly identified while 29% were wrongly identified. A large amount (40%) of the larvae submitted to the genetic analysis had not been previously discriminated to species by any external morphologic characters (Branchaud *et al.* 1996). Even though certain identification characteristics have been examined on juvenile redhorse (Gendron and Branchaud 1991) and those same characteristics have been studied for many years (R.E. Jenkins, professor, Roanoke College, Virginia, unpublished data) throughout North America, no identification key for the juvenile redhorse from Québec is available to this date.

Identification of the redhorse at its early stages is extremely important. For example, the capture and identification of eggs, larvae and juveniles are some of the most efficient and accurate means of research and delimitation of spawning and nursery areas. These habitats, qualified as essential, are protected by legislation against any and all project susceptible of modifying the characteristics of the aquatic environment. Moreover, out of the five sympatric species living in Québec, the copper redhorse has been designated a threatened species in April 1999 according to the *Act respecting Threatened or vulnerable species* from the Québec province. Meanwhile, the river redhorse is considered as a special concern species in Canada since 1987 by the COSEWIC (Parker 1988) and its status is currently under revision. In the United States, the river redhorse is considered in a precarious state in more than half of its distribution area (Moisan 1998).

Such a status could also, in the near future, be attributed to the greater redhorse in Canada (Campbell 1998). Recent samplings of juvenile redhorse in the Richelieu River leads us to believe there is low recruitment of the greater redhorse in the south of Québec (Vachon 1999ab, 2002).

This study follows the recommendations of the Intervention Plan for the restoration of the copper redhorse (1999-2003) that gave priority to the realisation of an identification key to the Québec juvenile redhorse (action 3.6) (Comité d'intervention 1995, 1999). That key of the Québec redhorse juveniles, first and foremost user friendly, is based on morphologic external and pigmentation criteria and developed pursuant to studies performed by Vachon (1999a). Specimens were first identified using the criteria provided by Dr R.E. Jenkins (professor, Roanoke College, Virginia, personal communication); which allowed the validation of these characteristics on Québec specimens. Some of the criteria were refined while newer criteria have been elaborated and utilised. Even though several external morphology and pigmentation aspects were examined during the course of this study, only the most distinguishing ones were retained.

2-MATERIAL AND METHODS

The key has been elaborated with young-of-the-year and yearlings redhorse that were seined from 1997 to 2001 (Vachon 1999ab, 2002). Most of the specimens have been captured from August to November in the course of a systematic sampling evenly distributed in time and space in the Richelieu River from Chambly to Sorel. Others specimens have also been considered. They come mainly from others fish surveys in the Richelieu and St. Lawrence Rivers done in 1965, 1974,1991 and from 1993 to 1995 by the MLCP (*Ministère du Loisir, de la Chasse et de la Pêche*) and the MEF, *Ministère de l'Environnement* et de la Faune (namely FAPAQ: *Société de la faune et des parcs du Québec*). redhorse caught in the fall of 2000 in the St. Lawrence River have been examined as well (Boulet *et al.* 1995, Vachon et Chagnon, *in revision*). A total of 6016 specimens have been identified (Table 1). A sub-sample of artificially reared copper redhorse (n=64) in aquarium or at the Tadoussac hatchery were also examined (Branchaud and Gendron 1993, Branchaud *et al.* 1995 et Branchaud and Fortin 1998), in order to compare their characteristics with those of natural specimens. Most of the 1997 and 1998 specimens were preserved in a 10% buffered formalin solution (Phosphate buffer) while the others (n=294 specimens from 1997) were fixed in a 95% ethanol solution in order to proceed with mitochondrial DNA analysis with the smallest juvenile (smaller than 25 mm, TL) and larvae and examine the otolith for age determination. At this time, these analysis have not yet been performed.

In this study however, all redhorse have been identified (without genetic analysis) by external and internal morphologic criteria. In fact, some characteristics used to distinguish juveniles such as the number of circumpeduncle scales rows, the morphology of the pharyngeal arch and teeth and the mouth (among certain species) are also used with adults. The knowledge of the spawning period of redhorse in the southern part of Québec and length distribution of youngs during their first two years guide the identification. The validity of the identifications is also based on the extensive examination of a reference collection of young-of-the-year and yearling redhorse captured in the Richelieu River in 1993 and 1994 (Table 1). The identification of these specimens was previously confirmed by R.E. Jenkins (professor, Roanoke College, Virginia) and Alain Branchaud (Environment Canada).

In order to preserve optimal pigmentation patterns, redhorse from 1997 and 1998 were kept in darkness before and after fixing. Because characteristics can differ with the size of the specimens, redhorse with similar total length were used to perform the illustrations. Only 1997 young-of-the-year specimens previously fixed in a 10% buffered formalin solution and preserved in a 70% ethanol solution were used. Technical drawings were made with a Leica MZ8 binocular microscope using techniques described by Douglas (1987), Faber and Gadd (1983), McAllister (1986) and Zweifel (1988).

Table1: Origin of the specimens identified in this study.

Year	1965, 1973, 1974, 1991, 1993 à 1995[1]		1997[2]		1998[2]		1999[3]	2000[4]	2001[5]	**TOTAL**
River	Richelieu and St. Lawrence		Richelieu					St. Lawrence	Richelieu	
Age	0	1+	0	1+	0	1+	0	0	0	
Shorthead redhorse	380	5	1258	39	330	1242	262	56	748	**4320**
Silver redhorse	37	3	397	16	219	127	89	19	92	**999**
Greater redhorse	56	0	126	6	21	62	4	1	43	**319**
River redhorse	20	0	113	1	1	86	14	0	112	**347**
Copper redhorse	10	3	12	1	1	2	1	0	1	**31**
SUB-TOTAL	503	11	1906	63	572	1519				
TOTAL	**514**		**1969**		**2091**		**370**	**76**	**996**	**6016**

[1] Société de la faune et des parcs du Québec (FAPAQ) collection. They are mostly young-of-the-year specimens from the Richelieu River

[2] Vachon (1999a)

[3] Vachon (1999b)

[4] Vachon and Chagnon (*in revision)*

[5] Vachon (2002)

3-RESULTS AND DISCUSSION

3.1 Generalities

3.1.1 Specimens preservation

To facilitate identification, it is important to manipulate with great care all specimens while on the field to insure preservation of scales; equally as important is to keep them in darkness before and after fixation to maintain pigmentation patterns. According to Snyder and Muth (1990), minimization of shrinking and deformations as well as optimization of pigmentation is obtained through fixation using 10% buffered formalin solution (preferably Phosphate buffer) and preservation of specimens in a diluted formalin buffered solution (3 to 5%) rather than ethanol 70%. It is also very important to avoid asphyxiation of the specimens before fixing in order to maintain the mouth closed.

