

**RANGE, POPULATION STABILITY AND  
ENVIRONMENTAL REQUIREMENTS OF RARE  
SPECIES OF FRESHWATER MUSSELS IN  
SOUTHERN ONTARIO**

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**Range, Population Stability and Environmental Requirements of  
Rare Species of Freshwater Mussels in Southern Ontario**

**A 1998 Endangered Species Recovery Fund Project**

**Final report to the World Wildlife Fund Canada**

by

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## MANAGEMENT PERSPECTIVE

In 1994, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) expanded its mandate to include invertebrates for the first time. The first two groups to be considered were the Mollusca and the Lepidoptera. The Mollusc Working Group was charged with the task of developing a list of Canadian mollusc species at risk and preparing status reports on them, thus providing the incentive for assessing the conservation status of Canada's freshwater mussel fauna. Recently, there has been heightened interest in the activities of COSEWIC. The Minister of the Environment signed the National Accord for the Protection of Species at Risk with the provinces and territories in 1996 and a Canada/US framework for cooperation in the protection and recovery of species in 1997, and federal endangered species legislation is in preparation. The goal of this research was to identify the mussel species most at risk in Canada, prepare - or provide the supporting data needed to prepare - status reports on the species most urgently requiring national status designation by COSEWIC, and provide the information required to develop and implement recovery plans for these species. The lower Great Lakes drainage basin was the focus of this research, because it historically supported the most diverse and unique mussel fauna in Canada and because of the severe impact of the zebra mussel, *Dreissena polymorpha*, on native mussel communities in Great Lakes waters.

In 1997, 37 sites on the Grand, Thames and Sydenham Rivers in southwestern Ontario were surveyed to determine the current conservation status of 21 species of mussels believed to be the most at risk. In 1998, 20 additional sites on these rivers, as well as 9 sites on two rivers in the lower Lake Huron drainage, were surveyed to determine the ranges, population stability and environmental requirements of nine species, including three species (*Epioblasma torulosa rangiana*, *Villosa fabalis* and *Lampsilis fasciola*) that were recommended for national status designation on the basis of the 1997 surveys. Results of this study provided much of the information needed to proceed with recovery plans for the above three species, justified the consideration of six additional species for national status designation, and identified the Sydenham River as a critical refuge for rare mussel species and the Thames River as in need of conservation action to restore its mussel fauna.

## SOMMAIRE À L'INTENTION DE LA DIRECTION

En 1994, le Comité sur le statut des espèces menacées de disparition au Canada (CSEMDC) a élargi son mandat de façon à inclure pour la première fois les invertébrés. Les deux premiers groupes à être étudiés étaient les mollusques et les lépidoptères. Le Groupe de travail sur les mollusques a été chargé d'établir une liste des espèces canadiennes menacées de disparition et de rédiger des rapports sur leur état, favorisant ainsi l'évaluation de l'état de conservation de la faune des bivalves d'eau douce du Canada. Il y a eu récemment un regain d'intérêt pour les activités du CSEMDC. Le ministre de l'Environnement a signé l'Accord national pour la protection des espèces en péril avec les provinces et les territoires en 1996 et un cadre de coopération Canada/É.-U. en matière de protection et de rétablissement d'espèces en 1997, et une loi fédérale sur les espèces en péril est en cours de rédaction. Le but de cette recherche était d'identifier les espèces de bivalves les plus menacées au Canada, de préparer ou de fournir les données nécessaires pour préparer les rapports d'étape sur les espèces dont la désignation au statut national par le CSEMDC est la plus urgente, et de fournir l'information requise pour élaborer et mettre en oeuvre des plans de rétablissement pour ces espèces. Cette recherche a porté sur le bassin hydrographique des Grands Lacs d'aval parce qu'il a toujours supporté la faune de bivalves la plus diversifiée et unique au Canada et à cause de l'impact considérable de la moule zébrée, *Dreissena polymorpha*, sur les communautés de bivalves indigènes dans les eaux des Grands Lacs.

En 1997, on a étudié 37 sites sur les rivières Grand, Thames et Sydenham, dans le sud-ouest de l'Ontario, afin de déterminer le statut de conservation actuel de 21 espèces de bivalves que l'on croyait les plus menacées. En 1998, on a étudié 20 autres sites sur ces rivières, ainsi que 9 sites sur deux rivières dans le bassin hydrographique inférieur du lac Huron afin de déterminer les aires de répartition, la stabilité des populations et les exigences environnementales de neuf espèces, y compris trois (*Epioblasma torulosa rangiana*, *Villosa fabalis* and *Lampsilis fasciola*) dont on a recommandé la désignation au statut national à la lumière des relevés de 1997. Les résultats de cette étude fournissent la plupart des informations nécessaires pour poursuivre les plans de rétablissement des trois espèces susmentionnées, justifier la prise en considération de

six autres espèces au statut national, et reconnaître la rivière Sydenham comme un refuge essentiel pour de rares espèces de bivalves et la rivière Thames comme ayant besoin d'une mesure de conservation afin d'y rétablir la faune des bivalves.

## ABSTRACT

An earlier review of historical data on the distributions of native freshwater mussels throughout the lower Great Lakes drainage basin provided compelling evidence that the steady decline in mussel diversity that has been documented in the United States is also occurring in Canada. In 1997, 37 sites on the Grand, Thames and Sydenham Rivers in southwestern Ontario were surveyed to determine the current conservation status of 21 species believed to be the most at risk. In this study, 20 additional sites on these rivers, as well as 9 sites on two rivers in the lower Lake Huron drainage, were surveyed to determine the ranges, population stability and environmental requirements of nine species, including three species (*Epioblasma torulosa rangiana*, *Villosa fabalis* and *Lampsilis fasciola*) that have been recommended for national status designation by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Continuous, reproducing populations of *E. t. rangiana* and *V. fabalis* were found in a 45-50 km stretch of the middle Sydenham River, and a low density population of *E. t. rangiana* was also discovered in the Ausable River. As *E. t. rangiana* is listed as federally endangered in the United States, with only one or two known reproducing populations left, the Sydenham River population may be globally significant. *L. fasciola* was found alive in the Grand, Thames, and Maitland Rivers, with the healthiest population occurring in a 60 km stretch of the upper Grand River. Its continued existence may be threatened by over-exploitation of its fish host, the smallmouth bass. Significant findings for other target species included the discovery of two species in the Sydenham River that were previously thought to be extirpated from Ontario (*Epioblasma triquetra* and *Simpsonaias ambigua*); and the complete absence of live *Obovaria subrotunda* from the study area, indicating that it has declined alarmingly and may now be extirpated. New information on these and three other species, *Obliquaria reflexa*, *Ptychobranhus fasciolaris* and *Pleurobema coccineum*, may justify formal assessments of their national conservation status. Fish hosts for many of these species in Canada are unknown, but the distribution patterns for mussels and fishes in the studied rivers implicate darters (*Etheostoma* and *Percina* spp.) as potential hosts for several rare species of mussels. The Grand, Sydenham and Ausable Rivers were found to be significant refuges for one or more of the target mussel species. However, the Thames River has lost one-third of its native mussel fauna, and many species that remain do not appear to be reproducing.

## RÉSUMÉ

Une étude antérieure des données historiques sur les distributions des bivalves d'eau douce indigènes dans tout le bassin hydrographique des Grands Lacs d'aval a fourni des preuves convaincantes que le déclin constant de la diversité des populations de bivalves, qui était documenté aux États-Unis, se produit également au Canada. En 1997, on a étudié 37 sites sur les rivières Grand, Thames et Sydenham, dans le sud-ouest de l'Ontario, afin de déterminer le statut de conservation actuel de 21 espèces de bivalves que l'on croyait les plus menacées. Dans cette étude, on a examiné 20 autres sites sur ces rivières, ainsi que 9 sites sur deux rivières dans le bassin hydrographique inférieur du lac Huron, afin de déterminer les aires de répartition, la stabilité des populations et les exigences environnementales de neuf espèces, y compris trois (*Epioblasma torulosa rangiana*, *Villosa fabalis* and *Lampsilis fasciola*) dont on a recommandé la désignation au statut national par le Comité sur la situation des espèces en péril au Canada (COSGPAC, autrefois CSEMDC). On a trouvé des populations reproductrices continues de *E. t. rangiana* et de *V. fabalis* sur une portion de 45 à 50 km du cours moyen de la rivière Sydenham, et une population peu dense de *E. t. rangiana* sur la rivière Ausable. Étant donné que *E. t. rangiana* est inscrit comme une espèce en danger reconnue par le fédéral aux États-Unis, avec seulement une ou deux populations reproductrices connues, la population de la rivière Sydenham a probablement une importance planétaire. On a trouvé que *L. fasciola* était bien en vie dans les rivières Grand, Thames et Maitland, avec la population la plus en santé dans une portion de 60 km du cours supérieur de la rivière Grand. Son existence continue peut être menacée par une surexploitation de son poisson hôte, l'achigan à petite bouche. Les résultats importants des recherches concernant d'autres espèces cibles comprenaient la découverte dans la rivière Sydenham de deux espèces que l'on croyait disparues en Ontario (*Epioblasma triquetra* et *Simpsonaias ambigua*); et l'absence complète de *Obovaria subrotunda* vivant dans la région à l'étude, indiquant que cette espèce a connu un déclin considérable et qu'elle pourrait maintenant avoir disparu. De nouvelles informations sur ces espèces et sur trois autres, *Obliquaria reflexa*, *Ptychobranchus fasciolaris* et *Pleurobema coccineum*, peuvent justifier des évaluations officielles de leur statut national de conservation. On ne connaît pas les poissons hôtes d'un grand nombre de ces espèces au Canada, mais les distributions des bivalves et des poissons dans

les rivières à l'étude supposent que les dards (*Etheostoma* et *Percina* spp.) sont des hôtes possibles de plusieurs espèces rares de bivalves. On a trouvé que les rivières Grand, Sydenham et Ausable étaient d'importants refuges pour une ou plusieurs espèces de bivalves visées. La rivière Thames a cependant perdu un tiers de sa faune de bivalves indigènes, et un grand nombre des espèces qui restent ne semblent pas se reproduire.

### **Mots clés**

bivalves d'eau douce, biodiversité, espèces en danger de disparition



## INTRODUCTION

A retrospective analysis of historical data on the distributions of native freshwater mussels throughout the lower Great Lakes drainage basin indicated a trend toward the loss of species over time, and the displacement of many unique and ecologically fragile species by fewer pollution-tolerant species (Metcalf-Smith *et al.* 1998a). The results of this work provided compelling evidence that the steady decline in freshwater mussel diversity that has been documented for the United States (e.g., Bogan 1993) is also occurring in Canada. A risk factor analysis approach was then used to identify and prioritize a list of candidate species of mussels to be recommended for national status designation by COSEWIC. Species were evaluated on the basis of their current conservation status ranks, distribution patterns, vulnerability to zebra mussels, fish host specificity, and evidence of decline, using the historical data (Metcalf-Smith *et al.* 1998b). Field studies to determine the current conservation status of 21 species believed to be the most at risk began in 1997.

In a 1997 Endangered Species Recovery Fund Project, Metcalf-Smith *et al.* (1998c) surveyed 37 sites on the Grand, Thames and Sydenham Rivers of southwestern Ontario that historically supported many of the target species. Twenty-seven, 41 and 24%, respectively, of the species previously reported from these rivers were not found alive during these surveys. Six species were believed to have been extirpated from all three rivers, and the ranges of an additional 13 species appeared to have been reduced. Based on this new information about current species distributions, changes to the provincial conservation status ranks (Ontario's S-ranks) of 11 species were proposed: 6 species were recommended for downlisting, and 5 species were suggested for uplisting. Eleven species were recommended for status designation by the Committee on the Status of Species at Risk in Ontario (COSSARO) and the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), and status reports were subsequently prepared for three of these species (*Epioblasma torulosa rangiana*, *Lampsilis fasciola* and *Villosa fabalis*). A conservation status score system for identifying areas of prime mussel habitat was devised for use by watershed managers responsible for protecting the water and habitat quality of Ontario's rivers.

The main objectives of this project were to more clearly delineate the ranges of the three species being considered for status designation, assess the stability of their existing populations, and determine their environmental requirements. This information is required for the preparation of recovery plans for these species. Several other species at risk were also studied, to determine if the preparation of status reports on one or more of these species is also justified.

