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Update on the Status of the Wavy-rayed Lampmussel (Lampsilis fasciola) in Ontario Waters

BY:

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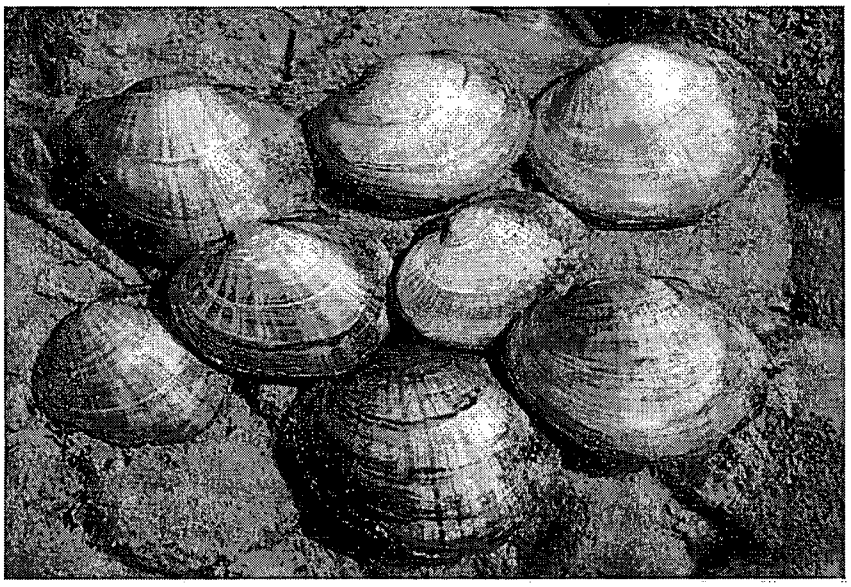

Live specimens of *Lampsilis fasciola* collected from the Grand River near Kitchener, Ontario in August 1997. Photo credit: S.K. Staton.

Prepared for the

Sydenham River Recovery Team

and the

Interdepartmental Recovery Fund

by

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ABSTRACT

The Wavy-rayed Lampmussel, *Lampsilis fasciola*, was listed as endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 1999. The species' range in Canada once included Lake Erie, Lake St. Clair, and the Grand, Thames, Sydenham, Detroit, St. Clair, Ausable and Maitland rivers in southwestern Ontario. According to the COSEWIC status report, which was prepared in 1998, its numbers in Great Lakes waters have been reduced by impacts of the zebra mussel, *Dreissena polymorpha*, and populations in the Thames, Sydenham and Ausable rivers are disappearing due to pollution and habitat destruction. Only the population in the Grand River appears to be healthy. This report provides an update on the status of *L. fasciola* in Ontario waters that includes new information from surveys conducted in the Sydenham and Ausable rivers and Lake St. Clair between 1999 and 2002. A variety of sampling techniques were used, including timed searches, quadrat surveys and "targeted" searches, i.e., searches that focused on the known habitat of this species. Results showed that the Wavy-rayed Lampmussel has likely been extirpated from the Sydenham River. This conclusion is based on over 800 person-hours (p-h) of search effort between 1997 and 2002, which greatly exceeds the 100-200 p-h expended in the other rivers and Lake St. Clair. No live *L. fasciola* had been found at any of the eight sites surveyed on the Ausable River in 1998. Seven more sites were surveyed in 2002, and only two large, old female specimens were found. These animals may be remnants of a larger population that once inhabited the river. Populations in the Thames River, which was surveyed in 1997-98, showed a similar trend. Surveys in the delta area of Lake St. Clair in 1999 and 2001 showed that this area serves as a "refuge" from the zebra mussel where many native mussel species, including the Wavy-rayed Lampmussel, continue to survive. The population of *L. fasciola* is of low density, but there is evidence of recent recruitment. This update forms the basis for the development of a recovery plan for the endangered Wavy-rayed Lampmussel, as required under the new Species at Risk Act (SARA). The report recommends that: (a) the Grand River population be protected; (b) the St. Clair delta population be studied further to determine if it is stable; (c) further surveys be conducted in the Maitland River where a few live specimens were found in 1998; and (d) studies be conducted to determine the factors responsible for the loss of this species from the Sydenham River.

RÉSUMÉ

En 1999, le Comité sur la situation des espèces en péril au Canada (COSEPAC) a ajouté la lampsile fasciolée, *Lampsilis fasciola*, à la liste de ces espèces. L'aire de répartition de cette espèce comprenait autrefois le lac Érié, le lac Sainte-Claire et les rivières Grand, Thames, Sydenham, Detroit, Sainte-Claire, Ausable et Maitland dans le sud-ouest de l'Ontario. Selon le rapport de situation du COSEPAC de 1998, le nombre d'individus de cette espèce dans les Grands Lacs a fortement baissé suite à l'impact exercé par la moule zébrée, *Dreissena polymorpha*; les populations de lampsile fasciolée des rivières Thames, Sydenham et Ausable sont en train de disparaître suite à la pollution et à la destruction de leur habitat. Seule la population de la rivière Grand semble en bonne santé. Le présent rapport est une mise à jour de la situation de *L. fasciola* dans les eaux ontariennes, incluant de nouvelles données qui proviennent d'études effectuées entre 1999 et 2002 dans les rivières Sydenham et Ausable ainsi que dans le lac Sainte-Claire. Diverses techniques d'échantillonnage ont été utilisées, notamment l'échantillonnage selon un temps déterminé, l'échantillonnage par quadrats et les recherches « ciblées », qui sont axées sur l'habitat connu de l'espèce. Les résultats ont montré que l'espèce avait probablement disparu dans la rivière Sydenham. Cette conclusion est basée sur plus de 800 personnes-heures (p-h) de travaux de recherches effectuées entre 1997 et 2002, ce qui est largement supérieur aux 100-200 p-h consacrées aux études d'autres rivières et du lac Sainte-Claire. Aucune *L. fasciola* vivante n'a été trouvée dans l'un quelconque des 8 sites explorés dans la rivière Ausable en 1998. Sept sites supplémentaires étudiés en 2002 n'ont donné lieu qu'à la découverte de deux grandes femelles âgées. Ces animaux pourraient être les restes d'une population plus importante qui habitait autrefois la rivière. Les populations de la rivière Thames, qui ont été étudiées en 1997-98, présentaient une tendance comparable. Des études effectuées en 1999 et 2001 dans la région du delta du lac Sainte-Claire ont montré que cette dernière sert de « refuge » contre la moule zébrée pour de nombreuses espèces de moules indigènes, y compris la lampsile fasciolée, qui continuent de survivre. La population de *L. fasciola* est peu dense, mais il y a des signes de recrutement récent. La présente mise à jour constitue la base de l'élaboration d'un plan de rétablissement pour la lampsile fasciolée, aux termes de la Loi sur les espèces en péril. Le présent rapport recommande que : a) la population de la rivière Grand soit protégée; b) la population du delta de la Sainte-Claire soit étudiée plus à fond afin de déterminer si elle est stable; c) des études additionnelles soient effectuées dans la rivière Maitland, où quelques spécimens vivants ont été découverts en 1998; d) des études soient entreprises afin de déterminer les facteurs responsables de la perte de cette espèces dans la rivière Sydenham.

INTRODUCTION

The wavy-rayed lampmussel, *Lampsilis fasciola* (Rafinesque 1820), was listed as endangered in 1999 by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 1999). The historical range of this species in Canada included Lake Erie, Lake St. Clair, and the Grand, Thames, Sydenham, Detroit, St. Clair, Ausable and Maitland rivers in southwestern Ontario. It has been eliminated, or nearly so, from the lower Great Lakes and connecting channels due to impacts of the zebra mussel, *Dreissena polymorpha*. It is still found alive in portions of its historical range, but is generally in decline. The species is also declining throughout most of its range in the U.S., particularly in the upper Midwest (Strayer *et al.* 1991; Strayer and Jirka 1997).