3.1.2 Limits of the approach

Even though it is a well-known fact that intra and inter regional pigmentation differences exist, many specialists believe that the use of those criteria are widespread and should be utilised more to distinguish at the species or the genus levels, particularly in larvae and juvenile stages. The presence and distribution of pigmentation is strongly affected by the variation of environmental conditions and food supply. Therefore, it is recommended that pigmentation criteria be used with caution and, preferably, in conjunction with other ones. Moreover, we must avoid considering certain interspecific pigmentation differences as absolute criteria (Buynak and Mohr 1979, Faber and Gadd 1983, Fuiman 1979, 1982, Fuiman et *al.* 1983, Hogue and Buchanan 1977, Kay *et al*. 1994, Long and Ballard 1976, McGowan 1984, Snyder 1981, 1983, Snyder and Muth 1990, Wang and Kernehan 1979). In light of the above, one must remember that the extrapolation of some of the criteria of this identification key, having been elaborated from Richelieu river redhorse, is not necessarily valid to other regions.

Identification of young redhorse is further limited as their size decreases. Although the more experienced researcher can identify the young from 25 mm (TL), the above criteria can only be considered reliable for specimens 35 mm (TL) and longer. During the course of this study, the smallest specimens (TL) of each species that have been identified are as follows: 24 mm (greater), 32 mm (river), 36 mm (copper), 30 mm (shorthead) and 40 mm (silver).

As mentioned, identification of smaller redhorse (TL<35 mm) requires more experience because of the incomplete squamation which impedes the count of the circumpeduncle scale rows. Moreover, at this size, the supraorbital canals and the characteristic pigmentation are not yet well developed. In fact, dissection of the pharyngeal arch is often necessary in order to confirm identification or, at the very least, to determine whether the pharyngeal arch presents comblike or ‘’molariform’’ teeth. For example, in this study, the smallest specimen identified is a 24 mm (TL) greater redhorse. A preliminary examination of its external morphological characteristics confirmed that it belonged to the *Megapharynx* subgenus while the dissection of the pharyngeal arch allowed the identification, although quite difficult, at the species level. Note that in this study we still use the classification proposed by Robins and Rainey (1956) which recognize two subgenera: *Moxostoma,* which includes shorthead, silver and river redhorse, and *Megapharynx,* which includes greater and copper redhorse. However, this classification is apparently unconventional in the light of a recent study based on mitochondrial cytochrome *b* sequence data (Harris *et al.* 2002).

3.1.3 Field identification

Identification of certain species of small redhorse (young-of-the-year and 1+) in the field is now possible thanks to three specific characteristics, such as the general pattern of chromatophores body distribution, intensity of the occipital pigmentation and the shape of the supraorbital canals. Nevertheless, only experienced persons should perform field identifications. Validation of this approach was performed initially by identifying redhorse (1+) in the field during the spring sampling of June 1998 and additionally by further observations in laboratory (Vachon 1999a). The success rate of field identification is close to 98%. The identification was supported by the knowledge of the redhorse spawning period in the Richelieu River. The average size of juveniles of different species during the first and second years of their life reflects the temporal spawning sequence in the Richelieu River (Vachon 1999ab, 2002 and Table 2). The shorthead and silver are the first to spawn (toward the end of May), followed by the greater and river (around the second and third week of June) and, finally, by the copper (last week of June up until the first week of July) (Boulet *et al.* 1995, La Haye *et al.* 1992, Mongeau *et al.* 1986, 1992). However, we must emphasize the existence of a great variability regarding size within the same cohort, particularly among the shorthead redhorse (Vachon 1999a).

Table 2 : Interannual growth comparison (by species) of young-of-the-year redhorse from the Richelieu River caught in 1997 (September, 3 to 15), 1998 (September, 21 to 24 and October 8), 1999 (September, 7 to 10) and 2001 (September, 17 to 24) (Modified from Vachon 2002).

Year	1997[1]		1998[1]		1999[2]		2001[3]	
Specie	Average[4] (Std Dev)	n	Average[4] (Std Dev)	n	Average[4] (Std Dev)	n	Average[4] (Std Dev)	n
shorthead redhorse	58,6 [a] (6,0)	319	ND		82,8 [b] (11,5)	54	72,6 [c] (6,7)	742
silver redhorse	59,6 [a] (5,0)	266	ND		79,6 [b] (7,2)	52	76,8 [c] (4,4)	91
river redhorse	47,8 [a] (4,4)	14	52,5*	1	66,7 [b] (4,4)	14	60,8 [c] (4,7)	112
greater redhorse	54,7 [a] (4,6)	24	57,5 [ab] (6,3)	20	75,0* (12,3)	3	57,6 [b] (3,8)	42
copper redhorse *	48,0	1	48,5	1	48,0	1	43,0	1

[1] Data from Vachon (1999a).
[2] Data from Vachon (1999b).
[3] Data from Vachon (2002).
[4] Averages with the same letter in superscript are not statistically different (ANOVA or Kruskal-Wallis tests, $p > 0,05$).
* Insufficient number to perform statistics.

3.2 Identification criteria

Even though some criteria are quite discriminating, in order to reduce the risk of errors we must use all of the criteria to identify young redhorse. The first step is always the counting of the circumpeduncle scale rows[1]. Among subgenus *Moxostoma*, the count is 12 to 14, whereas in the subgenus *Megapharynx* it is 15 or 16. Counting method for the circumpeduncle scale rows is described in Mongeau (1984b). It is imperative to count the number of scale rows around the entire caudal peduncle. As a matter of fact, several *Megapharynx* were wrongly identified as *Moxostoma* as a result of using the questionable method of counting the number of scale rows on one side.