## MATERIALS AND METHODS

### Selection of Target Species

This project primarily focused on the three species of mussels that were recommended to COSSARO and COSEWIC for official status designation, namely, the Northern Riffleshell (*Epioblasma torulosa rangiana*), the Rayed Bean (*Villosa fabalis*) and the Wavy-rayed Lampmussel (*Lampsilis fasciola*). The main reasons why these species urgently require status designation are as follows: *E. t. rangiana* is one of the last remaining species of a near extinct genus, and is declining rapidly throughout its range. It was previously thought that French Creek, PA supported the only reproducing population in the world. Thus, confirmation and protection of a reproducing population discovered in the Sydenham River in 1997 would be globally significant. *V. fabalis* is listed as endangered throughout most of its range in the United States, and was uplisted globally by The Nature Conservancy from G2 (very rare) to G1G2 (very to extremely rare) in 1997. A few healthy populations still occur in western New York and northwestern Ohio, and it is now known to be extant in the Sydenham River. *L. fasciola* has declined significantly in distribution and abundance in recent years, particularly in the Midwest. In Canada, it is mainly restricted to the clear, clean waters of the upper Grand River, where it should be protected. Executive summaries of the COSEWIC status reports on *E. t. rangiana* (Staton *et al.* 1998), *V. fabalis* (West *et al.* 1998) and *L. fasciola* (Metcalf-Smith *et al.* 1998d) are attached as Appendix I. The status of "Endangered" was recommended for both *E. t. rangiana* and *V. fabalis*, and the status of "Threatened" was recommended for *L. fasciola*.

Ten other species of mussels have a current or proposed rank of S1 or SH in Ontario (Table 1), and 6 of these species were also given consideration in 1998. These include 3 species that were not found alive in 1997, i.e., the Snuffbox (*Epioblasma triquetra*), Round Hickorynut (*Obovaria subrotunda*) and Mudpuppy Mussel (*Simpsonaias ambigua*), and three others that are believed to be declining severely, i.e., the False Pigtoe (*Pleurobema coccineum*), Kidneyshell (*Ptychobranhus fasciolaris*) and Threehorned Wartyback (*Obliquaria reflexa*). The remaining four species were not included for various reasons: the Fawnsfoot (*Truncilla donaciformis*) and Lilliput (*Toxolasma parvus*) inhabit river mouths, which are too deep to be surveyed effectively using our techniques; there is only one known historical record for the Olive Hickorynut (*Obovaria olivaria*) from the study area; and the Paper Pondshell (*Utterbackia imbecillis*) is primarily a Lake Ontario drainage species.

### Selection of Survey Sites

The selection of survey sites on the Grand, Thames and Sydenham Rivers was based on the results of surveys conducted at 37 sites on these rivers in 1997. New sites were chosen in the vicinities of sites where target species had been found alive, or in some cases where fresh shells had been located. The emphasis here was on better defining the ranges of the species, and determining if populations were isolated or continuous. As only one site on the North Sydenham River had been surveyed in 1997, three more sites on the main stem (Bear Creek) and one site on a major tributary (Black Creek) were surveyed in 1998 in order to have better coverage of this sub-basin. This was considered important because the site surveyed in 1997 had yielded 11 live species, including one of the target species (*P. coccineum*), and fresh shells of another target species (*S. ambigua*).

Following the recommendations of Metcalfe-Smith *et al.* (1998c), the study area was expanded to include the Ausable and Maitland Rivers in the lower Lake Huron drainage. The Lower Great Lakes Unionid Database (described in Metcalfe-Smith *et al.* 1998c) contains historical records for *E. triquetra* and an S2-ranked species, the Rainbow Shell (*Villosa iris*), from the Ausable River, as well as *L. fasciola* and *V. iris* from the Maitland River. These rivers fall outside the official

study area of the database, although some records for rare species in adjacent regions were included when the database was compiled. There are also recent records for live *P. fasciolaris* and *L. fasciola* from the Ausable River (Morris and Di Maio 1997). All of these sites (4 in total) were surveyed in 1998 (see Appendix II). An important historical site on the Sydenham River that had to be abandoned in 1997 due to high water levels was also surveyed in 1998. This site (SR-12) is the only one for which quantitative historical data exist over a time-series, i.e., 1973, 1991 and 1998 (Appendix II).

A total of 29 sites, i.e., 7 sites on the Grand River, 5 sites on the Thames River, 8 sites on the Sydenham River, 8 sites on the Ausable River, and 1 site on the Maitland River, were surveyed between Aug. 4 and Sept. 2, 1998. The locations of these river systems in southwestern Ontario are shown in Fig. 1. The survey sites are described in Table 2, and their locations are presented in Fig. 2 (Grand and Maitland Rivers) and Fig. 3 (Thames, Sydenham, and Ausable Rivers). For reference, the locations of the 1997 survey sites are also shown in these figures.

## Field Methods

### *Mussel Surveys*

For continuity, field methods were the same as in 1997. The timed search sampling method was again used, due to its documented effectiveness for detecting rare species (Strayer *et al.* 1997). At most sites, a visual search of the riverbed was conducted by a 3-person team using waders, polarized sunglasses and Waterview™ underwater viewers for a period of 1.5 hours, for a total sampling effort of 4.5 person-hours (p-h). Exceptions were turbid sites on the North Sydenham River (sites SR-13, SR-14, SR-15 and SR-16) and lower Sydenham River (SR-12 and SR-17). Visibility at these sites was very poor (maximum depth at which the streambed was clearly visible was generally <15 cm), necessitating searches by feel ("raccooning"). Sites on the lower Ausable River (AR-4, AR-5 and AR-6) weren't quite as turbid, but jagged, rocky substrates made using the Waterviews™ difficult at times and raccooning was also used as required at these sites.

Comparisons of the data from surveys conducted in 1997 with the data from other less intensive surveys conducted at the same sites on the Grand, Thames and Sydenham Rivers in recent years clearly showed that an increase in sampling effort resulted in a significant increase in the numbers of species and individual mussels found at a given site (Metcalf-Smith *et al.* 1998c). Thus, employing an intensive sampling effort when assessing the conservation status of rare species seems critically important. A study to quantify the effect of increasing the sampling effort on the detection of rare species, the estimate of overall diversity, and the apparent species composition of the mussel community at a given site, was conducted in conjunction with the 1998 mussel surveys. At each of the 29 survey sites, the survey period of 1.5 hours was divided into three 30 minute intervals. At the end of each interval, all members of the 3-person survey team combined the live specimens they had collected into one mesh diver's bag, which was then labeled and left submerged in the river while the search resumed for the next interval. At the end of the survey period, all live mussels collected in each time interval were identified to species, sexed where possible, counted, and their valve lengths measured to the nearest millimetre using vernier calipers. The data for each time interval were kept separate for the purpose of the sampling effort study, and later combined into site totals as were reported in 1997. Data on sex ratios and size distributions for the target species were used, in combination with data collected in 1997, to assess population stability and recruitment.

All live mussels were returned to the riverbed, with the exception of a very few specimens that were sacrificed to obtain their shells for taxonomic verification. When returning specimens of rare species to the river, care was taken to place them in the same location and orientation in which they were found. Photographs were taken of species not encountered live in 1997, and of better or unusual specimens of other species.

Shells were also collected, but not in a consistent manner for all species. For most species, shells were retained during the survey only until living specimens were found. If no living specimens of a particular species were found, the shells were then kept and tallied to generate a total number of live and dead species represented at the site (as per last year). In the case of rare species (all

target species and some others), all shells were kept regardless of whether or not living specimens were also found.

After completing the mussel survey at each site, the site was photographed and characterized. The length and width of the reach searched, water depth, velocity, clarity, temperature and air temperature were measured. Water clarity was defined as the maximum depth at which the streambed was clearly visible. The aquatic and streamside habitats were characterized using the Ontario Ministry of Natural Resources' (OMNR) Stream Habitat Assessment Methodology (see Metcalfe-Smith *et al.* 1998c for details). These data will be useful for determining the environmental requirements of the various species.

### *Water Quality Sampling*

As a limited budget was available for the analysis of water quality samples, the parameters to be measured were carefully chosen. Reynoldson *et al.* (1998) determined that the following chemical and physical parameters were critical determinants of benthic invertebrate community structure in lotic environments: temperature, dissolved oxygen, pH, conductivity, nitrate/nitrite, total Kjeldahl nitrogen, total phosphorus, alkalinity and total suspended solids. D.L. Strayer (Institute of Ecosystem Studies, personal communication, June 1998) considered turbidity, nitrate/nitrite, total reactive phosphorus and calcium to be important predictors of the composition of mussel communities, although only turbidity was shown to have a significant (inverse) relationship with species diversity in one of his recent studies. Based on these recommendations, temperature, pH and dissolved oxygen were measured in the field, and water samples were collected for analysis of the following parameters: alkalinity, specific conductivity, turbidity, hardness, and unfiltered chloride, sulphate, silica, calcium, magnesium, sodium, potassium, total Kjeldahl nitrogen, total phosphorus, soluble reactive phosphorus, nitrate/nitrite and ammonia.

Water sampling was conducted at all 66 sites surveyed for mussels in 1997 and 1998. Sampling was completed within a two week period from Sept. 15-24, 1998. Water samples were collected, preserved and stored according to the prescribed methods of the National Laboratory for

Environmental Testing, Burlington, and were submitted within two days of collection. They will be analyzed according to NLET's standard analytical methods.

### Lab Methods

Shells obtained from each survey site were sorted by species. The numbers of whole (both valves) and half (single valve) shells of each species, as well as the condition of the shells (i.e., "fresh" or "weathered") was recorded. Fresh shells were defined as having an intact periostracum, shiny nacre, and little or no signs of wear to the hinge teeth. Fresh shells were often found with the ligament intact, and occasionally with remnants of the soft tissues attached. Shells that exhibited dull nacre and wear to the periostracum and hinge teeth were defined as weathered. Shells in this condition could be decades old, and would not necessarily indicate the presence of living animals. Although these wear categories are somewhat subjective, and may be affected by site-specific factors such as gradient and substrate composition, information on the condition of shells found at a given site becomes important when live specimens cannot be found. Representative shells of common species, and all shells of rare species, were retained for future reference.

All shells of target species collected during the surveys of 1997 and 1998, as well as a few additional specimens obtained during related work, were counted, measured, and sexed (where possible), and their condition noted. These data were used to augment data on the sex ratios and size distributions of live specimens, which were often sparse.

It should be noted that only some species of mussels - all belonging to the Subfamily Lampsilinae - are sexually dimorphic, i.e., males and females can be distinguished from each other by the shape of their shells. Only the following target species could be sexed by visual inspection of either live specimens or shells: *E. t. rangiana*, *E. triquetra*, *L. fasciola* and *V. fabalis*. *V. iris* (an S2-ranked species) can also be sexed in this manner, but with less certainty. Several more common species that were encountered during these surveys can also be sexed, namely, the Pocketbook (*Lampsilis ovata*), Fat Mucket (*Lampsilis siliquoidea*) and Black Sandshell (*Ligumia recta*).

## RESULTS AND DISCUSSION

### Update on the Composition of the Freshwater Mussel Communities of the Grand, Thames and Sydenham Rivers

Twenty sites on the Grand, Thames and Sydenham Rivers were surveyed for mussels in 1998. These data, when combined with the data collected from the 37 sites surveyed in 1997, provide a comprehensive assessment of the conservation status of the mussel communities of these three rivers.

#### *Grand River*

A total of 24 sites on the Grand River were surveyed for mussels in 1997 (17 sites) and 1998 (7 sites). The numbers of live specimens of each species found at each of the sites surveyed in 1998, as well as the presence of fresh and/or weathered shells for species not found alive, are presented in Table 3. Data from 1997 for this and the other two rivers can be found in Metcalfe-Smith *et al.* (1998c), and a summary of the diversity and abundance of mussels for all 66 mussel survey sites is presented in Appendix III. Several 1997 survey sites were revisited in 1998 during other research activities. At 3 of these sites, species previously represented by shells only were found alive (*L. fasciola* and *L. siliquoidea* at site GR-8; *Elliptio dilatata* at GR-12; *Strophitus undulatus* at GR-14) and one new species was found alive at site GR-8 (*L. ovata*). In 1997, 24 species had been found alive in the Grand River and 3 others were represented by shells only. One species that was represented by shells only in 1997 was found alive in 1998 (*V. iris*). Thus, a total of 25 species currently inhabit the Grand River and a further 2 species are represented by shells only.