The National Water Research Institute began conducting mussel surveys in southwestern Ontario in 1997 to determine the conservation status of a number of rare species believed to be at risk. The COSEWIC status report (Metcalfe-Smith *et al.* 1998b) on *L. fasciola* considered information from 37 sites surveyed on the Grand, Thames and Sydenham rivers in 1997. Surveys were conducted at 29 additional sites on the Grand, Thames, Sydenham, Ausable and Maitland rivers in 1998. Information from these sites was included in a subsequent paper on the status of the species in Ontario and Canada (Metcalfe-Smith *et al.* 2000c). A considerable amount of additional sampling has been conducted since 1998, particularly in the Sydenham and Ausable rivers and Lake St. Clair.

The purpose of this report is to provide an update on the status of the wavy-rayed lampmussel in Ontario waters. This information will be needed for the preparation of a status update on the species, which is required by COSEWIC within 10 years of listing. The report also satisfies one of our commitments to the Interdepartmental Recovery Fund for 2002-03, which was to conduct additional searches for *L. fasciola* in the Sydenham River to determine if the species has been extirpated from the system. Perhaps most importantly, this report forms the basis for the development of a recovery strategy for the wavy-rayed lampmussel in Canada, as required under new Species At Risk legislation.

DESCRIPTION

The wavy-rayed Lampmussel, *Lampsilis fasciola*, is easily recognized by its yellow or yellowish-green rounded shell with numerous thin wavy green rays. The rays may be narrow and individual or narrow and coalesced into wide rays, but they are always wavy with multiple interruptions. Clarke (1981) described additional features of the shell as follows: "...mid-anterior shell wall about 7.5 mm thick; quadrate-ovate (males) or ovate (females), heavy and strong, moderately inflated, and heavily rayed. Surface smooth except for concentric wrinkles and growth rests. Posterior ridge indistinct....Nacre white or bluish white. Beaks elevated, and beak cavities moderately excavated. Beak sculpture rather fine and composed of about 6 concentric broadly curved bars that are sinuous or broken in the centre. Hinge teeth well developed and moderately heavy: pseudocardinal teeth stumpy or subconical, elevated, serrated, 2 in the right valve (the anterior tooth small) and 2 in the left; lateral teeth rather short, strong, slightly curved, 1 in the right valve and 2 in the left." Sexual dimorphism is pronounced, with the female having a distended shell shape. The maximum shell length ranges from 75-100 mm in the U.S. The largest specimen seen during recent surveys in Ontario was a 102 mm male (shell) collected from the Thames River.

DISTRIBUTION

Lampsilis fasciola was historically known from Alabama, Georgia, Illinois, Indiana, Kentucky, Michigan, New York, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, and Ontario. It was found throughout the Ohio and Mississippi River systems as far south as the Tennessee River system, in the upper Allegheny River drainage in western New York, in Lake Erie and Lake St. Clair and their drainages, and in tributaries of Lake Michigan, lower Lake Huron and Lake Ontario, including the Niagara River. Canadian populations were limited to Ontario and once included western Lake Erie, Lake St. Clair, and the Maitland, Ausable, St. Clair, Sydenham, Thames, Detroit and Grand rivers (Fig. 1).

The wavy-rayed lampmussel is considered to be stable in the U.S. (Williams *et al.* 1993) and has been assigned a global rank of G4 by The Nature Conservancy. However, it has disappeared

from several rivers in Illinois, Ohio, Tennessee, Virginia and Pennsylvania, and is listed as endangered in Illinois, threatened in Michigan and New York, and special concern or interest in Indiana, Ohio and North Carolina (Dennis 1984; Cummings and Mayer 1992; Strayer & Jirka 1997). *Lampsilis fasciola* has likely been extirpated from Lake Erie, the Detroit River (D.W. Schloesser, US Geological Survey, unpublished data), the Niagara River (K. Schneider, consultant, unpublished data) and the Sydenham River (this report). Figure 2 shows the current distribution of *L. fasciola* in southwestern Ontario.

HABITAT

Lampsilis fasciola inhabits clear, hydrologically stable rivers and streams, where it is typically found in clean sand/gravel substrates in and around riffle areas at depths of up to 1 m. It is most abundant in small (2^{nd} to 4^{th} order) to medium-sized (5^{th} to 7^{th} order) streams (Dennis 1984). Its habitat in the Great Lakes consists of shallow wave-washed shoals. The wavy-rayed lampmussel is almost invariably found at sites that support a great diversity of other mussel species, suggesting that it cannot tolerate sub-optimal conditions. Dennis (1984) found that *L. fasciola* frequently co-occurred with two other mussel species, the fluted shell (*Lasmigona costata*) and the spike (*Elliptio dilatata*), and we have also observed this association in some Ontario waters (Metcalfe-Smith *et al.*, unpublished data). The presence of these two common species may indicate habitats that are suitable for *L. fasciola*, and could therefore be used to identify areas for re-introductions of *L. fasciola* if required.

BIOLOGY

Lampsilis fasciola is a medium-sized, sexually dimorphic mussel that has been shown to live at least 10 years but rarely more than 20 years. It is a long term brooder (bradytictic); spawning occurs in August, and glochidia (larvae) are released the following July through August in Canadian populations. In females of the genus *Lampsilis*, the edge of the mantle has evolved into a minnow-shaped "lure". When the glochidia are ready to be released, the female waves her lure to attract potential fish hosts. Females displaying the typical lure, and others displaying unusual reddish-orange mantle flaps, have both been observed in the Grand River. Two or more

variations in mantle flap morphology have also been observed in populations in the United States and are believed to represent either pronounced polymorphism or sibling species. If the latter is true, then the conservation status of the species will have to be re-evaluated. Once expelled into the water by the female, the glochidia must attach to an appropriate fish host in order to complete their metamorphosis. The glochidia of *L. fasciola* are purse-shaped and without spines; they are higher than long, which indicates an adaptation to gill attachment. Two fish hosts, the smallmouth bass (*Micropterus dolomieu*) and largemouth bass (*Micropterus salmoides*), have been identified for this species (Zale and Neves 1982; G.T. Watters, Ohio State University, unpublished data). There may be other hosts for *L. fasciola*; however, metamorphosis was not recorded from 16 other fish species in laboratory exposures (Watters and O'Dee 1996).

Both respiration and feeding occur by means of the gills. As water is pumped through the gills by the inhalant siphon, food and oxygen are removed. Many mussels prefer flowing water because it is usually oxygen rich and continuously delivers a supply of food to these sedentary animals. Although exact food preferences and optimum particle sizes of *L. fasciola* are not known, they are probably similar to those of other freshwater mussels, i.e., suspended organic particles such as detritus, bacteria and algae.

POPULATION SIZES AND TRENDS IN ONTARIO

Table 1 presents all known records for the occurrence of *L. fasciola* in southwestern Ontario prior to 1997. Table 2 presents all records obtained by NWRI during mussel surveys conducted between 1997 and 2002. Most of the surveys were conducted using 4.5 person-hour (p-h) timed searches, which we have shown to be an efficient method for detecting rare species (Metcalfe-Smith *et al.* 2000a). Additional records were obtained during quantitative sampling and targeted searches in the Sydenham River, and further sampling in this and other rivers for various purposes. Most of the records for Lake St. Clair were obtained by D.T. Zanatta during his M.Sc. thesis research at the University of Guelph. Only about 0.5% of approximately 5000 historical records in NWRI's Lower Great Lakes Unionid Database are for this species, suggesting that it has always been rare in Canada. Recent surveys have yielded more individual specimens than in the past, likely as a result of increased sampling effort and targeted searches for this and other

rare mussel species. Results of the recent surveys are compared with the historical data to determine population trends for the wavy-rayed lampmussel in Ontario.