Body pigmentation between species varies according to chromatophores size and distribution (Figures 1A to E). Among river redhorse, two different pigmentation patterns were observed. The most common one consists of a diffusely spread of very small chromatophores on the entire body (Figure 1C). The other, although very rare, is a spread of slightly larger chromatophores into four distinct lateral saddles on the body. However, because this pattern is quite characteristic of the shorthead (Figure 1A) it is rather insidious, as it can lead to misidentification.

For at least three species (shorthead, silver and river), the use of external morphological and meristic criteria is sufficient to readily identify them. Comparable size specimens of shorthead, silver and river redhorse age 0 and 1+ are distinguished by the shape of their supraorbital canals. Those canals are, in the anterior part, curved among the silver and river, while they are mostly straight for the shorthead (Figures 2A, B, C). Note that the section of the supraorbital canal from the snout to approximately the middle of the eye is considered as the anterior part. Furthermore, as a general rule, the young silver redhorse show more perceptible pores than the others. However, since during the same season timeframe the supraorbital canals are less developed among the greater and copper (Figures 2D, E) (R.E. Jenkins, professor, Roanoke College, Virginia, personal communication), this criterion cannot be used to discriminate all the species. Nevertheless, we observed curved supraorbital canals among larger size greater redhorse. Those particular shapes were also observed on adult specimens of each species. Curved supraorbital canals were observed on all adults, copper (n=1), river (n=1) (captured in June 1998) as well as on a two-year old River (captured in the spring 1998) and on river age 1+ (n=9) captured in the fall of 1998, while all the older shorthead presented straighter supraorbital canals in the anterior part (Vachon 1999a). Observation of these canals is made easier by drying the surrounding area using a low jet of compressed air.

Juvenile shorthead, silver and river age 0 and 1+ are fairly easily identified in the field with the occipital pigmentation stripe. This stripe is strongly marked for the shorthead but diffused and pale for the silver and generally moderately marked for the River (Figures 2A, B, C). Age 0 and 1+ greater and copper display a rather diffused stripe (Figures 2D, E). The same stripe pigmentation pattern has been observed on adult shorthead and silver redhorse.

[1] Circumpeduncle scale rows is the number of scale rows around the caudal peduncle.

Regarding the shape of the lips, there is a great variability among young shorthead (Figures 3A, B). However, shorthead inferior lips are the straightest compared to all the other species. Lip and mouth morphology would not allow easy discrimination of age 0 and 1+ greater and copper juveniles (Figures 3D, F). Inversely, the unique mouth shape of the silver, even among its smallest specimens, permits easy identification and this criterion can be considered as a diagnostic for that species (Figure 3C). Mouth and lip morphology in young river redhorse is relatively similar to that observed in greater and copper (Figures 3D, E, F). Note that lip morphology can only be reliably assessed if the mouth has been preserved closed.

Snout pigmentation also differs depending on the species: generally there are large chromatophores in shorthead, while tiny ones within all other species. Greater redhorse display a snout pigmentation that most often gives a mottled aspect and sometimes a uniform one (Figures 1A to E and 4).

The shape of the dorsal fin can help to discriminate the two redhorse subgenera **at age 0 and 1+**. The dorsal fin is slightly concave among the subgenus species *Moxostoma*, which includes shorthead, silver and river redhorse, whereas it is very slightly concave or straight among the *Megapharynx*, which includes greater and copper redhorse (Figures 1A to E). This observation is particularly useful in cases where there are missing scales over the caudal peduncle, which is the basic criterion used to discriminate the two subgenera. Also worth mentioning is the fact that among silver redhorse, the dorsal fin is straight on larger juvenile and adult specimens

Pigmentation on the basal part of the first gill raker in river redhorse, as described by Jenkins and Burkhead (1994) concerning U.S. specimens, has also been observed in the Richelieu River specimens (Figure 5). Although the presence of pigmentation is sometimes observed over the same anatomical structure in other species, it is generally much less developed (Jenkins and Burkhead 1994, R.E. Jenkins, professor, Roanoke College, Virginia, personal communication and this study). This identification criterion can be considered as diagnostic to the river redhorse and must be systematically verified especially to discriminate the river redhorse from the shorthead without dissecting the pharyngeal arch. Of all river 0 and 1+ (n=215) and 2+ (n=1) examined during the course of this study, only two ($\approx$ 1%) did not present this particular pigmentation on the basal part of the first gill raker. Note that this character is not powerful to distinguish the river redhorse from the *Megapharynx* species.

Young greater and copper redhorse can often be differentiated by the distribution of the pigmentation on the opercle and the body. Among copper redhorse, pigmentation on the inferior half of the opercle is very weak or often absent (Figure 1E), while the greater has a uniformly pigmented opercle (Figure 1D) or pigmentation is mostly concentrated on the upper half of the opercle with a vertical row of pigmentation anteriorly (Figure 4). Pigmentation is very weak or often absent on the latero-ventral part of the body on the young copper redhorse (especially near the pectoral fins region), while it is present and more intense in the same region on the greater (Figures 1D, E). Additionally, the copper snout is shorter and rounder compared to that of the greater (Figures 2D, E).

Even though some external morphological criteria have been developed to discriminate young redhorse, **it is sometimes essential to dissect the pharyngeal arch to confirm identification, especially in copper redhorse.** Even on juveniles of the copper and river redhorse, the small number of teeth as well as their “molariform” aspects, and the widened base and greater robustness of the pharyngeal arch are already obvious and allow them to be distinguished from the other species (Figures 6D, E; 7; 8A, B, Vachon 1999a). On the other hand, the pharyngeal arch of the other three congeners is more delicate, the teeth are more numerous and resemble the teeth of a comb (Figures 6A, B, C). As for the young silver, their pharyngeal arch is less curved, thinner, with an elongated base compared to that of the greater and shorthead (Figure 6B).