#### *Thames River*

A total of 16 sites on the Thames River were surveyed for mussels in 1997 (11 sites) and 1998 (5 sites). The numbers of live specimens of each species found at each of the sites surveyed in 1998,



as well as the presence of fresh and/or weathered shells for species not found alive, are presented in Table 4. See Appendix III for a summary of the diversity and abundance of mussels for all 16 Thames River sites. Several 1997 survey sites were revisited in 1998 during other research activities. At one of these sites (TR-6), two species previously represented by shells only were found alive (*L. recta* and *L. ovata*) and one new species was found alive (*O. reflexa*). The record for *O. reflexa* represents the first occurrence of this species in the Thames River during our surveys. A fresh whole shell of *O. reflexa* was also found at site TR-10 in 1998. In 1997, 18 species had been found alive in the Thames River and 10 others were represented by shells only. Four species that were represented by shells only in 1997 were found alive in 1998 (*Lasmigona compressa*, *P. coccineum*, *Pyganodon grandis* and *V. iris*), and two species that had not been reported at all in 1997 were found alive (*O. reflexa*; see above) or as shells only (*S. ambigua*). Thus, a total of 23 species currently inhabit the Thames River and a further 7 species are represented by shells only.

#### *Sydenham River*

A total of 17 sites on the Sydenham River were surveyed for mussels in 1997 (9 sites) and 1998 (8 sites). The numbers of live specimens of each species found at each of the sites surveyed in 1998, as well as the presence of fresh and/or weathered shells for species not found alive, are presented in Table 5. See Appendix III for a summary of the diversity and abundance of mussels for all 17 Sydenham River sites. Several 1997 survey sites were revisited in 1998 during other research activities. At one of these sites (SR-6), one species previously represented by shells only was found alive (*S. ambigua*), and two species not previously reported from this site were represented by shells only (*U. imbecillis* and *O. reflexa*). The record for *S. ambigua* represents the first time this species was found alive in the Sydenham River during our surveys, and the record for a shell of *O. reflexa* represents the first occurrence of this species in this river during our surveys. In 1997, 25 species had been found alive and 5 others were represented by shells only in the Sydenham River. Two species that were represented by shells only in 1997 were found alive in 1998 (*S. ambigua* - see above, and *E. triquetra*), and two species that had not been reported at all in 1997 were found alive (*O. reflexa* and *T. donaciformis*). Thus, a total of 29

species currently inhabit the Sydenham River and a further 4 species are represented by shells only.

#### *Current Status of the Mussel Communities of the Grand, Thames and Sydenham Rivers*

According to Metcalfe-Smith *et al.* (1998c), a total of 36 species was historically known from the Grand, Thames and Sydenham Rivers, with 33 known from the Grand River, 31 from the Thames River, and 33 from the Sydenham River. As shown in Table 6, four of these species were not found alive in any of these rivers during the 1997 and 1998 surveys (*Ligumia nasuta*, *O. olivaria*, *O. subrotunda* and *U. imbecillis*). In the Grand River, no live specimens or shells of *Cyclonaias tuberculata*, *E. triquetra*, *Lasmigona complanata complanata*, *L. nasuta*, *O. olivaria* or *O. subrotunda* were found, and *P. fasciolaris* and *U. imbecillis* were represented by shells only. We believe that the one historical record for *C. tuberculata* may be erroneous. In the Thames River, there were no traces of *L. siliquioidea*, *O. olivaria* or *T. parvus*, whereas shells were found for *Alasmidonta viridis*, *E. triquetra*, *O. subrotunda* and *P. fasciolaris*. Shells of two species not previously reported from the Thames River were also found (*S. ambigua* and *T. donaciformis*), thus increasing the total number of species known from this system to 33. In the Sydenham River, no live specimens or shells of *T. parvus* were found, and *A. viridis*, *L. fasciola*, *O. subrotunda* and *U. imbecillis* were represented by shells only. One species not previously reported from the Sydenham River was found alive (*O. reflexa*), thus increasing the total number of species known from this system to 34.

In summary, 11% of the species (4 of 36) previously known from these rivers were not found alive during the surveys of 1997-98. Percentages for individual rivers were 24% for the Grand (8 of 33), 30% for the Thames (10 of 33), and 15% for the Sydenham (5 of 34). As shown in Table 6, nine species now occur in fewer rivers than they did historically, and four others appear to have been extirpated.

Based on a survey conducted in 1977-78, Strayer (1980) concluded that the Clinton River, a tributary to Lake St. Clair in southeastern Michigan, supported the most diverse mussel fauna of

any tributary to the Great Lakes with the exception of the Maumee River. Of a total of 31 species previously known from the Clinton River, 26 were found alive by Strayer (1980). However, historical data show that the Grand, Thames and Sydenham Rivers each supported more mussel species than the Clinton River at one time, and it is possible that the Sydenham River - at 29 live species - currently supports more mussel species than any other Great Lakes tributary at present. It is believed that 30 or fewer of the 40 species historically known from the Maumee River are still extant in the basin (David L. Strayer, Institute of Ecosystem Studies, New York, personal communication, December 1998).

### **Composition of the Freshwater Mussel Communities of the Ausable and Maitland Rivers**

As recent and historical data suggested the possible occurrence of some target species in these Lake Huron drainage rivers, 8 sites on the Ausable River and 1 site on the Maitland River were surveyed in 1998.

#### ***Ausable River***

The Ausable River enters Lake Huron at Grand Bend. A total of 18 species were found alive at the 8 sites surveyed in 1998, and 4 other species were represented by fresh and/or weathered shells at one or more sites (Table 7). Of the target species, one live *E. t. rangiana* was found alive at each of 2 sites, and *P. fasciolaris* was found alive at 3 sites - with large numbers found at two of these sites. Also, fresh or weathered shells of *E. triquetra* and *L. fasciola* were found at 4 and 5 sites, respectively.

Detweiler (1918) surveyed the river in 1916 primarily for commercially valuable species, i.e., thick-shelled species that could be used in the pearl button industry, and recorded live *Amblema plicata plicata*, *L. siliquoidea*, *L. ovata*, *P. grandis*, *L. costata*, *L. recta*, *F. flava*, *E. dilatata* and probably *Alasmidonta marginata* (uncertain, due to changes in nomenclature). Museum records for several of these species, as well as *E. triquetra* and *V. iris*, were found in the Lower Great Lakes Unionid Database (Appendix II). All of these species except *E. triquetra* were found alive

in 1998. Morris and Di Maio (1997) surveyed six sites on the Ausable River in 1993 and 1994, using a sampling effort of 1 p-h/site. Three sites were surveyed in both years. They recorded 14 live species, all of which were found in 1998 except *Actinonaias ligamentina* (not represented by either shells or live specimens in 1998) and *L. fasciola* (shells only found in 1998). It should be noted, however, that T.J. Morris is known to have confused *A. ligamentina* and *L. siliquioidea* in the past (based on J.L. Metcalfe-Smith's examination of shells collected from the Thames River by Morris in 1995).

### *Maitland River*

The Maitland River drains into Lake Huron at the town of Goderich. A site at Auburn, Ontario was selected for survey, because both *L. fasciola* and *V. iris* had been collected from this location by J.P. Oughton in the 1930s (Appendix II). *V. iris* had also been found at Seaforth and Wingham by Dr. Oughton, and at Auburn by C.L. Blakeslee (date unknown). Based on a total of 13 records obtained from the Royal Ontario Museum, Rochester Museum and Science Center, and University of Michigan Museum of Zoology, the following species are known from the Maitland River: *A. marginata*, *L. fasciola*, *Lasmigona costata*, *V. iris*, *A. viridis* and *L. compressa*. All had been found at Auburn. As shown in Table 8, the first 4 species were found alive at this site in 1998. *A. viridis* was represented by weathered shells only, and *L. compressa* was not found; however, two additional species, *L. ovata* and *S. undulatus*, were found alive in 1998.

Obviously, *L. fasciola* and *V. iris* still occur in the Maitland River. *V. iris* appears to be scattered at various locations in each of the rivers - it was found at one site on each of the Maitland, Grand and Ausable Rivers, where it was represented by a lone specimen in each case. It was also found at 3 sites on the Sydenham River and 2 sites on the Thames, where it was represented by one specimen in each case except for a site on the Thames where 3 live animals were found. This species was once widespread and fairly common (Metcalfe-Smith *et al.* 1998c), and the reasons for its severe decline should be investigated. A total of 29 *L. fasciola* were found alive during the 1997-98 mussel surveys, including 20 specimens at five sites on the Grand River, 6 at three sites

on the Thames River, and 3 animals at the single site on the Maitland River. This suggests that the Maitland River should be surveyed further to determine if it may be a significant refuge for *L. fasciola*.

### **Comparisons of the mussel communities of the Grand, Thames, Sydenham and Ausable Rivers**

The mussel communities of the Grand, Thames, Sydenham and Ausable Rivers appeared to differ from each other in terms of diversity, abundance and composition. The Maitland River cannot be compared as only one site was surveyed, but the community at this site appeared to be most similar to that of the Ausable River. As the sampling effort was consistent at all sites, measures of diversity and abundance can be directly compared among rivers. For the purpose of this analysis, only those data collected during the specified 4.5 p-h survey period were used (Appendix III). Average diversity per site was greatest in the Sydenham River (12 species), followed by the Ausable (10 species), the Thames (8 species), and the Grand (6 species). Abundance followed the same trend, except that average abundance was greater in the Ausable (231 individuals) than the Sydenham (129 individuals); average abundances in the Thames and Grand Rivers were 118 and 70 individuals, respectively. A one-way ANOVA was used to test for differences in diversity and abundance among rivers. Diversity was found to differ significantly among rivers ( $F = 8.65 > F_{3,61}(p < 0.05) = 3.34$ ), whereas abundance did not ( $F = 2.64 < F_{3,61}(p < 0.05) = 3.34$ ). It is likely that differences in abundance were not statistically significant due to the great variation in abundance among sites within each river. As the F-test was significant for diversity, we proceeded with t-tests to compare all pairs of rivers (at  $p < 0.05$ ). Where variances were not homogeneous, an adjusted test statistic with fewer degrees of freedom was used. The Grand River had a significantly lower mean diversity of mussel species per site than the Thames ( $t = 2.05 > t_{38} = 1.96$ ), Ausable ( $t = 3.15 > t_{30} = 1.96$ ) and Sydenham ( $t = 4.72 > t_{20} = 2.093$ ) Rivers. The Thames River supported significantly fewer species per site than the Sydenham River ( $t = 2.526 > t_{31} = 1.96$ ), but differences between the Thames and Ausable Rivers were not statistically significant ( $t = 1.19 < t_{22} = 2.074$ ). Similarly, the Sydenham and Ausable Rivers did not differ significantly from one another ( $t = 1.087 < t_{23} = 2.069$ ) in terms of mussel diversity.

The Carolinian zone, which is defined as the "...extreme southwest region of Ontario where the Eastern Deciduous Forest of North America has its northernmost limits" (Carolinian Canada 1998), is known for its rich diversity of flora and fauna. This region falls roughly below a line from Grand Bend to Toronto. The Sydenham River is the only one of the studied watersheds that falls entirely within the Carolinian zone. The Ausable River is at the northern periphery of this zone. It was therefore surprising that the diversity and abundance of mussels at sites on the Ausable River rivaled those on the Sydenham River. In fact, there is anecdotal information to suggest that the Ausable River was once even more productive for mussels than it is now. The natural outlet of the Ausable River was originally at Port Franks, approximately 15 km south of its present outlet at Grand Bend. The river was diverted in two places in the late 1800s to alleviate flooding. According to Detweiler (1918), the lower river was once "paved with shells" and the natural outlet contained "oceans of shells". He concluded that prior to the construction of the artificial channels, the Ausable River had been "...admirably suited to the support of mussel life."

Each river system was found to support a unique assemblage of mussel species. Table 9 lists the ten most common species in each river, with the species arranged in order from the most to the least dominant based on the number of sites where they were found alive in 1997-98. Only two species were among the 10 most common species in all four rivers, namely, *L. costata* and *A. marginata* (note that these two species also ranked first and second, respectively, in terms of abundance at the one site surveyed on the Maitland River). In addition to these two species, *L. fragilis* and *P. alatus* were important components of the mussel community in the Grand, Thames and Sydenham Rivers; *L. recta* and *P. grandis* were important in the Grand, Sydenham and Ausable Rivers; *A. p. plicata* was significant in the Thames, Sydenham and Ausable Rivers; *Q. quadrula* and *T. truncata* were major species in the Grand and Thames Rivers; *C. tuberculata* and *L. c. complanata* were important in the Thames and Sydenham Rivers; and *L. ovata*, *L. siliquioidea*, and *S. undulatus* were important in the Grand and Ausable Rivers.