Ausable River

The only historical data available for mussels in the Ausable River are those of Reimann in 1950 (museum records) and Detweiler (1918). Eleven species were recorded, but *L. fasciola* was not among them. Morris and Di Maio (1998) surveyed six sites on the river in 1993-1994 using a sampling effort of 1 p-h/site and found a single live specimen at a site near Brinsley.

We surveyed eight sites on the river in 1998 (Metcalfe-Smith *et al.* 1999) and seven sites in 2002 (Metcalfe-Smith *et al.*, unpublished data). One live specimen of *L. fasciola* was found at a site on the Little Ausable River near Ailsa Craig and another was found on the main stem near Nairn in 2002. Both specimens were female and one was gravid. A few fresh whole shells were also found at sites in the middle reach of the Ausable River between Brinsley and Nairn in 1998, suggesting that a small population of *L. fasciola* may occur in this section of the river.

Maitland River

Lampsilis fasciola was found at a site on the Maitland River near Auburn in 1935. We conducted a 4.5 p-h timed search at this site in 1998 and found one live female, two live males and three whole shells. As this was the only site sampled, additional surveys should be conducted to determine the distribution and abundance of the wavy-rayed lampmussel in the Maitland River.

Thames River

There are only three historical records of *L. fasciola* from the Thames River; one fresh whole shell was recorded from Chatham in 1902, and "occurrences" (condition of specimens not noted)

were reported from an unknown location in 1931 and at London in 1936 (museum records). Morris (1996) and Morris and Di Maio (1998) surveyed 46 sites throughout the system in 1994-95 using a sampling effort of 1 p-h/site and found no trace of this species.

We surveyed 16 sites on the Thames River in 1997-98 and found live animals and/or fresh shells of *L. fasciola* at six of nine sites examined in the upper reaches of the river above London (Metcalfe-Smith *et al.* 1998a, 1999). Only small numbers of specimens were found, including six live animals, eight fresh shells and 14 weathered shells. These are the first records of *L. fasciola* from the Thames River in 60 years, showing that the species continues to persist in the upper portion of the watershed. No additional surveys have been conducted on the Thames River since the COSEWIC status report was completed in 1999.

Grand River

There are only three historical records of *L. fasciola* from the Grand River and all are from the middle reaches of the river (Galt in 1894, Glen Morris in 1929 and Breslau in 1931). There have been three major surveys for mussels in the Grand River over the past 25 years. Kidd (1973) surveyed 76 sites throughout the system in 1970-72; Mackie (1996) surveyed 70 sites in 1995, focusing mainly on the tributaries; and we surveyed 24 sites in 1997-98, most of which were on the main stem. Kidd (1973) found two live animals at West Montrose. He also found shells at this and three other sites near Glen Morris and Kitchener, and at one site on the Nith River near Paris. Mackie (1996) found a few shells at the site near West Montrose. For a discussion of changes over time in the mussel communities of the Grand River, see Metcalfe-Smith *et al.* (2000b).

We conducted timed search surveys at 24 sites on the Grand River in 1997-98, including all sites where live specimens or shells had been found during previous surveys. Additional searches were conducted at several of these sites, and three more sites were visited between 1998 and 2001. We found a total of 31 live animals, 50 fresh shells and 35 weathered shells at 16 different sites. All live animals and fresh shells were found in the upper Grand River between Inverhaugh

and Cambridge, and at one site on the Conestogo River and two sites on the Nith River. A few weathered shells were found as far downstream as York. The upper Grand River supports the most significant population of the wavy-rayed lampmussel in Canada.

Lake St. Clair

Nalepa *et al.* (1996) surveyed 29 sites in Lake St. Clair in 1986, 1990, 1992 and 1994 and found only four live specimens of *L. fasciola*. It appeared that *L. fasciola*, like so many other native mussel species would soon be extirpated from Lake St. Clair due to impacts of the zebra mussel. However, Zanatta *et al.* (2002) discovered a significant refuge site for native mussels in the delta area of Lake St. Clair in 1999. This site continues to support at least 22 of the 32 species of unionids known to occupy the lake historically, including *L. fasciola*. A total of 19 live wavy-rayed lampmussels were found at five of 33 sites where live unionids occurred. Most sites inhabited by mussels were in shallow water (<1m) with firm sand/gravel substrates. *Lampsilis fasciola* represented 0.8% of the 2356 live individuals captured, and density was estimated to be 0.0015/m^2. The wavy-rayed lampmussel typically accounts for 1-2 % of the community at sites where it occurs, and up to 2-4% in optimum habitats (Dennis 1984). Densities of zebra mussels are relatively low in the delta, which lessens their impact on the native mussel community. Further studies are planned to determine if the unionid community of the delta is stable and to better understand the mechanisms responsible for its successful co-existence with zebra mussels.

Lake Erie and the Detroit and St. Clair rivers

Native mussel communities were virtually extirpated from the offshore waters of Lake Erie by 1990 (Schloesser and Nalepa 1994), with similar declines in the connecting channels and most nearshore habitats. However, significant communities have continued to survive in several nearshore locations in the US waters of Lake Erie, including Mezger Marsh, Thompson Bay and the mouth of the Raisin River (for details, see Zanatta *et al.* 2002). *Lampsilis fasciola* was not among the species found alive at any of these sites. Only one live specimen of the threeridge (*Amblema plicata*) was found during a survey of Rondeau Bay on the north shore of Lake Erie in

2001 (D. Zanatta and D. Woolnough, unpublished data). We are not aware of any other recent surveys in the Canadian waters of Lake Erie.

The wavy-rayed lampmussel was among 36 species recorded from the Detroit River between 1880 and 1940. Zebra mussels first invaded Lake St. Clair in 1986. Schloesser *et al.* (1998) conducted timed SCUBA searches for mussels at four sites in the Detroit River - immediately below the outlet from Lake St. Clair - in 1992 and 1994. The sites were surveyed again in 1998 (Schloesser *et al.*, in preparation). Abundance decreased from 720 to 39 to 4 individuals during this period and richness declined from 24 to 13 to 4 species, indicating that the mussel community of the Detroit River has essentially been lost. *Lampsilis fasciola* was not found during any of these surveys.

A single live specimen of *L. fasciola* was found at a site on the St. Clair River near Sarnia during benthic invertebrate sampling in 2001 (C. Logan, NWRI, pers. comm.). We are not aware of any recent surveys for mussels in the St. Clair River.

Sydenham River

Lampsilis fasciola was first recorded from the Sydenham River in 1965, when C.B. Stein found four fresh whole shells at a site near Florence. In 1967, she found two live specimens and eight fresh whole shells at a site near Alvinston. Athearn reported the species from a site near Shetland in the same year. Clarke (1973, 1992) surveyed 11 sites in the river in 1971 and 16 sites in 1991, and Mackie and Topping (1988) surveyed 32 sites in 1985. Only one live specimen of *L. fasciola* was found during these surveys; it was collected from a site above Alvinston in 1971. We surveyed 17 sites on the river in 1997 and 1998, including the four sites where live animals or shells had been found in the past. No living specimens were found, but three fresh whole shells were collected from the two sites nearest Alvinston.

To determine of the wavy-rayed lampmussel is still extant in the Sydenham River, intensive searches were conducted at six sites between Rokeby and Florence in 2002. Five sites were searched on July 9-11 using a five-person team and a sixth site was searched on July 30 using a

three-person team, for a total sampling effort of 41 person-hours. No live specimens were seen, but one weathered valve was found at each of three sites and one fresh whole shell from a very large, old animal was found at a fourth site.