Examination of artificially reared young copper redhorse revealed that their body pigmentation is more intense and uniformly distributed compared to wild specimens (Figures 1E, F). The pigmentation particularity of the opercle and the latero-ventral part of the body, observed among wild copper specimens does not apply to the artificially reared ones. Furthermore, the pectoral, pelvic and anal fin pigmentation varies between the wild and the artificially reared copper redhorse (Appendix 1). Among the latter, the pectoral and anal fins are moderately to strongly pigmented while their pelvic fins are slightly to moderately pigmented (Figure 1F, Appendix 1). In all wild copper redhorse, except for one specimen aged 1+ (no. 530), there was no pigmentation on the pelvic fins and the anal fin was only slightly pigmented. Moreover, one third of the specimens displayed slightly pigmented pectoral fins. Further investigations will be conducted in order to determine if specimen no. 530, whose general pigmentation pattern corresponds more with the artificially reared one, is a juvenile previously marked with oxytetracycline and stocked in 1996 (Branchaud *et al.* 1995, Branchaud and Fortin 1998). That same specimen, captured in the Richelieu River on June 6, 1997, is the only one whose origin is questioned (Vachon 1999a). However, the absence of fluorescent marks does not exclude the possibility that it could be a stocked specimen since the oxytetracycline marking technique of the copper redhorse did not turn out to be as efficient as it was hoped (Beaulieu 1996). Finally, even on small artificially reared copper redhorse, the particular characteristics of the pharyngeal arch and teeth are obvious (Figure 9). As it has been pointed in this study, Snyder and Muth (1990) also found pigmentation differences between wild specimens and artificially reared ones among the Catostomid family.

A dichotomous key is presented to aid in identifying young redhorse. The most obvious or diagnostic characters appear in *italic*. See Appendix 2 for details about characteristics of the specimens used for drawings.

3.3 DICHOTOMOUS KEY
Juvenile *Moxostoma* species of Québec
Total length : 35 to 150 mm

1 A **Circumpeduncle scale rows : 12 to 14** — Subgenus ***Moxostoma*** 2
1 B **Circumpeduncle scale rows : 15 or 16** — Subgenus ***Megapharynx*** 4

2 A **Supraorbital canals strongly developed (perceptible) and straight in the anterior part (from the snout to approximately the middle of the eye) (Fig. 2A)**

Strongly marked pigmentation stripe behind the supratemporal canal (occiput) (Fig. 2A). *Large lower lip straight or slightly curved.* Lip with obvious longitudinal ridges (plicae). Lower lip often with obvious deep transverse grooves (Fig. 3A, 3B). Dorsal fin slightly concave with 13 rays (rarely 12, 14 and 15). Moderate to low body height. *Large chromatophores distributed in 3 or 4 lateral distinct saddles on the body* (Fig. 1A). *Chromatophores on the snout generally large*. Delicate pharyngeal arches with numerous comblike teeth (Fig. 6A). — ***M. macrolepidotum*** shorthead redhorse

2 B **Supraorbital canals moderately or strongly developed (perceptible) and sinuous (Fig. 2B, 2C)** 3

3 A **Thin lower lip with an acute angle (90° and less) with very fine longitudinal ridges (Fig 3C)**

Area immediately behind the supratemporal canal (occiput) not strongly pigmented. Supraorbital canals moderately or strongly developed (perceptible) and sinuous especially in the anterior part with very perceptible pores (Fig. 2B). Dorsal fin slightly concave or straight (larger specimens) with 14 to *16* rays (very rarely 13 and *17*). High or moderate body height. Small chromatophores evenly distributed on the body (Fig. 1B). Delicate pharyngeal arches with numerous comblike teeth (Fig. 6B). — ***M. anisurum*** silver redhorse

3 B **Lower lip with more obtuse angle (>90°) with relatively perceptible longitudinal ridges (Fig. 3A, 3B, 3D, 3E, 3F)**

Moderately (generally) marked pigmentation stripe behind the supratemporal canal (occiput). Supraorbital canals moderately developed (perceptible) and sinuous in the anterior part and occasionally in the posterior part (Fig. 2C). Dorsal fin slightly concave with 12 to 14 rays (rarely 15). Elongate body. *Small chromatophores usually evenly distributed on the body* (Fig. 1C), very rarely forming 3 or 4 lateral saddles. *Presence of black spot(s) (chromatophore) at the base of the first gill raker* (Fig. 5). *Heavy pharyngeal arches with large base and molariform lower teeth* (Fig. 6D, 8A). — ***M. carinatum*** river redhorse

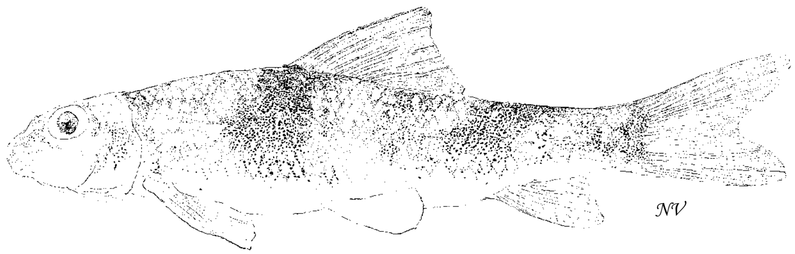
4 A **Pigmentation present and intense on the latero-ventral part of the body (especially near the pectoral fins region). Opercle pigmentation : totally and relatively uniformed (Fig. 1D) or mostly concentrated on the upper half with a vertical row of pigmentation anteriorly (Fig. 4)**

Relatively diffuse pigmentation stripe behind the supratemporal canal (occiput). Supraorbital canals not well developed, usually not perceptible (Fig. 2D). Dorsal fin very slightly concave or straight with 13 to 14 rays (rarely 12). High or moderate body height (Fig. 1D). Small chromatophores diffusely spreaded on the body and the snout giving a *mottled aspect*, very rarely forming 4 lateral saddles (Fig 1D, 4). Delicate pharyngeal arches with numerous comblike teeth (Fig. 6C). — ***M. valenciennesi*** greater redhorse

4 B **Pigmentation very weak or often absent on the latero-ventral part of the body (especially near the pectoral fins region) and on the inferior half of the opercle (Fig. 1E)**