The degree of community similarity among rivers was not evident by simply tallying the number of species that any two rivers had in common; rather, it was necessary to consider the relative dominance of the various species in each river. Spearman's rank correlation coefficient ( $r_s$ ) was used to compare species dominance ranks between all pairs of rivers. Species dominance ranks were based on the number of sites where each species was found in a given river. Results are shown in Table 10. The Thames and Sydenham Rivers, which both drain into Lake St. Clair, had the most similar communities. Relationships between the other pairs of rivers appear to be related to distance apart and the lake into which they drain (see Fig. 1). The extreme dissimilarity between the Thames and Ausable may be explained by the fact that several species that were important components of the community in one river were either very rare or absent in the other. For example, *A. ligamentina* was found at 10 of 16 sites surveyed on the Thames River, making it the 3<sup>rd</sup> dominant species, but it was absent from the Ausable River. Conversely, *L. siliquioidea* was found at 7 of 8 sites on the Ausable River, but was not found at any site on the Thames River.

The composition of the mussel community changed considerably from site to site in the Grand River, less so in the Thames River, and relatively little in the Sydenham and Ausable Rivers. For example, only 4% of species in the Grand River were found at more than 75% of the sites, as compared with 9%, 19% and 44% of species in the Thames, Sydenham and Ausable Rivers, respectively (Fig. 4). It appears that the smaller the river, the more similar the composition of the mussel community remains over its course. Small rivers are likely to be more homogeneous with respect to water quality and habitat characteristics than large rivers, and they also tend to have fewer dams and impoundments, which can be barriers to the movements of host fish.

Two species were found alive only in the Grand River (*A. viridis* and *T. parvus*), and three others were found alive only in the Sydenham River (*E. triquetra*, *S. ambigua* and *V. fabalis*). Although the remaining target species were found in more than one river, some rivers were more important for some species and other rivers for other species. For example, the Sydenham River was clearly the most significant refuge for *E. t. rangiana*, as 26 of the 28 live specimens found were from this river. The same was true for *P. coccineum*, for which 21 of 26 specimens were from this river.

The Sydenham was also home to 90% of the approximately 300 specimens of *C. tuberculata* found during these surveys. Similar numbers of *Fusconaia flava* and *P. fasciolaris* were found in the Sydenham and Ausable Rivers. However, as only half as many sites were surveyed on the Ausable as the Sydenham, the Ausable may turn out to be the most important river for these two species (*P. fasciolaris* was not found alive in the Grand or Thames Rivers, and only 14 of the 117 specimens of *F. flava* were found in these rivers). The Thames River supported the largest populations of *A. ligamentina* and *Quadrula pustulosa pustulosa*, whereas the Grand River is the main refuge for *L. fasciola* (pending further surveys of the Maitland River; see above). Approximately a dozen *T. donaciformis* were found at one site on each of the Grand and Sydenham Rivers. These results show that different rivers support different species and communities of freshwater mussels, and that all rivers must be properly managed in order to conserve and protect our native mussel fauna.

### **Ranges and Population Characteristics of the Target Species**

Metcalf-Smith *et al.* (1998c) provided brief assessments of the current conservation status of 21 rare species of mussels in southern Ontario, based on comparisons between historical records and the occurrences of these species at the 37 sites surveyed in 1997. Based on these assessments, three species (*E. t. rangiana*, *V. fabalis* and *L. fasciola*) were recommended for status designation by COSSARO (Committee on the Status of Species at Risk in Ontario) and COSEWIC (Committee on the Status of Endangered Wildlife in Canada). Status reports to both committees, which were completed in 1998, provided detailed information on the taxonomy, distribution, population size and trend, habitat requirements, biology, limiting factors and threats, special significance, protection, and management options for these species. In this section, new data from 1998 have been integrated with information from the status reports to generate a comprehensive and up-to-date assessment of the range and population characteristics of these species. As all three species are sexually dimorphic, sex ratios and sex-specific size frequency distributions were examined for those watersheds that yielded enough live animals and shells for analysis. Detailed assessments were also prepared for the other six target species; this information may serve to justify the preparation of status reports on one or more of these species in the near future.



*Epioblasma torulosa rangiana*

*Epioblasma torulosa rangiana* has been collected only sporadically over the past century in the Canadian waters of the lower Great Lakes; only 14 records existed prior to 1997. Its historical distribution included western Lake Erie, Lake St. Clair, the Detroit River, and the Sydenham River in southwestern Ontario (see Staton *et al.* 1998). Due to the recent invasion of the zebra mussel, *Dreissena polymorpha*, it may be reasonably assumed that *E. t. rangiana*, like so many other native mussel species, has been eradicated from Lake Erie, Lake St. Clair, and the Huron-Erie corridor. Until recently, the subspecies was presumed extirpated from Canada. However, the discovery of live animals in the Sydenham River in 1997 (Metcalf-Smith *et al.* 1998c) showed that the subspecies is extant and should therefore be uplisted provincially from SH (known from historical records only) to S1 (extremely rare).

Based on data collected in 1997, Staton *et al.* (1998) described the range of *E. t. rangiana* in the Sydenham River as covering a 40 km stretch of the river between sites SR-3 and SR-6 (see Fig. 5). A total of 11 live animals numbering 2-5 individuals/site were encountered at four sites in this reach, and fresh shells were found at one other site and at a site 5 km upstream (SR-2). In 1998, *E. t. rangiana* was found alive at two of four sites surveyed on the main stem of the river. Two live animals were found at a site (SR-12) located 9 km below its previously known range (note: extra sampling effort was expended here), thus extending its range to approximately 50 km. Site SR-12 is expected to be the downstream limit of the population, as there is little gradient below this point (and thus no riffle habitat) and water levels fluctuate with the levels in Lake St. Clair. Site SR-17 produced the largest number of live specimens of *E. t. rangiana* of any site on the Sydenham River (11), and also supported the most species of any of the 66 sites surveyed (21 live species). No live animals or shells were found at sites SR-10 and SR-11 (see Fig. 3), which were upstream of a site where fresh shells were found in 1997 (SR-2); thus, site SR-2 appears to define the upstream limit of the subspecies in the Sydenham River.

Assessing changes over time in the population of *E. t. rangiana* in the Sydenham River is difficult, because most historical records lack information on sampling effort. However, Dr. Carol B. Stein (retired from the Ohio State University Museum of Biological Diversity) surveyed sites corresponding to our sites SR-5 and SR-12 in 1965 (SR-5 only) and 1973 (both sites) using similar survey techniques and a sampling effort of 6 p-h/site. In 1965, Stein observed a healthy population of *E. t. rangiana* at site SR-5. She collected 23 live specimens, representing almost 30% of all live mussels encountered. In 1973, she collected 32 fresh whole shells from a muskrat midden at the site, but did not find any live animals. In contrast, 4.5 p-h of sampling effort in 1997 yielded only 2 individuals (less than 2% of the 124 live mussels encountered). Capture rates were 3.8 specimens/h in 1965 as compared with only 0.4 specimens/h in 1997, representing a decline in abundance of nearly 90% over the past three decades at this site. The fact that only 12 weathered valves and one fresh shell were found at the site in 1997, whereas 21 and 32 fresh whole shells were found in 1965 and 1973, respectively, provides further evidence of a declining population. Dr. Stein found only 1 live animal at site SR-12 in 1973 using a sampling effort of 6 p-h. Two live specimens were found in 1998, using a sampling effort of 12 p-h (6 people for 2 hours); thus, capture rates were identical in both years (0.2 specimens/h). Although a decline in the abundance of *E. t. rangiana* over time has been documented for only one site on the Sydenham River, the paucity of live animals (maximum 11) and fresh shells (no more than a single valve or whole shell at any site) encountered in 1997 and 1998, as well as the complete absence of the subspecies from the 1991 collections of Clarke (1992), suggest that the entire Sydenham River population has suffered serious declines. This is unfortunate, as the Sydenham River population was once believed to be the healthiest extant population in North America (Clarke 1978).

In 1998, a previously unknown population of *E. t. rangiana* was discovered in the Ausable River. Eight sites were surveyed, and 1 live specimen was found at each of two sites, AR-7 and AR-8 (Fig. 5). Fresh shells were found at these and two other sites (AR-5 and AR-6). Weathered shells were found at all sites except site AR-2 in the headwaters; they were most numerous at sites AR-5 and AR-6 (34 of 52 shells found), where they may have accumulated from sites further upstream (see Fig. 3). These findings suggest that *E. t. rangiana* was once distributed throughout

the Ausable River in substantially higher densities than now currently exist. Although many more live specimens were found in the Sydenham than the Ausable (28 from 17 sites vs. 2 from 8 sites), the reverse was true for shells (21 fresh and 52 weathered shells from the Ausable vs. 4 fresh and 19 weathered shells from the Sydenham). These results suggest that: (i) the population of *E. t. rangiana* in the Ausable River may once have been larger than that in the Sydenham River, and (ii) the Ausable River population has declined in recent years to a level far below that in the Sydenham River. With so few live animals in evidence, the sustainability of the Ausable River population appears doubtful.

Based on the current distribution of live animals and shells, the historical range of *E. t. rangiana* in the Ausable River would have been greater than 55 km (the approximate distance between AR-8 and AR-6). As the gradient flattens out a few kilometres below site AR-6, the lower region of the river would not have provided suitable riffle habitat for *E. t. rangiana*.

Sex-specific size frequency distributions for live animals and dead shells were examined for both watersheds. In the Sydenham River (Fig. 6), the M:F (male:female) sex ratio for live animals was heavily skewed towards males at 22:4 (or 85% male), whereas the sex ratio for shells was more balanced at 14:13 (or 52% male). Although the Sydenham River population shows clear signs of recent reproduction, with juveniles as small as 17 mm found, the apparent lack of females is disconcerting. There is little information in the literature on normal sex ratios for any mussel species. However, Trdan and Hoeh (1993) studied the demographics of *E. t. rangiana* and *E. triquetra* in the nearby Black and Clinton Rivers, respectively. Both rivers are located in southeastern Michigan; the Black River is a tributary of the St. Clair River and the Clinton River is a tributary of the Detroit River. Based on a sample size of 114 live *E. t. rangiana*, a M:F sex ratio of 59%:41% was reported for the agriculturally-impacted Black River. In the much cleaner Clinton River, a nearly even M:F sex ratio of 52%:48% was observed for 799 live *E. triquetra*. These results suggest that females of *E. t. rangiana* are unnaturally scarce in the Sydenham River.

Shell lengths of the 22 live males collected from the Sydenham River ranged from 39 to 90 mm (mean = 56 mm), with the exception of a single 17 mm juvenile believed to be a male. The four

females ranged in length from 35 to 54 mm (mean = 46 mm). Although total lengths reported in the literature vary, lengths greater than 76 mm have not been reported (Staton *et al.* 1998). The only Canadian reference (Clarke 1981) states that mature males are 45 mm and mature females 50 mm in length. In the Black River, Michigan, *E. t. rangiana* ranged in length from 36 to 68 mm (sexes combined), with an average length of 52 mm for males and 48 mm for females (Trdan and Hoeh 1993). Thus, females in the Sydenham River appear average in size, or a little small, whereas the size distribution of males clearly shows a tendency towards very large animals - well beyond sizes reported in the literature. The size frequency distribution for males (see Fig. 7) indicates the presence of several year classes, but with a bias towards larger, older animals. The co-occurrence of old, large males and fewer, small females implies that males may have a better survival rate than females. The reasons for this are unknown, but it could be that females more readily succumb to environmental stresses due to the depletion of their energy reserves during reproduction. Interestingly, female shells exhibited a similar size distribution to live females (32 to 52 mm), whereas male shells (34 to 62 mm) tended to be smaller than live males.

In the Ausable River, insufficient numbers of live *E. t. rangiana* were encountered to determine the sex ratio - only 1 individual of each sex was found, a 60 mm female and a 57 mm male. However, large numbers of shells were collected. Male shells (n = 69) ranged in length from 33 to 74 mm, and female shells (n = 26) from 38 to 67 mm (Fig. 8). These size ranges are similar to those for shells from the Sydenham River.