The wavy-rayed lampmussel is one of 14 COSEWIC-listed aquatic species that are being addressed in the Sydenham River Recovery Strategy (Sydenham River Recovery Team 2003). One of the short-term (5-year) objectives of the Strategy is to establish a broad-based monitoring program to track changes in the system and its species as recovery action as are implemented. A network of 15 index sites was set up to monitor changes in the mussel community, with particular emphasis on the five endangered species, i.e., the wavy-rayed lampmussel, northern riffleshell (*Epioblasma torulosa rangiana*), rayed bean (*Villosa fabalis*), snuffbox (*Epioblasma triquetra*) and mudpuppy mussel (*Simpsonaias ambigua*). The sampling protocol consists of quantitative sampling using 1 m^2 quadrats and a systematic sampling design. A total area of approximately 400 m^2 is sampled at each site, using a three-person team and covering 20% of the sampling area. Ten index sites were sampled between 1999 and 2002, with a total sampling effort (i.e., actual time spent excavating the substrate) of 98 p-h. No live *L. fasciola* were found. One fresh valve and one weathered whole shell were found at a site near Rokeby and one weathered valve was found at a site near Florence. Researchers from the University of Guelph logged an additional 200 p-h of sampling effort in 2001 (D. Woolnough, pers. comm.) and 300 p-h in 2002 (K. McNichols, pers. comm.) during their searches for gravid females of COSEWIC-listed mussel species for host fish testing. Although they found many specimens of the other target species, they did not observe a single live specimen of *L. fasciola*.

We have concluded that the wavy-rayed lampmussel has been extirpated from the Sydenham River. It was last seen alive in 1971.

Synopsis and Comparisons of Populations Health among Systems

The wavy-rayed lampmussel has been lost from much of its former range in Canada as a result of anthropogenic impacts and zebra mussels, and the populations that remain are at continued risk from these threats (see Limiting Factors). It has been extirpated from Lake Erie, the Detroit and

Niagara rivers and most of Lake St. Clair due to impacts of the zebra mussel. A sparse population remains in the St. Clair delta, and we do not know at this point if it is stable or declining. Ten females and nine males ranging in shell length from 34 to 67 mm were found alive in recent years (Fig. 3), suggesting that recruitment is occurring. Note that the "lake form" of this and many other mussel species is considerably smaller than the river form.

The healthiest population of the wavy-rayed lampmussel in Canada occurs in a 60 km stretch of the upper Grand River between Inverhaugh and Cambridge. Smaller populations – or perhaps just scattered specimens – may be found in the Nith and Conestogo rivers. Shell lengths of specimens found alive between 1997 and 2001 ranged from 30-90 mm and were normally distributed, indicating a healthy reproducing population (Fig. 3). The sex ratio for live animals was slightly skewed (30% M: 70% F), but it was nearly 1:1 when all 110 live specimens and shells were considered. Further surveys are needed to determine if the Maitland River also sustains a significant population of the wavy-rayed lampmussel. The six specimens that we collected from this river (3 live, 3 shells) ranged from 46 to 69 mm in shell length, indicating the presence of several year classes.

Four female *L. fasciola* and two males were found alive in the upper reaches of the Thames River, and all were large (58-72 mm shell length). Similarly, only two large specimens, a 75 mm male and a 78 mm female, were found alive in the Ausable River (Fig. 3). We suspect that these specimens may be remnants of larger populations that once inhabited these rivers. The shells that we collected were also large, ranging from 54-102 mm (mean = 75 mm) for the Thames and 60-96 mm (mean = 77 mm) for the Ausable (Appendix 1). In contrast, shells collected from the Grand River ranged from 27-92 mm (mean = 65 mm). We have noticed that many species do not grow as large in the Grand River as they do in the Ausable, Thames and Sydenham Rivers (McGoldrick *et al.*, in prep.), and this could explain the smaller mean size of Grand River specimens. However, if the populations in the Thames and Ausable were reproducing, we would have expected to find at least some small animals.

As stated earlier, we believe that the wavy-rayed lampmussel has been extirpated from the Sydenham River. Our conclusion is backed by an extraordinary amount of search effort

expended in the Sydenham River between 1997 and 2002 relative to the other rivers and Lake St. Clair (Table 3). We are mindful of the fact that Clarke (1992) declared five species, namely, the northern riffleshell, snuffbox, mudpuppy mussel, rainbow (*Villosa iris*) and wavy-rayed lampmussel, extirpated from the Sydenham River in 1991 after only 39 p-h of sampling effort at 16 sites. It now appears that his conclusion was premature for all but one of these species (Metcalfe-Smith *et al.* in press). We have shown elsewhere that increasing the sampling effort in timed search surveys can dramatically improve the detection of rare species (Metcalfe-Smith *et al.* 2000a).

Fewer shells were collected from the Sydenham River (10) than from the Thames and Ausable rivers (22 and 14, respectively), and all were relatively large (56-81 mm shell length; Appendix 1). The absence of smaller shells suggests that the wavy-rayed lampmussel has been unable to reproduce successfully in the Sydenham River for some time.

LIMITING FACTORS

Limiting factors for *L. fasciola* are described in detail in Metcalfe-Smith *et al.* (2000c). This information has been summarized and updated below:

Habitat loss and degradation due to dams, dredging, channelization, siltation and pollution are major causes of the decline of freshwater mussels across North America over the last century (Williams *et al.* 1993). According to Strayer and Fetterman (1999), the main threats to mussels today are high loads of sediment, nutrients and toxic chemicals from non-point sources, especially agriculture. Fine sediments are believed to be more harmful to mussels in streams with low gradients than high gradients, as the sediments will settle instead of being flushed out. The main factor limiting the occurrence of *L. fasciola* in Ontario is probably the availability of clean, silt-free, riffle/run habitat. Susceptibility to siltation differs from species to species, and there is evidence that *L. fasciola* can tolerate some silt deposition during low flow periods (Dennis 1984). However, *L. fasciola* is the only species of unionid that has been extirpated from the Sydenham River (Metcalfe-Smith *et al.* in press), and we believe that poor water clarity due to high loadings of suspended sediment may be responsible. Table 4 shows the relationship

between water clarity and the occurrence of *L. fasciola* at 73 sites on five rivers in southwestern Ontario. All sites on the Grand, Thames, Maitland and Ausable rivers where the wavy-rayed lampmussel was found alive in 1997-98 or 2002 had water clarity readings of greater than 45 cm, except for one site on the Ausable River that had a reading of 12 cm (data not shown). Over half of the sites on the Grand and Thames rivers and the single site on the Maitland River had water this clear, as compared with 20% of sites on the Ausable and only one site on the Sydenham River. In all rivers, the mean water clarity of sites supporting *L. fasciola* was greater than the mean water clarity of all sites. Furthermore, catch-per-unit effort (CPUE) for *L. fasciola* increased as water clarity increased. These results imply that water clarity is an important limiting factor for *L. fasciola.*

Due to the parasitic stage in their life cycle, unionids are sensitive not only to environmental factors that limit them directly, but also to factors that affect their hosts (Bogan 1993). Any factor that changes the distribution or abundance of the host fauna may have detrimental effects on mussel populations. There are two known hosts for *L. fasciola*, namely, the largemouth bass and the smallmouth bass. The smallmouth bass is the more likely host in Ontario waters because it tends to be associated with rocky and sandy substrates rather than the soft sediments and heavy weed growth preferred by largemouth bass (Scott and Crossman 1973). Bass are sight predators, and we speculate that *L. fasciola* relies on clear water – and hence, good visibility – in order to attract its host and successfully reproduce. This may be the mechanism by which water clarity limits the distribution of *L. fasciola.*

Results of fish surveys in the Sydenham River in 2002 show that smallmouth bass are rare in this system (M. Poos, University of Guelph, pers. comm.). There is anecdotal evidence to suggest that this popular game fish was once more common in the river, but the last confirmed record is from 1975 (E. Holm, Royal Ontario Museum, pers. comm.). Declining numbers of smallmouth bass may be responsible for the extirpation of *L. fasciola* from the Sydenham River. Over the past decade, smallmouth bass populations in the upper Grand River between Cambridge and West Montrose have been significantly reduced, most likely due to angling pressure (Cooke *et al.* 1998). This is of great concern, since the population of wavy-rayed lampmussels in this reach of the Grand River is the only one in Ontario that is known to be reproducing successfully.