Relatively diffuse pigmentation stripe behind the supratemporal canal (occiput). Supraorbital canals not well developed usually not perceptible (Fig. 2E). Dorsal fin very slightly concave or straight with 12 to 13 rays (rarely 14). High or moderate body height. Small chromatophores diffusely spreaded on the body, very rarely forming 4 lateral saddles (Fig 1E). ***Heavy pharyngeal arches with large base and molariform lower teeth* (Fig. 6E, 7, 8B, 9).** — ***M. hubbsi*** copper redhorse

Subgenus *Moxostoma*

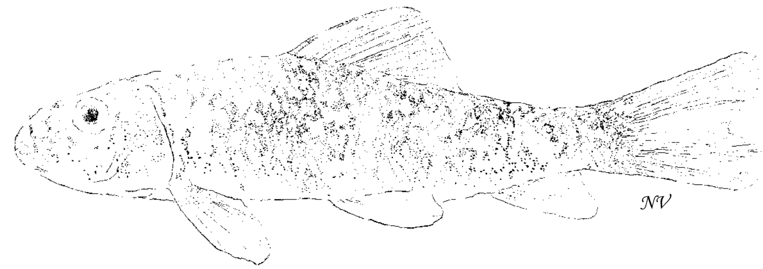


A shorthead redhorse (60,0 mm)

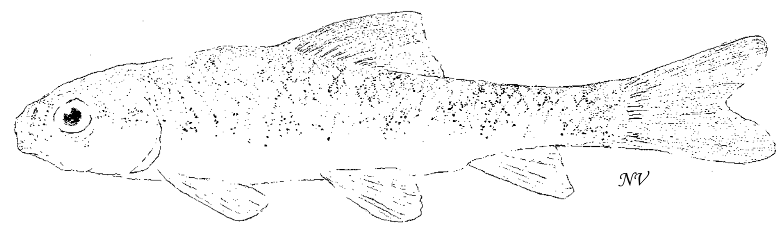
B silver redhorse (56,0 mm)

C river redhorse (58,5 mm)

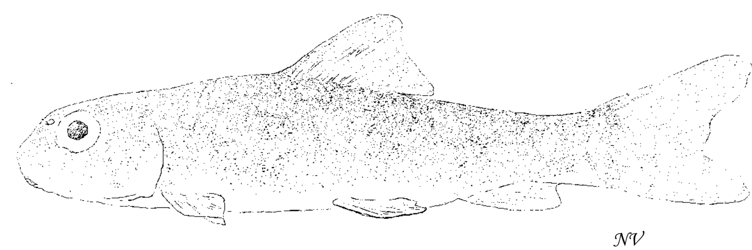
Subgenus *Megapharynx*



D greater redhorse (55,5 mm)

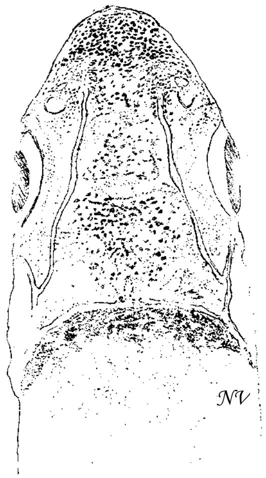


E wild copper redhorse (38,0 mm)

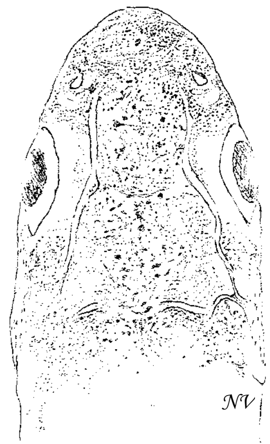


F artificially reared copper redhorse (40,0 mm)

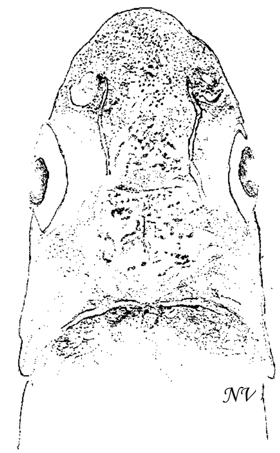
**Figure 1 : Young redhorse from Québec (entire body, lateral view).
Total length of specimen is in parentheses.**



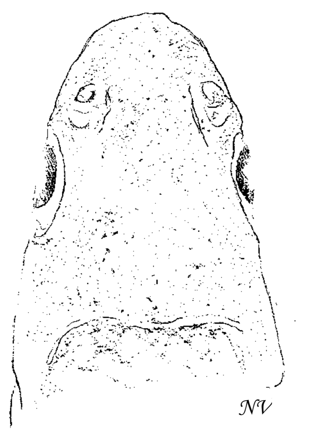
A shorthead redhorse (55,5 mm)



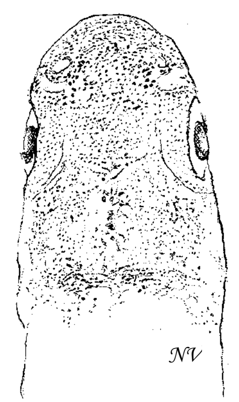
B silver redhorse (53,0 mm)



C river redhorse (51,0 mm)



D greater redhorse (52,0 mm)



E copper redhorse (42,0 mm)

Figure 2 : Young redhorse from Québec (dorsal view of the head). Total length of specimen is in parentheses.