### *Villosa fabalis*

The historical distribution of *Villosa fabalis* in the Canadian waters of the lower Great Lakes included the Detroit, Sydenham, and Thames Rivers in the Lake St. Clair drainage, and the Pelee Island region of western Lake Erie (West *et al.* 1998). The species has evidently been lost from western Lake Erie as it was not found during a survey of 17 sites in 1991 (Schloesser and Nalepa 1994). All populations in Lake Erie and the Detroit River have likely been destroyed by zebra mussels. The Thames River population also appears to have been extirpated, as only weathered

shells were found at 4 of the 16 sites surveyed in 1997 and 1998. Thus, it appears that the only location in Canada where *V. fabalis* still survives is the Sydenham River.

Based on 1997 data, West *et al.* (1998) described the range of *V. fabalis* in the Sydenham River as covering a 45 km stretch of the river between sites SR-2 and SR-6 (see Fig. 9). A total of 9 live animals numbering 1-5 individuals/site were encountered at four sites, and a fresh shell was found at an additional site. Weathered shells were also found at site SR-1 further upstream (see Fig. 3). Six live animals were found at another site surveyed in this reach in 1998 (SR-17), and a few fresh shells were found at sites SR-10, SR-11 and SR-12. Based on the presence of live animals, the range of *V. fabalis* in the Sydenham River remains at approximately 45 km. However, if fresh shells are taken to indicate the presence of live animals at perhaps lower densities, the range of this species may extend to about 65 km. It is possible that *V. fabalis* is present in the Sydenham River at greater densities than these data suggest, as its diminutive size and tendency to burrow in the substrate make it difficult to find.

The data of Dr. Stein can again be used to assess population trends over time. In 1967, Dr. Stein recorded 2 live animals, 16 fresh whole shells and 3 fresh valves at site SR-2 with a sampling effort of 6 p-h. Thirty years later, we recorded 1 live animal and 1 fresh valve in 4.5 p-h of effort at this site. In 1965, Dr. Stein recovered 1 live animal, 9 fresh whole shells and 2 fresh valves at site SR-5; in another visit in 1973 she found only 1 fresh valve. We found 1 fresh whole shell and 1 fresh valve at this site in 1997. In 1998, we found 1 fresh valve at site SR-12, which is exactly what Dr. Stein found at this site in 1973. Although these comparisons suggest that densities of *V. fabalis* may have decreased since the mid-1960s, there is no evidence that its range has contracted.

Sizes of live *V. fabalis* collected from the Sydenham River ranged from 20-38 mm. The maximum size observed (38 mm), is the same as the maximum size reported in the literature for this species (Clarke 1981). Shells ranged in length from 15-36 mm. As 90% of the shells collected from this river were fresh, i.e., probably from animals that died this year, data for live specimens and shells were combined to generate an overall size frequency distribution (Fig. 10).

The wide size range and fairly even distribution observed for both live specimens and shells suggests regular recruitment and, therefore, a healthy, reproducing population. The sex ratio could not be determined for live animals, as the specimens found in 1997 were not sexed. However, the sex ratio for the 64 shells collected was skewed towards females (M:F = 38%:62%), with female shells being smaller, on average, than male shells (mean lengths 23 and 28 mm, respectively). The sex ratio for the 40 weathered shells collected from the Thames River in 1997 and 1998 was more even (M:F = 43%:57%), and shell lengths for both males and females averaged 28 mm. We are not aware of any information in the literature on normal sex ratios for healthy populations of this species.

### *Lampsilis fasciola*

According to Metcalfe-Smith *et al.* (1998d), the historical distribution of *Lampsilis fasciola* in the Canadian waters of the lower Great Lakes included western Lake Erie, Lake St. Clair, and the Maitland, Ausable, Sydenham, Thames, Detroit, Grand and Nith Rivers (the latter is a tributary of the Grand). Since 1990, it has been found alive in the Ausable, Grand and Thames Rivers (Morris and DiMaio 1997; Metcalfe-Smith *et al.* 1998c). A single specimen was also found at one of 29 sites surveyed in Lake St. Clair in 1994 (Nalepa *et al.* 1996), but the species has probably now been eliminated from this and all other zebra mussel-infested waters. It should be noted, however, that *L. fasciola* is primarily a river-dwelling species that would not encounter the zebra mussel throughout most of its range.

Based on live animals collected in 1997, Metcalfe-Smith *et al.* (1998d) concluded that the range of *L. fasciola* in the Grand River has contracted and the species is now restricted to a 40 km reach of the upper river above Kitchener. Three sites in this reach (GR-3, GR-12 and GR-13) yielded a total of 17 live animals (see Fig. 11). To determine if the population was continuous within this reach, two more sites were surveyed in 1998. Site GR-20 yielded 2 live animals, 5 fresh whole shells and 2 fresh valves, while site GR-19 produced 5 fresh whole shells and 1 fresh valve. Only 1 fresh whole shell was found at site GR-18, which was located 5 km above the previously known upstream limit of the species (GR-13). Habitat suitability ends abruptly above this site where the

river flows through the Elora Gorge, and reaches above the Gorge are impounded and offer little habitat. A single live animal was found just upstream of the sewage treatment plant (STP) at Galt while conducting other studies in 1998, thus extending the previously estimated downstream range of the species by about 15 km.

Although *L. fasciola* had been reported from the middle reaches of the Grand River historically (Metcalf-Smith *et al.* 1998d), it now appears to be absent below Galt; only a few weathered shells were found at 3 of the 13 sites surveyed in the middle and lower Grand River in 1997 and 1998. The stretch of river immediately below the Galt STP may be severely degraded, as no live specimens of any mussel species were found during searches at several sites within 4 km of the outfall in related work (Metcalf-Smith *et al.*, unpublished data). At a distance of 4 km below the STP, only 5 specimens of a single tolerant species (*L. costata*) were found alive.

As *L. fasciola* had previously been reported from the Nith River, 2 sites on this tributary to the Grand River were surveyed in 1997 (GR-8 and GR-14) and another site in 1998 (GR-24). Only weathered shells were found at the most upstream site (GR-14), whereas one fresh whole shell was found at each of the other two sites. These results suggest that *L. fasciola* may persist at very low densities in the lower reaches of the Nith River. Weathered shells were collected from the Conestoga River, another tributary to the Grand River, in 1998 by A. Timmerman, Ontario Ministry of Natural Resources (A. Timmerman, personal records), prompting us to conduct a survey at this site (GR-23). One live animal and one fresh whole shell were found. The extent of the Conestoga River population of *L. fasciola* is unknown; however, it is probably of low density, as the species was not detected at any of the three sites surveyed on the river in 1995 by Mackie (1996).

Twenty-one live *L. fasciola* were found in the Grand River in 1997-98. Most measured between 51 and 66 mm in shell length, but two females were considerably smaller (30 and 44 mm). Shells ( $n = 85$ ) ranged from 27 - 93 mm, with female shells being smaller, on average, than male shells (mean length = 61 and 67 mm, respectively). The maximum size observed (93 mm), is similar to the maximum size reported in the literature for this species (95 mm; Clarke 1981). Sex ratio was

21%:79% (M:F) for live specimens, suggesting a scarcity of males. As the sex ratio for shells was more even (55%:45%), the skewed ratio for live animals may be a function of the small sample size. The presence of small live specimens may be taken to indicate that successful reproduction has recently occurred.

There are only three museum records for *L. fasciola* from the Thames River; thus, its historical distribution in this system is virtually unknown. Metcalfe-Smith *et al.* (1998c) found a few live specimens at site TR-2 and fresh shells at sites TR-11 and TR-3 in the upper Thames River between Dorchester and London in 1997. Based on these results, 5 more sites in the upper portion of the watershed were surveyed in 1998. Two sites on the North Thames River (TR-12 and TR-13) yielded one live specimen each, while one of two sites on the Middle Thames River (TR-15) produced a fresh whole shell and a few weathered shells (Fig. 11). The Middle Thames River is organically enriched due to livestock farming (WQB 1989), and is unlikely to support a significant population of this species. The 4 live males and 2 live females collected live from the Thames River in 1997 and 1998 were large, ranging from 58 to 83 mm in shell length. No juveniles were found.

In the Sydenham River, *L. fasciola* has been reported only sporadically over the past 30 years (see Metcalfe-Smith *et al.* 1998d for a detailed summary). No live specimens were encountered during the most recent surveys (Mackie and Topping 1988; Clarke 1992). In 1997, Metcalfe-Smith *et al.* (1998c) surveyed 9 sites on the Sydenham River and reported a small number of fresh whole shells at sites SR-2 and SR-3 near Alvington (Fig. 11). Close examination of all historical and recent data revealed that most records for *L. fasciola* from the Sydenham River, including all records for live animals, are from the vicinity of Alvington. Surveys at 8 more sites throughout the watershed in 1998, including several in this reach, failed to produce even a weathered shell of this species. These results suggest that a small, isolated population of *L. fasciola* may occur in the Sydenham River just below Alvington.

*L. fasciola* was recorded from a site on the Maitland River at Auburn in 1935. In 1998, 63 years later, 1 live female (60 mm shell length) and 2 live males (66 and 69 mm), as well as several fresh



whole shells (46-68 mm), were found at this site (MR-1; Fig. 11). As this was the only site surveyed in recent years, the results are inconclusive but encouraging. Clearly, additional surveys should be conducted in this river to determine if it may harbour a significant population of *L. fasciola*.

To our knowledge, there are no historical records for *L. fasciola* from the Ausable River. Morris and DiMaio (1997) surveyed six sites on the river in 1993 and 1994, and found a single live specimen at one site. They used a sampling effort of only 1 p-h effort/site, but three sites were surveyed in both years. No live specimens of *L. fasciola* were encountered in the present study, even though two survey sites were located at (AR-1) and just above (AR-8) the site where Morris and DiMaio (1997) had seen a live specimen in 1993. A single fresh whole shell was found at site AR-8, and a weathered valve at AR-1. A few fresh whole shells were also found at sites AR-3 and AR-7, and a weathered whole shell at AR-2. All 10 shells collected were from very large, presumably old, specimens (mean size = 75 mm). It appears that *L. fasciola* may soon be lost from the Ausable River.

In summary, the current distribution of *L. fasciola* in Canada may optimistically (i.e., assuming that fresh shells indicate the presence of live animals) be described as including a 60 km of the upper Grand River above Galt, low density populations in the lower Nith and possibly the Conestoga Rivers (tributaries to the Grand River), an isolated population near Alvinston on the Sydenham River, remnant and possibly non-reproducing populations in the Upper Thames and Ausable Rivers, and perhaps a healthy population in the Maitland River (further surveys needed to confirm this). It should be cautioned, however, that living specimens were found only in the upper Grand, Conestoga, upper Thames and Maitland Rivers.

### *Epioblasma triquetra*

Three-quarters of the historical records for *Epioblasma triquetra* are from Lake St. Clair, Lake Erie and the Niagara River, which are now infested with zebra mussels (Metcalf-Smith *et al.* 1998c). The remaining records came from the Grand, Thames, Sydenham and Ausable Rivers.

Metcalfe-Smith *et al.* (1998c) failed to locate live animals at any of the 37 sites surveyed on the Grand, Thames and Sydenham Rivers in 1997. In the Thames River, only a few weathered shells were recovered. Personal data provided by a biological consultant, F.W. Grimm (personal communication, September 1997) noted the occurrence of an apparently healthy population of *E. triquetra* at a site on the Middle Thames River north of Thamesford in 1970. Based on this information, two sites on the Middle Thames River (TR-15 and TR-16) and three sites in the upper watershed of the Thames River were surveyed in 1998. No trace of the species was found at any of these sites. Similarly, no live animals or shells were found at any of the 24 sites surveyed in the Grand River watershed in 1997-98. It therefore appears relatively certain that *E. triquetra* has been extirpated from the Thames and Grand River systems.

A remnant population of *E. triquetra* was discovered in the Sydenham River in 1998, with a total of three live animals found at sites SR-12 and SR-17 in the lower river (see Fig. 3). All were males; the two specimens from site SR-12 measured 40 and 48 mm, and the single mussel from site SR-17 measured 68 mm. Clarke (1981) considered a male 55 mm long to be "large", and Trdan and Hoeh (1993) reported a maximum size of 68 mm for the species, based on measurements of 799 individuals from the Clinton River in southeast Michigan. Trdan and Hoeh (1993) also reported mean sizes of 48 mm for males and 39 mm for females from this population. Clearly, the extremely large male from site SR-17 is a very old animal, and quite possibly a remnant of a disappearing population in that section of the river. The more average sizes of the males collected from site SR-12, along with a smaller, very fresh shell of a female are encouraging signs of recent reproductive success. The Sydenham River population appears to be restricted to a 20 km stretch of the lower river between sites SR-12 and SR-17. As no live animals or fresh shells were found at two other sites surveyed within this reach (SR-5 and SR-6), the population appears to be discontinuous. Eight sites in the upper river were also surveyed in 1997-98. Only a single fresh valve was found at one site (SR-1); thus, it is likely that the species has disappeared from the upper reaches of the Sydenham River.