The introduction and spread of dreissenid mussels throughout the Great Lakes has decimated native freshwater mussel populations in infested areas (Schloesser *et al.* 1996). Zebra mussels attach to a unionid's shell where they interfere with activities such as feeding, respiration, excretion and locomotion – effectively starving it to death (e.g., Baker and Hornbach 1997). We previously stated that zebra mussels should not pose a significant threat to *L. fasciola* in Canada, because this unionid is primarily a riverine species (Metcalfe-Smith *et al.* 2000c). However, we have since discovered a significant population in the delta area of Lake St. Clair (Zanatta *et al.* 2002). We do not know if this population is stable or if it is simply declining more slowly than in other areas of the lake. Until this question has been answered, we must consider zebra mussels to be a significant threat to the survival of *L. fasciola* in Canada.

Havlik and Marking (1987) showed that heavy metals, pesticides, ammonia, crude oil, and many other environmental contaminants are toxic to mussels, especially during their early life stages. However, the specific effects of these substances, and the levels at which they are toxic, are still not well understood. We are aware of only one published study on the toxicity of an environmental contaminant to the wavy-rayed lampmussel. Jacobson *et al.* (1997) found *L. fasciola* to be more sensitive to copper than four other species of unionids.

Freshwater mussels are known to be a food source for a variety of mammals and fishes (Fuller 1974). Predation by muskrats in particular may be a limiting factor for some mussel species. Tyrell and Hornbach (1998) and others have shown that muskrats are both size- and species-selective in their foraging, and Neves and Odum (1989) found that *L. fasciola* is one of their preferred species. Although predation is a natural control on mussel populations, we must recognize that land use practices can significantly influence the distribution and density of predators. Although we are not aware of any studies on raccoon predation, we have observed raccoons feeding on mussels in the field, and there is anecdotal information from the farming community in the Sydenham River watershed that the recent adoption of conservation tillage practices has led to an explosion in the raccoon population.

Another potential threat to unionid communities is the recreational use of waterways, particularly by canoeists. During surveys on the Grand River in 1997 and 1998, we observed heavy canoe traffic, especially in the upper reaches where *L. fasciola* still occurs. At some sites where the water was shallow, the substrate was extensively disturbed. As canoeing is becoming an increasingly popular form of outdoor recreation in Ontario, the impact of this human activity on mussel populations that are already declining and under stress could become significant.

RECOMMENDATIONS FOR MANAGEMENT AND RECOVERY

The conservation of native freshwater mussels has been an ongoing effort in the United States since the Clean Water Act and Endangered Species Act were passed in 1972 and 1973, respectively. According to Bogan (1998), these efforts have so far had only a localized or limited effect. In 1998, the National Native Mussel Conservation Committee, an ad hoc committee with representatives from US state, tribal, and federal agencies, the mussel industry, conservation groups, and academia, released its "National Strategy for the Conservation of Native Freshwater Mussels" (NNMCC 1998). The National Strategy identifies research, management, and conservation actions necessary to maintain and recover mussel populations, and many of the recommendations can be applied in Canada.

There are two accepted ways to manage declining mussel populations, i.e., to maintain and protect the existing populations, and to expand the current range to historical proportions (TNC 1986). The latter may be accomplished by stocking with laboratory-reared specimens; augmenting marginal populations with specimens from large, stable populations; and translocating mussels from healthy populations into areas from which they were extirpated. Captive breeding programs have come a long way since the status report on the wavy-rayed lampmussel was prepared in 1998, and they are now a viable option. A host fish testing and juvenile mussel rearing facility has been set up at the University of Guelph, and this facility could potentially provide animals for release into the wild. Genetic studies must first be conducted to ensure that the source and destination populations are genetically compatible. Otherwise, adaptations to local conditions will be lost and the population may decline even more quickly. Before translocations can be considered, it must be determined that the source

populations can withstand the reduction in their numbers, and that the animals being moved can survive the stress. In some cases, translocations have resulted in the loss of both populations (R.J. Neves, Virginia Polytech, pers. comm.).

The best course of action at present would be to preserve the existing populations of the wavy-rayed lampmussel. We must: (a) protect the Grand River population, which appears to be the strongest remaining population in Canada; (b) determine the status (stable or declining) of the St. Clair delta population and (c) conduct further surveys to determine if there are viable populations in the Maitland River or other tributaries to lower Lake Huron. We must also try to determine the factors responsible for the loss of this species from the Sydenham River, which still supports so many other rare and endangered species of mussels.

The goal of the Sydenham River Recovery Strategy is to "sustain and enhance the native aquatic communities of the Sydenham River through an ecosystem approach that focuses on species at risk (Sydenham River Recovery Team 2003). The Strategy describes a wide range of approaches that will benefit the aquatic ecosystem as a whole and individual species in particular. The draft Recovery Action Plans (RAPs), which will be finalized in March 2003, include a number of activities that will benefit the wavy-rayed lampmussel if and when it is reintroduced to the system. Some examples are: Management RAP – enforce legislation to protect species and their habitat, and ensure that road and bridge construction projects respect the natural stream geomorphology and do not further degrade the system; Research and Monitoring RAP – conduct water sampling for pesticides and other agricultural chemicals to determine if levels observed are likely to impact sensitive aquatic species, conduct surveys to determine the distribution and abundance of smallmouth bass (host of *L. fasciola*), and test the hypothesis of a link between high turbidity and the reproductive failure of this mussel; Stewardship RAP – re-establish riparian vegetation to reduce sediment and nutrient loading to the river, and install header tiles and silt traps on tile drain systems and open agricultural drains to minimize the loss of soil; Community Awareness and Outreach RAP – disseminate information on conservation incentive programs, best management practices, etc., in order to promote good land stewardship; set up a website to inform the public, landowners and educators about Species at Risk in the river and encourage their participation in recovery activities.

Recovery Strategies currently being developed for the aquatic ecosystems of the Thames River, Ausable River, and Walpole Island will include provisions for the protection and recovery of the wavy-rayed lampmussel in these systems. However, the new Species At Risk Act (SARA), which comes into force in 2003, also requires the development of species-specific recovery strategies for all endangered and threatened species within one year and two years, respectively, of listing. This report, in conjunction with the COSEWIC status report (Metcalfe-Smith *et al.* 1998b) and subsequent paper (Metcalfe-Smith *et al.* 2000c), form the basis for the development of a recovery strategy for the wavy-rayed lampmussel. This recovery strategy would be the first of its kind for a freshwater mussel in Canada.

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Table 1. Occurrence records for *Lampsilis fasciola* in Canada prior to 1997. Records taken from NWRI's Lower Great Lakes Unionid Database.