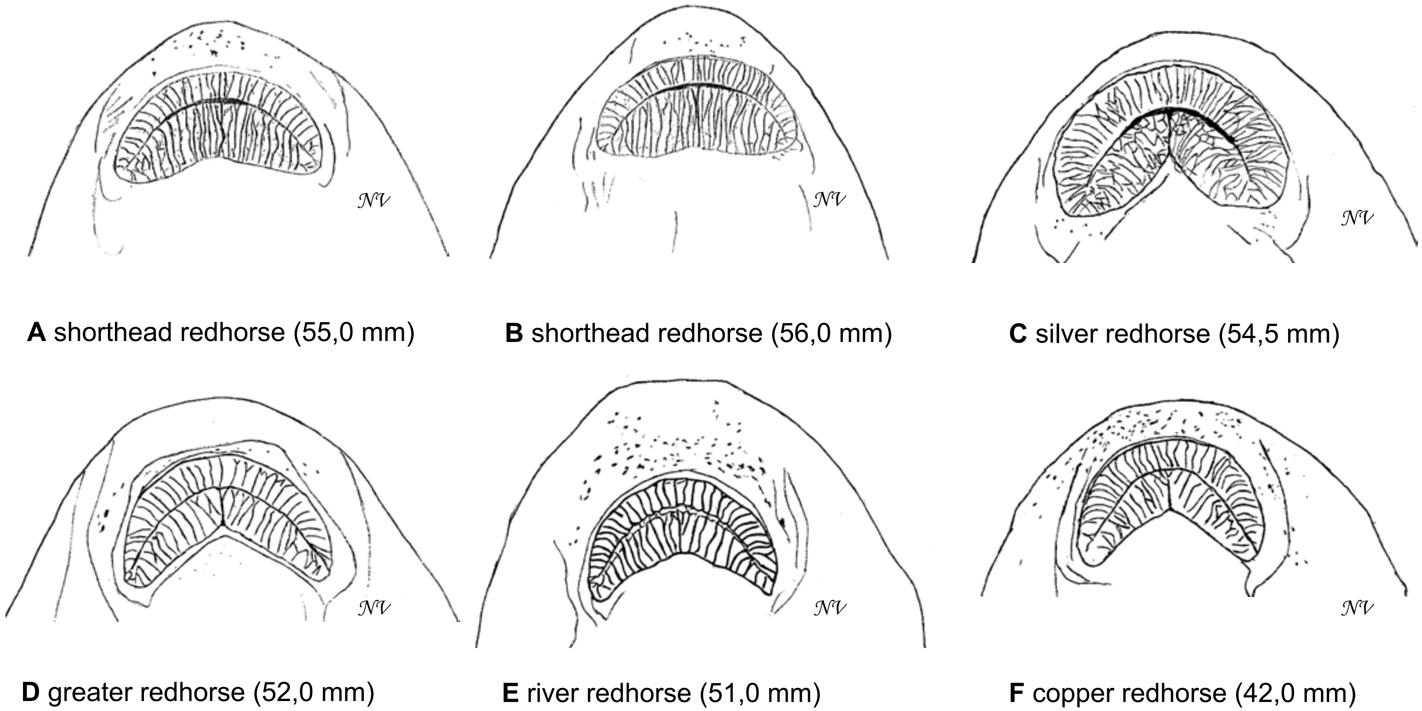


Figure 3 : Mouth and lips morphology and characteristics of young redhorse from Québec. Total length of specimen is in parentheses.

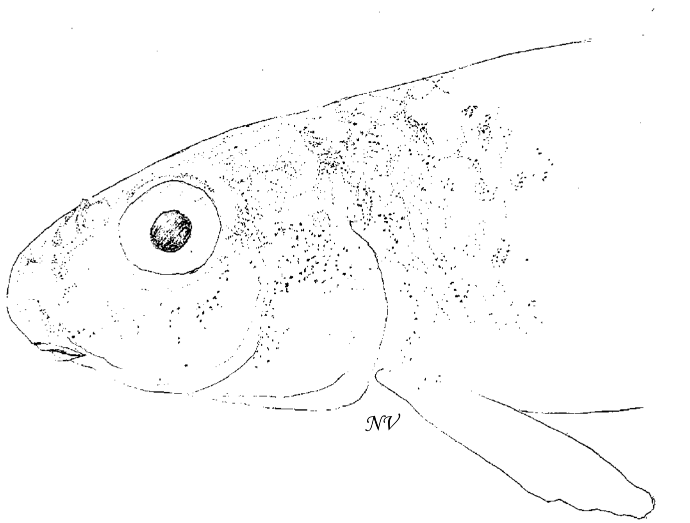


Figure 4 : Snout and opercle pigmentation pattern on a greater redhorse (TL : 51,0 mm).