In the Ausable River, our surveys failed to uncover a single live *E. triquetra*. However, weathered shells were found at four sites in the middle reaches (AR-4, AR-5, AR-6 and AR-7). A

few scattered individuals may still persist in the river, as a fresh whole shell with the ligament intact was collected from site AR-5 in 1998.

*Epioblasma triquetra* was previously ranked SH (no verified occurrences in the last 20 years) in Ontario by the Natural Heritage Information Centre in Peterborough, ON (D.A. Sutherland, personal communication, December 1996). With the discovery of live animals in the Sydenham River in 1998, the species should be downlisted to S1 (extremely rare; five or fewer occurrences in the province).

### *Obovaria subrotunda*

*Obovaria subrotunda* was once widely distributed throughout the lower Great Lakes drainage basin. It is known from a total of 45 historical records from the Detroit, Sydenham, Thames, Grand and Welland Rivers, as well as Lake Erie and Lake St. Clair (Metcalf-Smith *et al.* 1998b). This species is believed to have declined dramatically in recent years, and was not found alive at any of the 66 sites surveyed on the Grand, Thames, Sydenham, Ausable and Maitland Rivers in 1997 and 1998. No trace of the species was found in the Grand, Ausable or Maitland Rivers, and only weathered shells were found at three sites in the middle reaches of the Thames River. Thus, it appears that *O. subrotunda* has been lost from these watersheds.

*O. subrotunda* was last seen alive in the Sydenham River in 1991 by Clarke (1992), who found one specimen at each of three sites and two animals at a fourth of 16 sites surveyed. As two fresh whole shells and one fresh valve were found at the two most upstream sites in 1997 (SR-1 and SR-8, respectively), two more sites were surveyed in this reach in 1998. One fresh whole shell was found at one of these sites (SR-11), which was located immediately upstream of site SR-1, and a fresh valve was also found at site SR-17 in the lower river. The two fresh shells from site SR-1 measured 67 and 68 mm in shell length. Considering that Clarke (1981) gave the maximum size of the species to be 65 mm, these specimens were undoubtedly old and may have been among the last to perish.

The rapid decline of *O. subrotunda* in the Sydenham River can be documented for site SR-12 (see Appendix II). In 1973, Dr. Carol Stein found this species to be quite common, accounting for 10% (18 specimens) of 165 live mussels collected in approximately 6 p-h of effort. Eighteen years later, Clarke (1992) found only 2 live specimens of *O. subrotunda* in 3.5 p-h of searching, indicating a substantial reduction in density. Seven years later, in 1998, an exhaustive search (12 p-h effort) at this site failed to produce even shells of *O. subrotunda*, although most of the other 20 species listed as occurring at the site in 1973 were found alive. Two other species found alive by Stein but not by us 25 years later were *E. dilatata* and *L. ovata*. On the other hand, we found two species (*O. reflexa* and *T. donaciformis*) that Stein did not. The rapid decline in *O. subrotunda* at a site where other extremely rare species have persisted suggests a species-specific impact such as the disappearance of the host fish.

#### *Simpsonaias ambigua*

Only 4 historical records exist for *Simpsonaias ambigua*, and these are from the Detroit and Sydenham Rivers. In 1997, Metcalfe-Smith *et al.* (1998c) found fresh shells of this species at five sites on the Sydenham River (SR-3, SR-4, SR-5, SR-6, and SR-7) and one site in the headwater region of the North Sydenham River (SR-9). In 1998, a fresh whole shell was found at site SR-17 (between sites SR-7 and SR-5) in the Sydenham River, but four other sites in North Sydenham watershed revealed no trace of the species. Site SR-6 yielded by far the greatest number of fresh whole shells or valves (25), which displayed a continuous size distribution ranging from 24 to 49 mm. When this site was searched again in 1998 in connection with another study, a single live *S. ambigua* (19 mm), 3 fresh whole shells and 6 fresh valves were found.

*S. ambigua* is usually found under flat stones (Clarke 1981), thus it is difficult to find using traditional survey methods. As such, the discovery of a live juvenile and a total of 46 fresh shells of numerous sizes should be taken as evidence of a reproducing population within the reach bounded by sites SR-3 and SR-6. For this particular species, searching for fresh shells may be the most efficient way of detecting live populations without developing a species-specific protocol that recognizes its unique habitat preference.

*S. ambigua* was reported for the first time in the Thames River in 1998, when a single fresh valve was found at site SR-14 in the City of London. The species was not seen at any of the other 15 sites surveyed in the watershed in 1997 or 1998. This single record, similar to the one reported for site SR-9 on the North Sydenham River, may be indicative of a small isolated population.

*S. ambigua* is currently ranked SH in Ontario, although Metcalfe-Smith *et al.* (1998c) recommended downlisting it to S1 based on the large numbers of fresh shells found in the Sydenham River in 1997. As the occurrence of live animals in the Sydenham River was confirmed in 1998, it should be downlisted.

### *Obliquaria reflexa*

Historically, *Obliquaria reflexa* was found in the Grand and Thames Rivers and Lake Erie. In 1997, this species was not found in the Thames or Sydenham Rivers; however, it was represented at 6 of the 7 sites surveyed in the lower Grand River between York (GR-5) and Port Maitland (GR-16; see Fig. 2). A single live animal was found at three of these sites, and fresh shells (sometimes numerous) were found at the other three sites. Based on these findings, Metcalfe-Smith *et al.* (1998c) concluded that the species was now confined to the lower reaches of the Grand River. Additional data collected in 1998, however, proved that the species also exists in the lower reaches of both the Sydenham and Thames Rivers. A single live specimen was found at each of TR-6 and SR-12, while a single fresh shell was found at each of TR-10 and SR-6.

Living specimens and shells of *O. reflexa* from the lower Grand River exhibited an even size distribution ranging from 26 to 58 mm. This is consistent with Clarke (1981), who states that the maximum size of Canadian specimens is 53 mm. At 39 mm in length, the live specimen found in the Sydenham River appears to be of average size. In contrast, the only live specimen from the Thames River measured 63 mm in length and is probably a very old animal. As *O. reflexa* seems to prefer fine mud and sand substrates in slower currents, additional populations may exist in unexplored regions of the lower Thames and Sydenham Rivers.

*Ptychobranthus fasciolaris*

*Ptychobranthus fasciolaris* was historically known from Lake Erie, Lake St. Clair, and the Grand, Thames, Sydenham, Ausable, Niagara and Welland Rivers (Metcalf-Smith *et al.* 1998c). Surveys of the Grand and Thames Rivers in 1997 failed to produce live animals, although weathered shells were found at several sites on each river. A few fresh shells were also found at two of the sites on the Thames River. No further specimens were found at any of the 12 sites surveyed on these rivers in 1998, suggesting that *P. fasciolaris* has been extirpated from these systems. Interestingly, the 5 shells from the Grand River were much larger than the 6 shells from the Thames River (87-110 mm vs. 38-87 mm, respectively).

The population of *P. fasciolaris* in the Sydenham River seems to be widespread but of low density. Of the 12 sites surveyed on the main branch of the Sydenham in 1997 and 1998, 9 sites produced live animals (from 1 to 7 animals/site) and fresh shells were found at the remaining 3 sites). The 24 live animals found ranged in length from 43-124 mm (mean = 96 mm), and displayed a fairly continuous size distribution that is indicative of sustained reproduction (Fig. 12). *P. fasciolaris* was not found at any of the 5 sites surveyed on the North Sydenham River.

The discovery of *P. fasciolaris* in the Ausable River by Morris and Di Maio (1997) in 1993-94, prompted us to survey this river in 1998. Results revealed a concentrated population of *P. fasciolaris* in the middle to upper portion of the watershed between sites AR-7 and AR-8. Sites AR-1, AR-7, and AR-8 yielded 1, 15, and 11 live individuals, respectively. These 27 animals ranged in length from 54-117 mm (mean = 100 mm), with good representation in many size classes (Fig. 12). Fresh shells were also encountered at all three sites, and at site AR-3 in the same reach (see Fig. 3). No live animals or shells of this species were found at the remaining survey sites above and below this reach. Compared to the population found in the Sydenham River, the Ausable River population is of greater density but is confined to a much shorter reach.

Clarke (1981) reported shell length up to 100 mm for *P. fasciolaris* from Canadian environments. Sixty percent of live specimens found in the Ausable River and 50% of those from the Sydenham River were larger than this. It is unclear at this point if this means there is a disproportionate number of old specimens in these populations, which could indicate a trend toward declining reproductive success, or simply that the species grows particularly well in these watersheds. The maximum size reported for *P. fasciolaris* in the U.S. Midwest is 152 mm (Cummings and Mayer 1992). From a conservation perspective, the existence of populations of *P. fasciolaris* in two separate watersheds greatly improves the future chance of survival for this species.

### *Pleurobema coccineum*

*Pleurobema coccineum* was once widely distributed throughout the lower Great Lakes drainage basin; there are records from the Detroit, Thames, Sydenham, Grand and Niagara Rivers, as well as Lake Erie and Lake St. Clair (Metcalf-Smith *et al.* 1998c). There are almost the same number of historical records for this species (63) as for *P. fasciolaris* (64; Metcalf-Smith *et al.* 1998b). *P. coccineum* appears to have declined alarmingly in both numbers and range in recent years.

In their survey of the Grand River in 1997, Metcalf-Smith *et al.* (1998c) reported only a single live specimen of this species at site GR-6 in the lower river. Fresh shells were found at two nearby sites (GR-10 and GR-4), and weathered shells were found at a third nearby site (GR-5) and at a site further upstream (GR-1). Surveys at two additional sites in these areas in 1998 (GR-21 and GR-22) yielded a single live animal in each case. The three live animals found ranged in size from 59 to 100 mm. These data indicate that *P. coccineum* still occurs in very low densities in the lower Grand River. The presence of two weathered shells at site GR-20 in the upper river suggests it may once have been more widely distributed, as indeed the historical records show.

*P. coccineum* was not found alive in the Thames River at any of the 11 sites surveyed in 1997, although weathered shells were found at 7 sites. A single fresh whole shell was also found at one of these sites (TR-7) in the lower river. Further surveys in the upper watershed in 1998 resulted

in the discovery of 2 live animals and a fresh whole shell at site TR-16 in the Middle Thames River. However, no trace of the species was found in the North Thames River. It appears that the only surviving population of *P. coccineum* in the watershed is restricted to the headwaters of the Middle Thames branch. The two live animals measured 95 and 115 mm in length, which is large by Clarke's (1981) standards (max. size 100 mm for Canadian waters). Thus, they may be remnants of a dying population.

No live *P. coccineum* were found in the main branch of the Sydenham River in 1997, although fresh shells were found at sites SR-1, SR-2 and SR-3 in the middle reaches and weathered shells were found at several sites downstream. In contrast, 15 live animals were found at site SR-9 in the headwaters of the North Sydenham River. No live animals or fresh shells were found at four other sites surveyed in the North Sydenham River in 1998, but 1-2 live specimens were found at each of four sites in several stretches of the Sydenham River. In light of these data, it now appears that *P. coccineum* is scattered in low numbers throughout most of the main stem of the Sydenham River, whereas a dense population inhabits the headwaters of the North Sydenham sub-basin. Specimens collected from site SR-9 ranged in size along a gradient from 58-120 mm, indicating regular recruitment. Further study is needed to determine why *P. coccineum* has been lost from most of its former range but still flourishes in the North Sydenham River.

We know of no historical records for *P. coccineum* from the Maitland or Ausable Rivers, and it was not found, either as live animals or shells, during surveys on these rivers in 1998.

### **Environmental Requirements**

The known environmental requirements of *E. t. rangiana*, *V. fabalis* and *L. fasciola* are described in detail in the sections on habitat, biology, and limiting factors in the COSEWIC status reports on these species. This information is summarized in the Executive Summaries of these reports, which are attached as Appendix I and will not be repeated here. In general, the substrate and flow rate preferences, tolerance to low oxygen levels and siltation, and susceptibility to zebra mussel infestation and muskrat predation are fairly well known or can be surmised for these and many



other mussel species. On the other hand, our knowledge of their food preferences, thermal tolerances, sensitivity to specific toxic chemicals and various land use practices, and suitable host fish species is generally lacking.