Water Body	Date	Nearest Urban Centre	Live Specimens	Shells	Latitude	Longitude	Collector(s)
Ausable River	08/1993	McGillary	1		43.2482	-81.5272	Morris, T.J. &. J. Di Maio
Detroit River	1934	Bois Blanc Island		*	42.0958	-83.1194	Walker, B
Grand River	06/04/1970	West Montrose	2	1	43.5889	-80.4708	Kidd, B.T.
Grand River	06/10/1972			3	43.3986	-80.3856	Kidd, B.T.
Grand River	06/10/1972			6	43.3986	-80.3856	Kidd, B.T.
Grand River	06/10/1972	Glen Morris		2	43.2778	-80.3444	Kidd, B.T.
Grand River	06/10/1972	Kitchener		1	43.4222	-80.4083	Kidd, B.T.
Grand River	1894	Galt	1		43.3556	-80.3167	Macoun, J.
Grand River	08/1995	West Montrose		2	43.5875	-80.4728	Mackie, G.L.
Grand River	05/27/1929	Glen Morris	1		43.2778	-80.3417	Cain, R.F.
Grand River	1931	Breslau		*	43.4778	-80.4222	unknown
Nith River	08/01/1971	Paris		2	43.1903	-80.4542	Kidd, B.T.
Lake Erie	07/11/1967	East Sister Island		*	41.8150	-82.8573	Condit, J.M & J.L. Forsyth.
Lake Erie	08/13/1980	Holiday Prov. Park		*	42.0380	-83.0447	Freitag, T.M.
Lake St. Clair	09/19/1986		1		42.3717	-82.8717	Nalepa, T. & J. Gauvin
Lake St. Clair	09/17/1986		1		42.3717	-82.4550	Nalepa, T. & J. Gauvin
Lake St. Clair	09/18/1986		1		42.4550	-82.6667	Nalepa, T. & J. Gauvin
Lake St. Clair	1994		1		-	-	Nalepa, T. & J. Gauvin
Maitland	08/19/1935	Auburn		*	43.7736	-81.5403	Oughton, J.P.
Sydenham River	08/23/1971	Alvinston	1		42.8500	-81.8167	Clarke, A.H. & L.R. Clarke
Sydenham River	08/07/1967	Alvinston	2	8	42.8071	-81.8448	Stein, C.B. & K.A. Heffelfinger
Sydenham River	08/13/1967	Shetland		*	42.7170	-81.9510	Athearn, H.D. & M.A. Athearn
Sydenham River	08/15/1965	Florence		4	42.6499	-82.0999	Stein, C.B. & J.E. Stillwell
Thames River	12/17/1902	Chatham		1	42.4069	-82.1833	Saunders, W.E.
Thames River	1931	unknown		*	-	-	Lathrop, G.A.
Thames River	03/1936	London		*	42.9750	-81.2458	unknown

*indicates that condition of specimens at time of collection, i.e., live or dead, is unknown

Table 2. Occurrence records for *Lampsilis fasciola* in Canada from 1997 to 2002.

Water Body	Site #	Date	Nearest Urban Centre	Sampling Effort (p-h)	Live specimens	Fresh shells whole	Fresh shells valves	Weathered shells whole	Weathered shells valves	Latitude	Longitu
Ausable R.	AR-1	08/10/1998	Brinsley	4.5[1]					2	43.2458	-81.526
Ausable R.	AR-2	08/11/1998	Exeter	4.5[1]				1		43.3617	-81.508
Ausable R.	AR-3	08/17/1998	Ailsa Craig	4.5[1]		2			2	43.1667	-81.526
Ausable R.	AR-7	08/20/1998	Nairn	4.5[1]		2				43.1069	-81.565
Ausable R.	AR-8	08/20/1998	Brinsley	4.5[1]		1				43.2472	-81.525
Ausable R	AR-8	08/29/2001	Brinsley	12.75[1]					1	43.2472	-81.525
Ausable R.	AR-9	09/09/2002	Huron Park	4.5[1]					1	43.2828	-81.522
Ausable R.	AR-12	09/10/2002	Hwy 81	4.5[1]				1		43.0631	-81.688
Little Ausable R.	AR-13	09/11/2002	Ailsa Craig	4.5[1]	1			1		43.1830	-81.499
Ausable R.	AR-14	09/12/2002	Nairn	4.5[1]	1					43.1186	-81.566
Maitland R.	MR-1	08/21/1998	Auburn	4.5[1]	3	2		1		43.7736	-81.540
Thames R.	TR-2	08/11/1997	Dorchester	4.5[1]	4	1				42.9872	-81.070
Thames R.	TR-3	08/12/1997	London	4.5[1]		1				42.9819	-81.113
Thames R.	TR-11	09/26/1997	Dorchester	4.5[1]		2			1	42.9833	-81.023
North Thames R.	TR-12	08/12/1998	Plover Mills	4.5[1]	1	1			7	43.1500	-81.191
North Thames R.	TR-13	08/12/1998	Science Hill	4.5[1]	1	2		1	3	43.2933	-81.172
Middle Thames R.	TR-15	08/13/1998	Thamesford	4.5[1]		1		1	1	43.0917	-80.988
Grand R.	GR-2	07/24/1997	Glen Morris	4.5[1]					1	43.2764	-80.347
Grand R.	GR-3	07/29/1997	Kitchener	4.5[1]	8	12	5			43.4047	-80.433
Grand R.	GR-3	09/18/1997	Kitchener	unknown		6		7		43.4047	-80.433
Grand R.	GR-4	07/30/1997	Caledonia	4.5[1]					1	43.0736	-79.956
Grand R.	GR-5	07/31/1997	York	4.5[1]					2	43.0422	-79.904

Table 2 (cont'd). Occurrence records for *Lampsilis fasciola* in Canada from 1997 to 2002.

Water Body	Site #	Date	Nearest Urban Centre	Sampling Effort (p-h)	Live specimens	Fresh shells		Weathered shells		Latitude	Longitu
						whole	valves	whole	valves		
Nith R.	GR-8	08/05/1997	Canning	4.5[1]		1		1	2	43.1903	-80.454
Nith R.	GR-8	07/27/1998	Canning	unknown	1					43.1903	-80.454
Grand R.	GR-12	08/07/1997	Kitchener	4.5[1]	8	9	2		3	43.4208	-80.409
Grand R.	GR-12	07/09/1998	Kitchener	4.5[1]	2					43.4208	-80.409
Grand R.	GR-13	08/07/1997	West Montrose	4.5[1]	1			2	2	43.5853	-80.480
Grand R.	GR-13	08/05/1998	West Montrose	unknown	1					43.5853	-80.480
Nith R.	GR-14	08/08/1997	Plattsville	4.5[1]					1	43.3278	-80.637
Grand R.	GR-18	08/04/1998	Inverhaugh	4.5[1]		1			2	43.6306	-80.477
Grand R.	GR-18	04/29/1998	Inverhaugh	unknown	1					43.6306	-80.477
Grand R.	GR-19	08/05/1998	Waterloo	4.5[1]		4		2	4	43.5042	-80.479
Grand R.	GR-20	08/31/1998	Breslau	4.5[1]	2	4	2		3	43.4736	-80.425
Conestogo R.	GR-23	09/02/1998	St. Jacobs	4.5[1]	1	2			2	45.5417	-80.558
Nith R.	GR-24	09/02/1998	Drumbo	4.5[1]		1				43.2431	-80.522
Grand R.	GR-25	09/18/2001	Waterloo	6.0[1]	5					43.5272	-80.479
Grand R.	GR-26	07/03/1998	Cambridge	1.0[1]	1					43.3418	-80.319
Grand R.	GR-27	07/03/1998	Cambridge	1.0[1]		1				43.3220	-80.314
Lake St. Clair	WI-11	07/15/1999	Bassett Island	1.5[2]	1					42.5167	-82.608
Lake St. Clair	WI-22	07/14/1999	Squirrel Island	1.5[2]	1					42.5000	-82.566
Lake St. Clair	WI-31	07/14/1999	Squirrel Island	1.5[2]	9					42.4919	-82.546
Lake St. Clair	WI-41	07/13/2000	Johnston Channel	1.5[2]	2					42.4869	-82.531
Lake St. Clair	WI-54	06/22/1999	Grassy Bend Islands	1.5[2]	1					42.4592	-82.511
Lake St. Clair	WI-41	06/01/2000	Johnston Channel	1.5[2]	2					42.4869	-82.531
Lake St. Clair	WI-11	09/05/2001	Bassett Island	1365 sq. m^3	2	1				42.5167	-82.608
Lake St. Clair	WI-31	08/21/2001	Squirrel Island	650 sq. m^4	1					42.4919	-82.546

Table 2 (cont'd). Occurrence records for *Lampsilis fasciola* in Canada from 1997 to 2002.