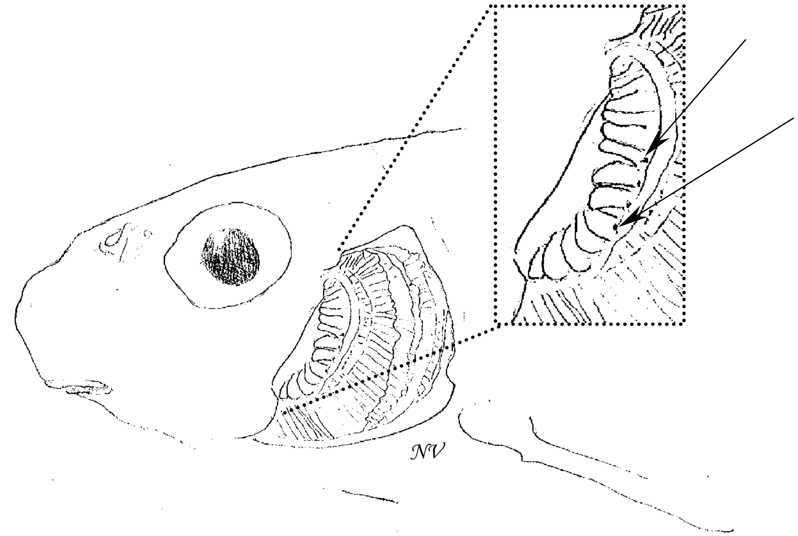
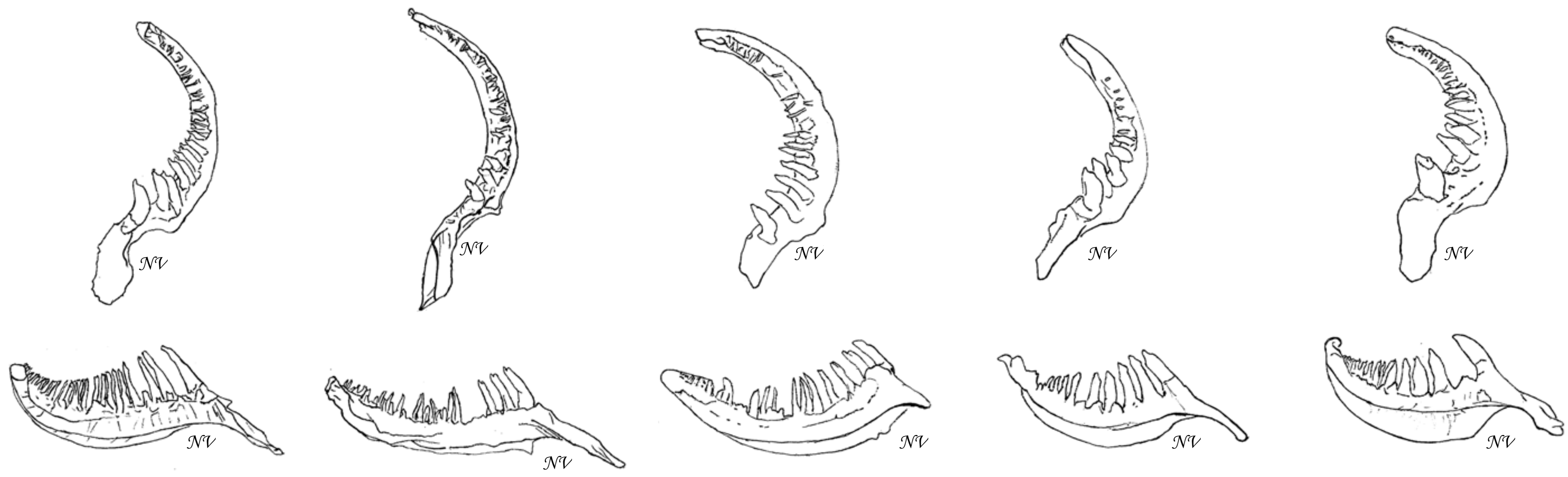
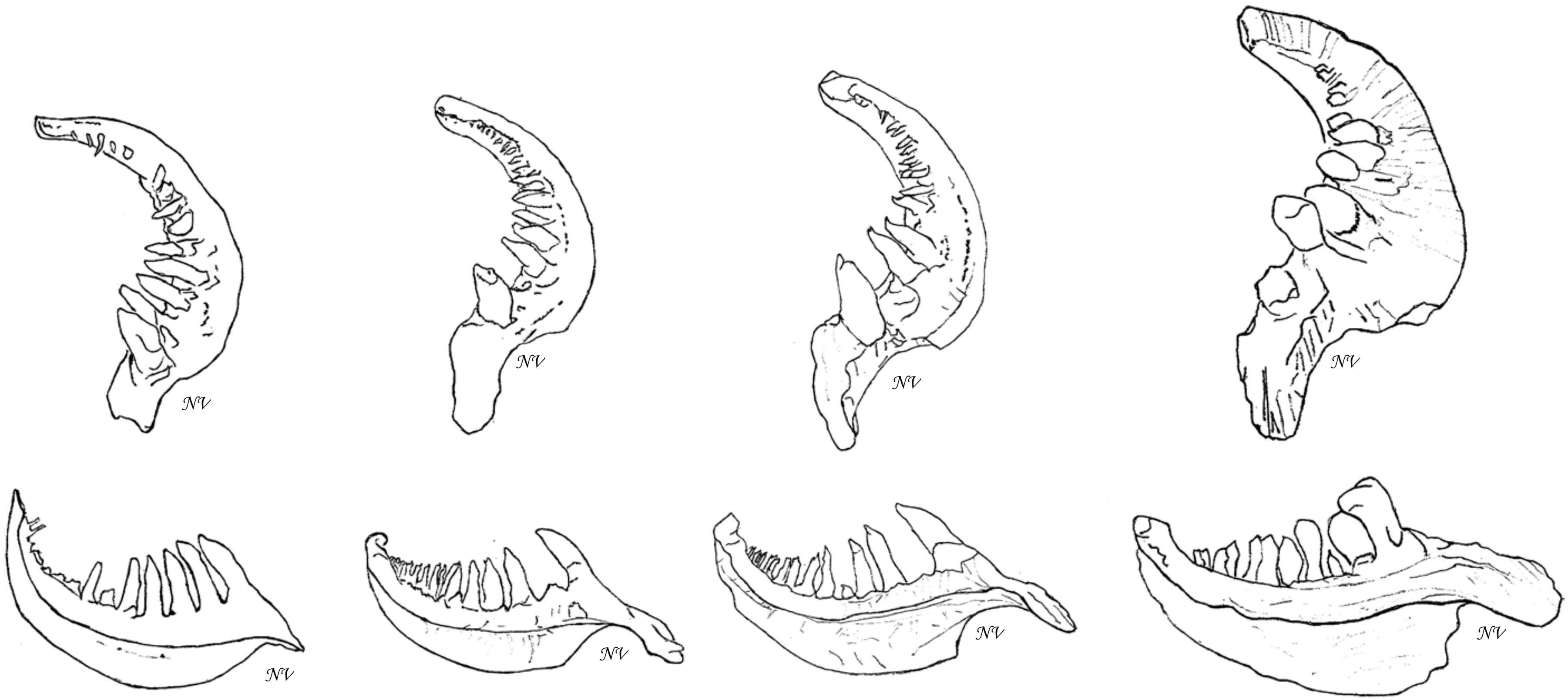


Figure 5 : Typical pigmentation on the basal part of the first gill raker in river redhorse (TL : 51,0 mm).



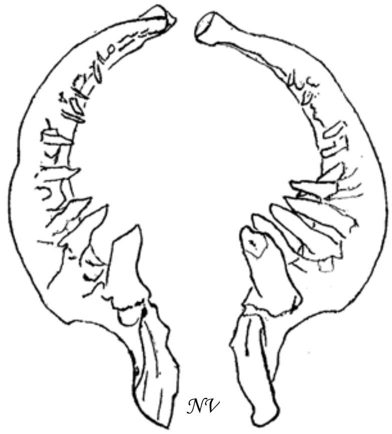
A shorthead redhorse (56,0 mm) | **B** silver redhorse (49,5 mm) | **C** greater redhorse (55,5 mm) | **D** river redhorse (41,5 mm) | **E** copper redhorse (42,0 mm)

Figure 6 : Pharyngeal arch and teeth morphology of the young-of-the-year redhorse from Québec (dorsal and lateral views). Total length of specimen is in parentheses.