A secondary objective of the present study was to provide a preliminary assessment of the environmental factors (e.g., water and sediment quality, land use, and presence of host fish) that may be limiting the distributions of the target mussel species. Data on physicochemical features of the habitat were obtained from all study sites in both years, and samples for water quality analysis were collected from all 66 sites in the fall of 1998. At the time of writing, data on water quality parameters had not yet been received from the National Water Quality Laboratory. A 30-year series of water quality data for the five studied rivers was also acquired from the Ontario Ministry of Environment and Energy in the fall of 1998. All of these data, as well as land use data to be acquired from sources such as Statistics Canada, Agriculture Canada and OMAFRA will be examined in detail next year.

Perhaps the most important environmental requirement of any mussel species is access to a suitable fish host. Because mussels are parasitic on fish during their early life stage (see Metcalfe-Smith *et al.* 1998b for a detailed discussion of the mussel-host fish relationship), they cannot exist even in areas of prime habitat unless their host fish are present. As such, the identification of fish hosts is listed as an urgent research need in the U.S. Fish and Wildlife Service's Draft National Strategy for The Conservation of Native Freshwater Mussels (Biggins *et al.* 1995). The focus of the present study was two-fold: (i) to compile a list of known and possible fish hosts for the nine target mussel species, and (ii) to compare the distributions of mussels with the distributions of fish in the studied rivers, in order to provide a list of potential fish hosts for these species in Canada.

#### *Fish Hosts for the Target Mussel Species*

A list of recognized fish hosts for the target mussel species was extracted from two recent reviews (Hoggarth 1992; Watters 1994). This information was updated with more recent data from the Triannual Unionid Reports. These reports provide a mechanism for the exchange of information

on the status of North American unionid research, management and conservation prior to formal publication. The results of this review are presented in Table 11, which also identifies the host fishes that are native to Ontario (as per Scott and Crossman 1973).

Data on the current and historical distributions of fishes in the Ausable, Grand, Sydenham, and Thames River watersheds were obtained from the Royal Ontario Museum (ROM) and the Ontario Ministry of Natural Resources' Ontario Fisheries Information System (OFIS). The OFIS records were collected between 1967 and 1977. The ROM data are much more extensive, having been collected between 1884 and 1997; over half of the records are from the 1990s. The number of records in each database for each watershed is given below:

<b>Watershed</b>	<b>OFIS records</b>	<b>ROM records</b>
Ausable R.	179	252
Grand R.	578	1687
Sydenham R.	577	1211
Thames R.	995	1906
<b>Total</b>	<b>2329</b>	<b>5056</b>

The following is a synopsis of the most probable fish host(s) for each mussel species *in Ontario*, with particular reference to the above data on fish distributions in the studied rivers. Where host fish species are unknown, potential hosts are suggested based on the known hosts for closely related (congeneric) mussel species. It should be noted that a fish cannot be confirmed as a host for a particular mussel species until it has been shown to facilitate the metamorphosis of glochidia in laboratory tests. Even then, there is no proof that the mussel is actually using this fish species as a host in nature unless wild fish are observed to be infested with glochidia. As sculpins and darters were found to be hosts or potential hosts for many of the target mussel species, the occurrences of these fishes in the Ausable, Sydenham and Thames Rivers are summarized in Table 12.

*Epioblasma torulosa rangiana*

As reported by Staton *et al.* (1998), none of the host fish identified by Watters (1996) for *E. t. rangiana* are native to Ontario waters. Thus the native fish host(s) for Canadian populations of this subspecies remain unknown.

Since *Epioblasmas* are frequently associated with darters and sculpins (G.T. Watters, Ohio State University, personal communication, June 1998), the most probable host fishes can be determined by scrutinizing records from both the Sydenham and Ausable River watersheds where *E. t. rangiana* still exists. Referring to Table 12, the first three darter species are unlikely candidates as they did not serve as hosts in laboratory tests (Watters 1996). Only three other species of darters, the least darter, johnny darter, and blackside darter, were common to both watersheds and are therefore the most likely hosts for Canadian populations of *E. t. rangiana*.

It should be noted that a sculpin host is also possible. Although neither the mottled sculpin nor the slimy sculpin was common to both watersheds (Table 12), these species are closely related members of the *bairdi* species group (Scott and Crossman 1973). Since these species prefer cold water temperatures, their ranges have undoubtedly declined considerably with the inevitable thermal changes brought about by intensive agriculture in the Sydenham and Ausable River watersheds. Thus, although sculpins may have served as hosts in the past, they are likely now restricted to colder headwater regions where *E. t. rangiana* does not presently occur.

*Villosa fabalis*

As for *E. t. rangiana*, the only known host fish for *V. fabalis* is a species of darter not found in Canada. As *V. fabalis* still inhabits the Sydenham River, all species of darters with which it co-occurs are potential hosts (West *et al.* 1998). All darter species listed in Table 12 except the fantail darter and river darter were collected live in 1997 from the stretch of the Sydenham River where *V. fabalis* presently occurs. The darter community of the Thames River is almost identical to that of the Sydenham River, except that it includes an additional species, the Iowa darter. It is

likely that one or more of these fishes may serve as hosts for *V. fabalis* in Canada. If so, then the disappearance of *V. fabalis* from the Thames River may not be due to the loss of its host fish.

### *Lampsilis fasciola*

The known fish host species for *L. fasciola* are the largemouth and smallmouth bass (*Micropterus salmoides* and *M. dolomieu*, respectively), both of which are common to the waters of southern Ontario. Numerous records from the ROM and OFIS indicate that both species are found in the Ausable, Grand, Sydenham and Thames Rivers. In all but the Sydenham River, the smallmouth bass is represented by more records than the largemouth bass. This is not surprising, as the flowing water and rocky substrates of most rivers are much more suited to smallmouth bass. In contrast, largemouth bass are almost universally found in association with soft bottoms, stumps, and extensive growths of aquatic vegetation (Scott and Crossman 1973). As *L. fasciola* generally inhabits gravel or sand bottoms of riffle areas of medium-sized streams (Metcalf-Smith *et al.* 1998c), the smallmouth bass is the more likely functional host for this mussel in Ontario waters. Although no data were acquired on the fish community of Maitland River, where *L. fasciola* was also found, smallmouth bass were observed during field work at the only site surveyed in this watershed (S.K. Staton, personal observation).

Although the upper reaches of the Grand River apparently support the healthiest remaining population of *L. fasciola* in southern Ontario, recent evidence suggests that its most probable host fish, the smallmouth bass, may be in decline here. Cooke *et al.* (1998) used Catch Per Unit Effort (CPUE) data from the Grand River Bass Derby to show that the relative abundance of smallmouth bass has decreased significantly in the past 10 years in the reach of the river bounded by West Montrose (site GR-13) and the Parkhill Dam in Cambridge (immediately upstream of Galt; see Fig. 11). These findings raise concerns that increased angling pressure in the Grand River could reduce smallmouth bass populations to levels that affect *L. fasciola*.

Greater declines of *L. fasciola* are apparent for the Ausable, Sydenham, and Thames Rivers, which are more turbid than the Grand River. We hypothesize that this may be linked to *L.*

*fasciola*'s specialized method of attracting its host fish. As for all females of the genus *Lampsilis*, the edge of the mantle in *L. fasciola* has evolved into a minnow-shaped "lure" (Strayer and Jirka 1997). Once the glochidia are ready for release, the female waves her lure to attract potential fish hosts. When a fish touches the lure, the glochidia are released to attach to the gills of the host fish where they complete their metamorphosis into free-living juveniles. In clear waters, this method would be ideal for attracting a sight predator such as the smallmouth bass; however, in turbid waters the method would be much less effective. Field data support this hypothesis: water clarity measurements at the nine sites where *L. fasciola* was found alive in 1997-98 (Grand, Maitland and Thames Rivers) indicate exceptionally clear waters with the stream bottom clearly visible at depths greater than 50 cm. In contrast, water clarity measurements in the Sydenham River system, where *L. fasciola* was not found alive, were consistently below 30 cm with some measurements as low as 7 cm.

#### *Epioblasma triquetra*

Three of the five known fish hosts for *E. triquetra* are native to Ontario: the logperch, mottled sculpin, and blackside darter. Although the mottled sculpin is found only in the Sydenham River (see above), the logperch and blackside darter are present in both the Sydenham and Ausable Rivers and are therefore most likely to serve as the functional hosts for *E. triquetra* in Ontario. It should be noted, however, that many other darter species have yet to be tested.

#### *Obovaria subrotunda*

The host fish species for *O. subrotunda* is unknown. The closest related mussel species in Canada, *O. olivaria*, is known to use the shovelnose sturgeon in the United States (Watters 1994). Only one species of sturgeon, the lake sturgeon (*Acipenser fulvescens*), occurs in southern Ontario (Scott and Crossman 1973). As there are no ROM or OFIS records for lake sturgeon from the Grand, Sydenham or Thames Rivers where *O. subrotunda* historically occurred, it is difficult to suggest any potential fish hosts for this mussel.

### *Simpsonaias ambigua*

*S. ambigua* is unique in that it is the only mussel species that requires an amphibian host, the mudpuppy (*Necturus maculosus*). The mudpuppy is widely distributed throughout southern and central Ontario, with the Grand, Sydenham, and Thames River watersheds falling substantially into the species' core area (see distribution map in GLFC 1998). Considering that *S. ambigua* is primarily restricted to the lower Sydenham River, its distribution does not appear to be solely determined by the presence of its host species. However, adequate host densities are required to sustain mussel populations, and it may be that the lower Sydenham River supports an abundance of mudpuppies.

In recent years, the mudpuppy has been adversely affected by habitat loss, water pollution, and siltation over much of its range (GLFC 1998). Some riverine populations have also been reduced by the use of lampricides for the control of sea lampreys in Great Lakes tributaries (GLFC 1998). Fortunately, the Sydenham River has never been treated with lampricides as the number of lampreys present is low (Wayne Westman, Sea Lamprey Control Centre, Sault Ste. Marie, Ontario, personal communication, January 1999). Thus, populations of mudpuppies and the mudpuppy mussels that depend on them remain free from this threat.

### *Obliquaria reflexa*

The only known fish hosts for *O. reflexa* that are native to Ontario are the common shiner (*Notropis cornutus*) and longnose dace (*Rhinichthys cataractae*). Longnose dace are characteristic of clean, fast flowing, gravel or bouldery streams, often inhabiting very turbulent waters (Scott and Crossman 1973). Similarly, the common shiner prefers clear streams, requiring gravely riffles for spawning and apparently avoids turbidity (Scott and Crossman 1973). As such, both species seem unlikely hosts for Ontario populations of *O. reflexa*, which occur principally in deeper, slower moving, muddy, turbid habitats (such as those found in the lower Grand River). Furthermore, neither longnose dace nor common shiners were recorded from the lower Grand River by the ROM, although numerous records exist throughout the upper and middle portions of

the Grand River watershed. It is therefore likely that the Grand River population of *O. reflexa* uses different fish host species than those reported in the literature.

### *Ptychobranhus fasciolaris*

The host fish species for *P. fasciolaris* is unknown. However, a related species, *P. greeni*, was found to use four species of darters (*Percina* and *Etheostoma* species) as hosts (Haag and Warren 1997). Since *P. fasciolaris* presently occurs in both the Sydenham and Ausable Rivers, the darter species common to both watersheds represent the most likely host candidates. These include the following six species: greenside darter, rainbow darter, logperch, least darter, johnny darter and blackside darter. A detailed temporal analysis of the darter communities in these watersheds, as well as the watersheds from which *P. fasciolaris* has been extirpated (Grand and Thames Rivers) may help to narrow the list of potential fish hosts.

### *Pleurobema coccineum*

The only known fish host for *P. coccineum* is the bluegill (*Lepomis macrochirus*). The ROM database lists 13 records for the bluegill from the Sydenham River, but only 4 records from the Grand River, and 4 records from drains and small streams in the Thames River watershed. There are only 3 records for bluegill in the OFIS database, including 2 from the Sydenham River and 1 from the Grand River. As the bluegill appears to be most common in the Sydenham River system where *P. coccineum* is also most abundant, it is likely that *P. coccineum* is using the bluegill as its host in Ontario.