Water Body	Site #	Date	Nearest Urban Centre	Sampling Effort (p-h)	Live specimens	Fresh shells whole	Fresh shells valves	Weathered shells whole	Weathered shells valves	Latitude	Longitu
St. Clair R.	6665	09/18/2001	Sarnia	3 Ponar grabs		1				42.9374	-82.443
Sydenham R.	SR-2	08/19/1997	Alvinston	4.5[1]		1				42.8056	-81.846
Sydenham R.	SR-3	08/19/1997	Alvinston	4.5[1]		2				42.7792	-81.835
Sydenham R.	SR-10	08/07/2001	Rokeby	9.5[5]			1	1		42.8458	-81.825
Sydenham R.	SR-17	07/30/2001	Florence	10.5[5]					1	42.6792	-82.016
Sydenham R.	SR-2	07/09/2002	Alvinston	7.5[1]					1	42.8056	-81.846
Sydenham R.	SR-5	07/11/2002	Florence	7.5[1]					1	42.6505	-82.008
Sydenham R.	SR-10	07/10/2002	Rokeby	7.5[1]					1	42.8458	-81.825
Sydenham R.	SR-BB	07/30/2002	Rokeby	6.0[1]		1				42.8472	-81.848

[1]4.5 p-h timed search while wading
[2]1.5 p-h timed search while snorkeling
[3]10-65 m^2 areas searched while snorkeling
[4]21-65 m^2 areas searched while snorkeling
[5]quadrat surveys of ~ 400 m^2 area at 20% coverage

Table 3. Numbers of live *Lampsilis faciola* observed during mussel surveys in Ontario waters between 1997 and 2002, relative to the amount of sampling effort expended.

River/Lake	# sites	Sampling effort (p-h)			Numbers of live *Lampsilis fasciola*
		Timed search surveys[1]	Other searches[2]	Total search time	
Ausable River	15	67.5	51.75	119.25	2
Grand River	25	114	56.5	170.5	31
Maitland River	1	4.5	-	4.5	3
Thames River	16	72	40	112	6
Sydenham River	17	84	217.25 + 500[3]	801.25	0
Lake St. Clair	38	64.5	57	121.5	19

[1] generally 4.5 p-h/site, but occasionally longer.

[2] includes quantitative sampling (Sydenham River and Lake St. Clair); targeted searches for *L. fasciola* (Sydenham River only); and sampling for other purposes, e.g., collecting samples of various species for genetic analysis (occurrences of COSEWIC-listed and candidate species are always recorded).

[3] includes searches by D. Woolnough and K. McNichols from the University of Guelph.

Table 4. Relationship between water clarity[1] and the occurrence of *Lampsilis fasciola* at 73 sites on the Maitland, Grand, Thames, Ausable and Sydenham rivers.

			Mean water clarity (cm)		
River	# sites surveyed[2]	# sites with water clarity > 45 cm	All sites	Sites with live *L. fasciola*	CPUE[3]
Maitland	1	1	100	100	0.67/h
Grand	24	13	55	99	0.18/h
Thames	16	10	50	62	0.05/h
Ausable	15	3	25	47	0.02/h
Sydenham	17	1	20	n/a	0

[1]water clarity is defined as the maximum depth at which the streambed is clearly visible.
[2]based on timed search data.
[3]catch-per-unit-effort calculated as numbers of live specimens found/total search time (from Table 3).

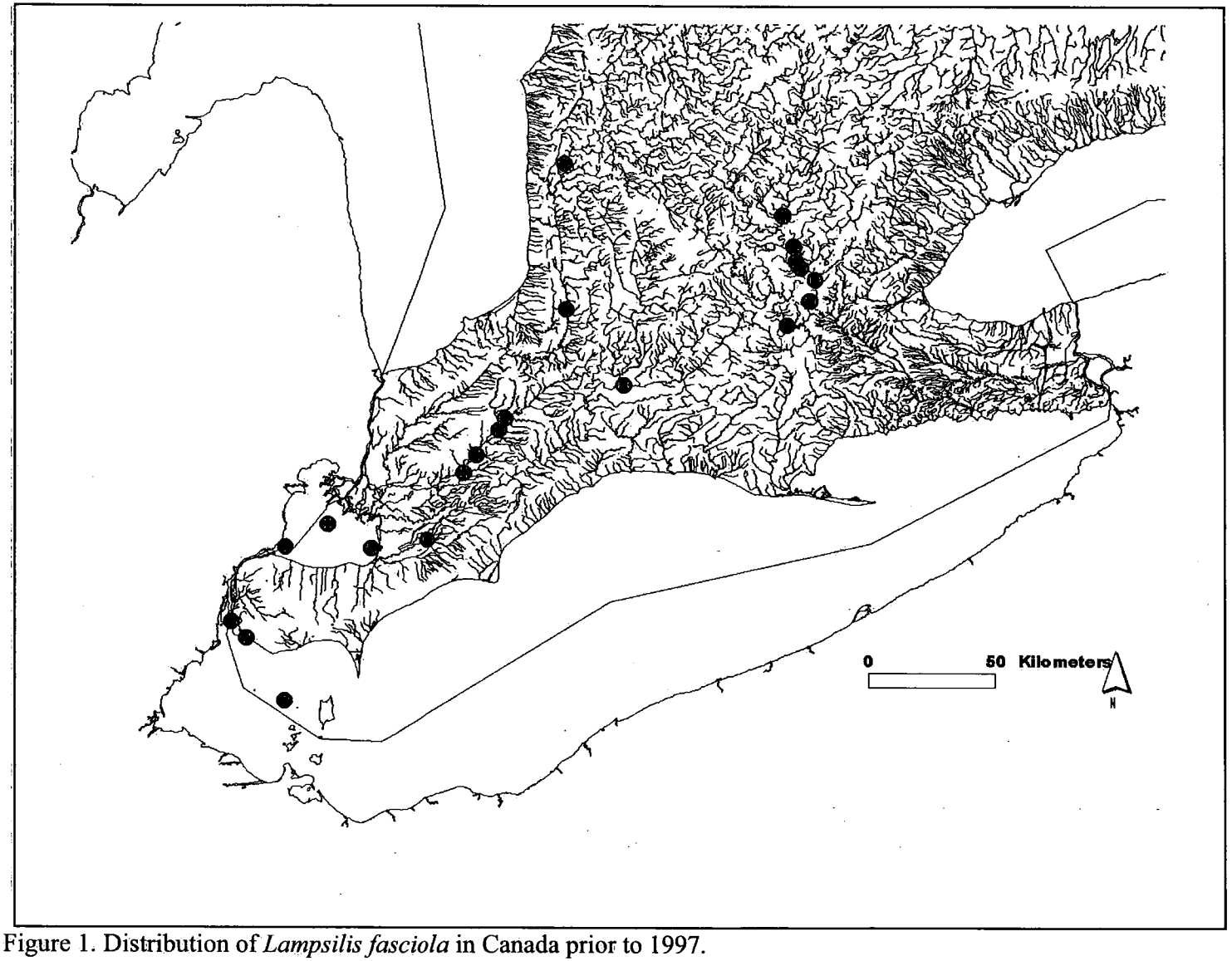

Figure 1. Distribution of *Lampsilis fasciola* in Canada prior to 1997.