A : 38,5 mm **B :** 42,0 mm **C :** 53,5 mm **D :** 143,0 mm

Figure 7 : Pharyngeal arch and teeth morphology of young copper redhorse at different lengths (dorsal and lateral views).



A : river redhorse (44,0 mm)
Entire structure

B : copper redhorse (144,0 mm)

Figure 8 : Pharyngeal arch and teeth morphology of the young river and copper redhorse from Québec (dorsal and lateral views). Total length of specimen is in parentheses.

Figure 9 : Pharyngeal arch and teeth morphology of an artificially reared copper redhorse (TL : 37,0 mm) (dorsal and lateral views).

4-CONCLUSION

Action 3.6, considered as a priority in the Intervention Plan for the restoration of the copper redhorse (1999-2003) (Comité d'intervention 1995, 1999), which suggest the elaboration of an identification key for the Québec juvenile redhorse, has now been completed for specimens of 35 mm (TL) and larger. Criteria developed in the course of this study allow an easier identification of Québec redhorse juveniles using external morphological characteristics. Even though some of these criteria are based on pigmentation, they proved to be relatively constant between the different cohorts examined. Because the variability of pigmentation patterns has not been compared with specimens from other regions, the use of this key should, at this moment, be restricted to Québec redhorse. The general body pigmentation pattern, the occipital pigmentation intensity and the shape of the supraorbital canals are the three main criteria for field identification of at least three species: shorthead, silver and river redhorse. Persons intending to identify redhorse in the field must be experienced by examining a large number of specimens of all redhorse species. Discrimination by external morphologic characteristics of the two species of the subgenus *Megapharynx* is subtler and could be eventually improved. More specifically, we are referring to the considerable efforts undertaken by R.E. Jenkins for North American species whose works will eventually complete this study. Meanwhile, the best method to make an accurate discrimination between the copper and the greater redhorse requires the dissection of the pharyngeal arch.

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The revision of this document was performed by Pierre Dumont (FAPAQ) and Erling Holm (Royal Ontario Museum).

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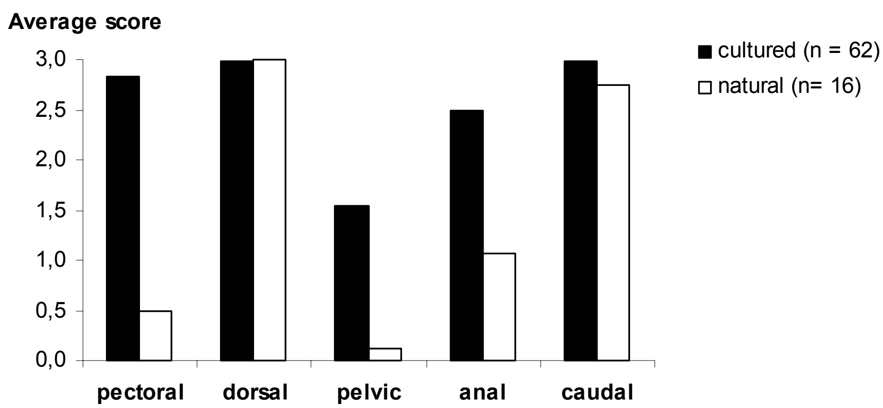
APPENDIX 1

Comparison of the average score of fin pigmentation between natural and and cultured copper redhorse. Score definition : **0** = absent, **1** = slightly, **2** = medium. **3** = very pigmented.



APPENDIX 2

Characteristics of the specimens used for drawings. All specimens were captured in the Richelieu River mainly from August to October 1997 (Vachon 1999a).

Figure	Illustration type	Species	TL (mm)	Age	Date of capture	Station	No.	Magn.
1A	Entire body, lateral view	shorthead	60,0	0	30 / 10 / 97	22AV1	117	6,3X
1B		silver	56,0	0	15 / 09 / 97	96D	321	6,3X
1C		River	58,5	0	05 / 11 / 97	8GV1	399	6,3X
1D		greater	55,5	0	21 / 10 / 97	22A	460	6,3X
1E		copper	38,0	0	05 / 11 / 97	22A	409	8X
1F		copper	40,0	-	20 / 01 / 91	aquarium 1[1]	-	8X
2A	Dorsal view of the head	shorthead	55,5	0	15 / 09 / 97	96D	317	8X
2B		silver	53,0	0	15 / 09 / 97	96D	332	8X
2C		River	51,0	0	07 / 10 / 97	92G	273	8X
2D		greater	52,0	0	24 / 09 / 97	21A	111	8X
2E		copper	42,0	0	21 / 10 / 97	22A	451	8X
3A	Mouth	shorthead	55,0	0	03 / 09 / 97	88D	-	25X
3B		shorthead	56,0	0	03 / 09 / 97	88D	-	25X
3C		silver	54,5	0	26 / 08 / 97	81D	211	25X
3D		greater	52,0	0	24 / 09 / 97	21A	111	25X
3E		River	51,0	0	07 / 10 / 97	92G	273	25X
3F		copper	42,0	0	21 / 10 / 97	22A	451	25X
4	Lateral view of the head	greater	51,0	0	05 / 11 / 97	22A	410	8X
5	Gill raker pigmentation	River	51,0	0	24 / 09 / 97	24G	423	10X
6A	Pharyngeal arch	shorthead	56,0	0	03 / 09 / 97	88D	-	25X
6B		silver	49,5	0	26 / 08 / 97	83D	-	25X
6C		greater	55,5	0	05 / 11 / 97	6G	414	25X
6D		River	41,5	0	26 / 08 / 97	83D	198	25X
6E		copper	42,0	0	21 / 10 / 97	22A	451	25X
7A		copper	38,5	0	16 / 10 / 97	22A	381	25X
7B		copper	42,0	0	21 / 10 / 97	22A	451	25X
7C		copper	53,5	1+	09 / 06 / 98	22AM3	601	25X
7D		copper	143,0	-	19 / 09 / 74	Richelieu River	29290	8X
8A		River	44,0	0	03 / 09 / 97	89D	73	25X
8B		copper	144,0	-	19 / 09 /74	Richelieu River	29068	8X
9		copper	37,0	-	20 / 01 / 91	aquarium 1 [1]	-	25X

[1] Branchaud and Gendron (1993). Reared specimens.