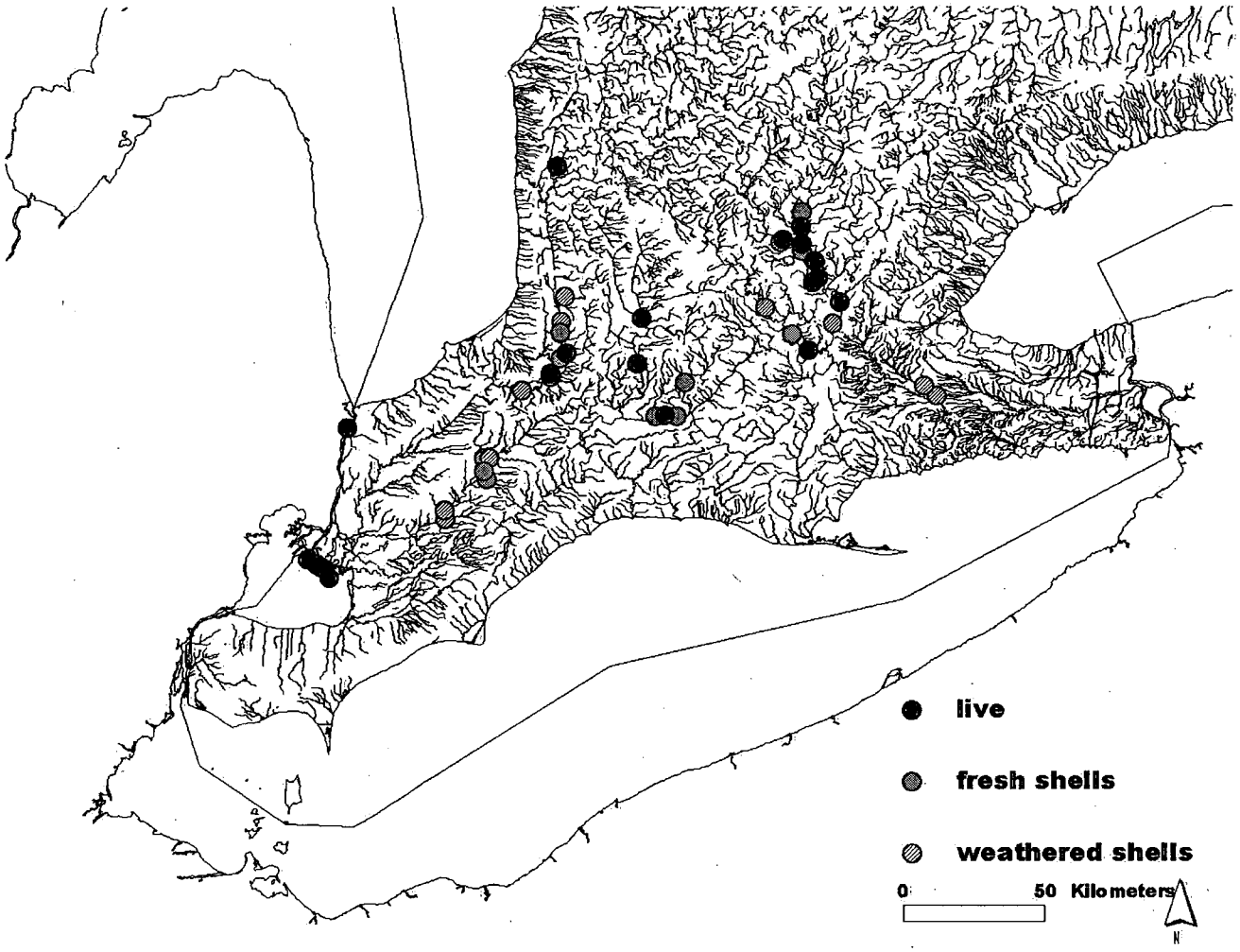

Figure 2. Current distribution of *Lampsilis fasciola* in Canada, based on surveys conducted from 1997 to 2002.

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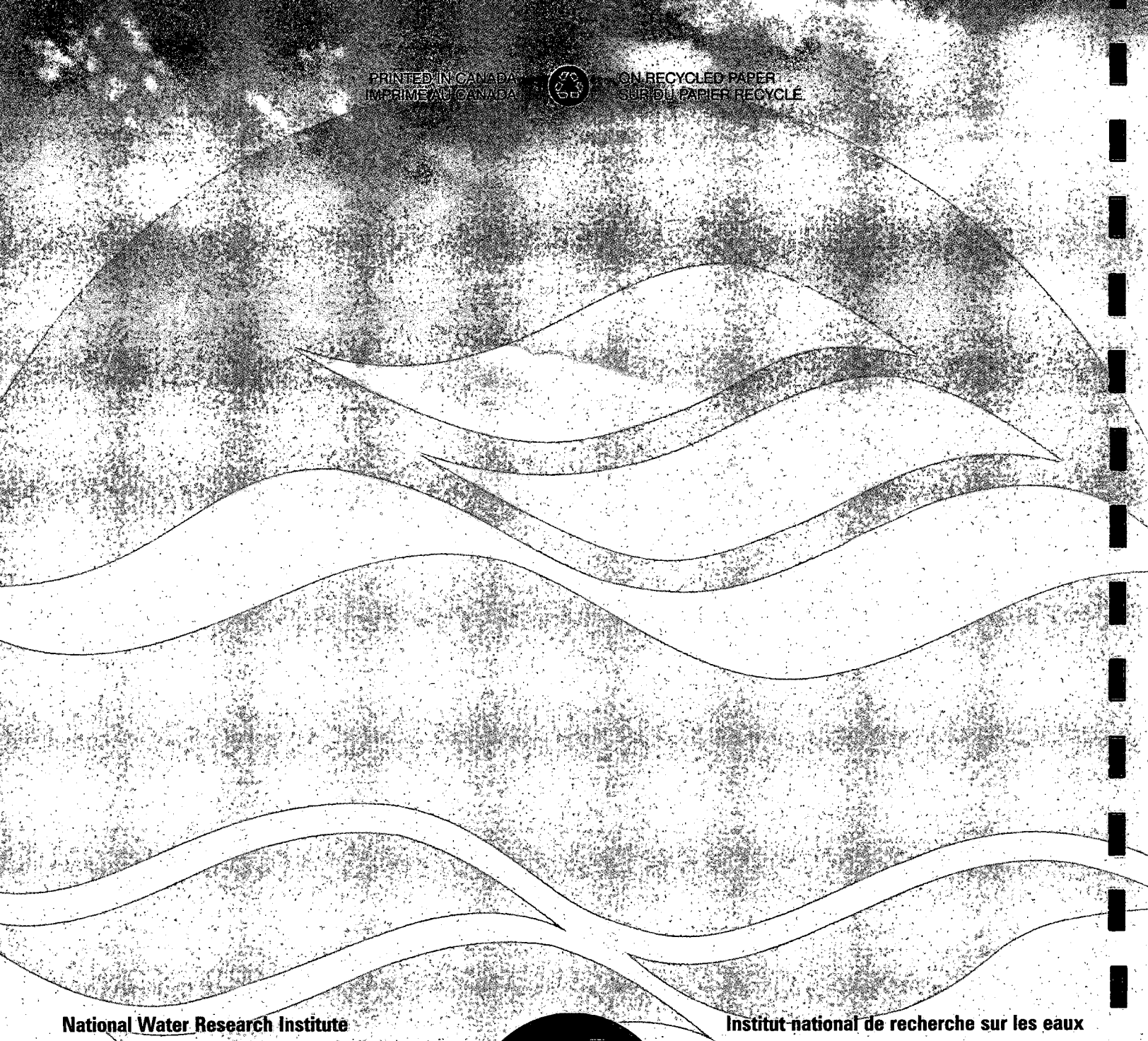

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