### **Effect of sampling effort on the detection of rare species, diversity estimates, and apparent composition of the mussel community**

In 1997, the numbers of species found at seven survey sites using 4.5 p-h of sampling effort were compared with the numbers of species found during surveys conducted at the same sites in recent years by other researchers using shorter search times. Results showed that a longer search period

resulted in the discovery of significantly more species, as well as more individual mussels, at a given site. Based on these findings, Metcalfe-Smith *et al.* (1998c) concluded that an intensive sampling effort was needed to properly assess the conservation status of rare species. The amount of sampling effort needed for an adequate assessment remained unknown, and this was the focus of our investigation in 1998.

There is a general consensus in the literature that quadrat sampling tends to detect fewer rare species, and fewer species in total, than the timed search method (e.g., Strayer *et al.* 1997; Vaughn *et al.* 1997). Quadrat sampling is preferred, however, if density or demographic information are needed. Several studies have offered advice on the best sampling design to use and the numbers of replicates to collect when conducting quadrat surveys (e.g., Downing and Downing 1992; Green and Young 1993), but to our knowledge there have been no studies to determine the influence of sampling effort on the effectiveness of the timed search method.

In this study, 29 sites were surveyed for a total of 4.5 p-h, which was divided into three successive time intervals of 1.5 p-h each. The number of mussels of each species collected during each time interval was recorded separately for this purpose. Three questions were asked of the data: (i) What is the effect of increasing the sampling effort on the detection of rare species; (ii) What is the effect of increasing the sampling effort on the total number of species found at a given site, i.e., on the diversity estimate; and (iii) Does an increase in sampling effort result in a change in the apparent composition of the community, i.e., the occurrence and relative dominance of the various species?

### *Detection of Rare Species*

To determine the effect of increasing the sampling effort on the detection of rare species, it was first necessary to define "rare". For the purpose of this study, rare species were defined as those species represented by 1-5 individuals/4.5-p-h/site, uncommon species were those with 6-10 individuals/4.5 p-h/site), and common species were those with >10 individuals/4.5 p-h/site. These are similar to definitions used by Strayer (1979), which are (calculated from a per man-hour



basis): rare = < 5 individuals/4.5 p-h/site; and common = 5-20 individuals/4.5 p-h/site. Note that these terms relate to the number of individuals of a particular species found at a particular site, and not to the species' official conservation status rank. Thus, some species could fall into the rare category at one site and the uncommon category at another site, etc.

A total of 28 species were found at the 29 survey sites. The total number of species occurrences (defined as the presence of a given species at a given site) was 243. For each of these occurrences, we determined the time interval in which each rare, uncommon and common species was first observed at each site. The results are presented in Table 13. The results show that 53% of the species occurrences were for species that would be considered rare, 12% were for uncommon species, and 35% were for common species. Of the rare species occurrences, 56 of 131 (43%), were found during the first 1.5 p-h of searching; 27% were found in the second 1.5 p-h, or after a total of 3.0 p-h; and 30% were found in the last 1.5 p-h, or after 4.5 p-h had elapsed. The proportions for the uncommon species occurrences were 89%, 11% and 0, respectively, and those for the common species occurrences were 93%, 7% and 0, respectively. Thus, if we had sampled for only 1.5 p-h, which is similar to the sampling effort most commonly used in recent surveys (e.g, Mackie 1996; Morris and DiMaio 1997; Strayer *et al.* 1997), we would have detected approximately 90% of the common and uncommon species at our survey sites, but fewer than 50% of the rare species.

As the detection of rare species is the main focus of this work, it is of interest to know if we would have missed some occurrences of the target species if we had used less sampling effort. Data for the three main target species were examined. *L. fasciola* was found alive at a total of 5 sites; it was found in the first 1.5 p-h at 1 site, the second 1.5 p-h at 3 sites and the last 1.5 p-h at 1 site. *E. t. rangiana* was found at a total of 4 sites; it was found in the first 1.5 p-h at 2 sites, the second 1.5 p-h at 1 site and the last 1.5 p-h at 1 site. *V. fabalis* was found at only one site, and it was encountered in the second 1.5 p-h. Thus, we would have missed 7 out of 10 encounters with these target species if we had used a sampling effort of 1.5 p-h.

*Estimate of Total Diversity*

For each of the 29 sites, the proportion of the total number of species found during the survey was calculated for each time interval. These percentages varied considerably from site to site (Table 14). However, on average, 63% of the species found at a given site were observed in the first 1.5 p-h, 21% were observed in the second 1.5 p-h, and 16% were discovered in the last 1.5 p-h. Thus, we could routinely expect to miss over one-third of the species at a given site by using only 1.5 p-h of sampling effort. This is perhaps best illustrated in Fig. 13 which shows the significance of longer search time on the detection of new species over a wide range of total diversity estimates (from 2 species at site SR-16, to 21 species at site SR-17).

Although these data show that increasing the sampling effort will generally result in a larger number of species being found, it does not tell us whether all, or even most, species would be encountered during a search time of 4.5 p-h. At the second most diverse site (SR-12), we surveyed an additional 1.5 p-h (6.0 p-h in total) and detected a further 2 species, thus increasing the diversity estimate for the site from 16 to 18 species. An additional 2 species were found by other researchers conducting related work in the same area on the same day (their sampling effort was also 6.0 p-h). Assuming that 20 species is the total diversity of mussels occurring at this site, 60%, 65%, 80% and 90% of the species were found (cumulatively) by us after each of the four time intervals. A highly significant positive correlation was observed between time searched and number of species found over the 29 sites surveyed ( $r = +0.99$ ). The linear regression equation predicting diversity ( $y$ ) from time searched ( $x$ ) is as follows:  $y = 4.023 + 0.966x$ . Based on this equation, the average number of species that we would expect to find after 1.5, 3.0, 4.5 and 6.0 p-h of effort at a given site were 5.4, 7.0, 8.3 and 9.8, respectively. These findings support the direct observations from SR-12 that even a relatively intensive sampling effort of 4.5 p-h of effort may still not be adequate for detecting all species present at a given site.

### *Community Composition*

As previously stated, an increase in sampling effort results in an increase in the number of species and the number of individuals found at a given site. Unless mussels are evenly distributed throughout the survey area, which is highly unlikely, it seems probable that the composition of the community, i.e., the proportion of individuals accounted for by each species, could change considerably with increasing sampling effort. Changes in community composition with increasing sampling effort were determined for two representative sites: GR-22 (low abundance and diversity) and SR-17 (high abundance and diversity). At site GR-22, 67% of the species had been found in the 1<sup>st</sup> time interval, 11% in the 2<sup>nd</sup> and 22% in the 3<sup>rd</sup>, whereas at site SR-17, these proportions were 76%, 10% and 14%, respectively; thus, these are "average" sites with respect to the proportions of species found in each time interval (see Table 14). The apparent community composition at these sites changed considerably after each sampling interval, as shown in Fig. 14 (Grand River) and Fig. 15 (Sydenham River). For example, *L. recta* was found to be the dominant species in the community at site GR-22 by the end of the survey, yet it appeared to be one of the least common species after the first sampling interval. Conversely, *P. grandis* was less dominant than it appeared to be after the 1<sup>st</sup> interval. Similarly, at site SR-17, *Q. quadrula* was the 2<sup>nd</sup> dominant species (after *L. costata*) after the 1<sup>st</sup> sampling period, tied for 4<sup>th</sup> place after the second sampling period, and 8<sup>th</sup> of 21 species after the final sampling period.

In conclusion, an increase in sampling effort dramatically affects the detection of rare species and may also significantly alter the apparent composition of the mussel community, and hence our perception of which species are dominant and which are minor components of the community. As new species were still being found in the last time interval at 65% of our sites, this suggests that our estimates of diversity may be low for the majority of sites. Our findings also show that the majority of species occurrences are in fact for rare species (53% of all occurrences were for species represented by only 1-5 individuals at a site). If we do not employ sampling techniques and efforts that can detect these species, a significant amount of information about the mussel community will be lost.

## SUMMARY AND CONCLUSIONS

In a 1997 Endangered Species Recovery Fund (ESRF) Project, Metcalfe-Smith *et al.* (1998c) surveyed 37 sites on the Grand, Thames and Sydenham Rivers to determine the health of the native freshwater mussel communities of these southwestern Ontario rivers. Results of this project provided an assessment of the current distributions of 21 rare species; showed that some mussel species have been lost, and the ranges of many other species have contracted; recommended changes in the conservation status ranks (S-ranks) of 11 species; advocated that S1-ranked species be given first consideration for national status designation; facilitated the preparation of provincial (COSSARO) and national (COSEWIC) status reports on three of these species; and highlighted the importance of using an intensive sampling effort when investigating the status of rare species. The present (1998) ESRF Project continued this research in several areas. The major findings are as follows:

Comparisons between surveys conducted in 1997 and other less intensive surveys conducted at the same sites in recent years showed that a greater sampling effort resulted in the discovery of significantly more species, as well as individual mussels, at a given site. In 1998, the effect of sampling effort (i.e., search time in person-hours) on the detection of rare species, the total number of species found, and the apparent composition of the mussel community was determined quantitatively using data obtained after 1.5, 3.0 and 4.5 p-h of sampling effort at all 29 sites surveyed. Results showed that an increase in sampling effort dramatically improved the detection of rare species. Fewer than 50% of the species defined as "rare" (<1-5 specimens per site) were detected after 1.5 p-h of effort, which is the sampling effort most commonly used in mussel surveys. In fact, 70% of encounters with the three main target species, *Epioblasma torulosa rangiana*, *Villosa fabalis* and *Lampsilis fasciola*, would have been missed if the search had ended after 1.5 p-h. Results also showed that an increase in sampling effort may significantly alter the apparent community composition, and hence our perception of which species are dominant and which are minor components of the community. The fact that new species were still being found in the last time interval at 65% of the sites suggests that even a relatively intensive sampling effort

of 4.5 p-h may not locate all species present at all sites. It is clear that a significant amount of information about the mussel community will be lost if sufficient sampling effort is not used.

Although sampling effort/site is critical, it is also important, especially when assessing the mussel communities of large watersheds, that enough sites be surveyed to provide adequate coverage of the system. Strayer (in review) suggests that increasing the number of sites surveyed may actually be a better approach to detecting declines in mussel populations than increasing the sampling effort/site. Surveys of 20 additional sites on the Grand (7 sites), Thames (5) and Sydenham (8) Rivers in 1998 increased the total number of sites surveyed on these rivers from 37 (in 1997) to 57, and resulted in the discovery of an additional 1, 5 and 4 species, respectively, living in these systems. Species losses are therefore not as great as originally thought (see Metcalfe-Smith *et al.* 1998c). Rather, 4 (11%) of the 36 species previously known from these rivers were not found alive during the surveys of 1997-98, and the losses for individual rivers were 24% for the Grand (8 of 33), 30% for the Thames (10 of 33), and 15% for the Sydenham (5 of 34). Although a total of 32 species were found alive, nine species now occur in fewer rivers than they did historically. The Sydenham River appears to have suffered the least in terms of species losses, and there is evidence to suggest that it may now support more species of mussels than any other tributary to the Great Lakes.

Surveys of 8 sites on the Ausable River and 1 site on the Maitland River in 1998 confirmed our suspicions that rivers of the lower Lake Huron drainage also harbour many rare species, including several of the species targeted in this study. For such a small system, the Ausable River supports a remarkably diverse mussel community with a total of 18 species found alive and an additional 4 species represented by shells. In fact, average diversity and abundance of mussels per site did not differ significantly from the Sydenham River. Although only one site was surveyed on the Maitland River, 6 live species were recovered, including the target species *L. fasciola* and the increasingly uncommon *Villosa iris*.

A major objective of the 1998 surveys was to more clearly define the ranges of the three main target species and assess the stability of their existing populations. Based on the results, the range

of *E. t. rangiana* in the Sydenham River has been extended by about 10 km to a total of 50 km in middle reaches of the main stem of the river. A previously unknown population was also discovered in the Ausable River. Sustainability of the Ausable River population appears doubtful, as only a few live animals were found. The Sydenham River population may be healthier, as live animals were found at most sites surveyed in the occupied reach, and the size class structure showed evidence of regular recruitment. However, the sex ratio was heavily skewed towards males, and this does not bode well for the future. The previously defined range of *V. fabalis* remains unchanged from 1997; this species is restricted to a 45 km stretch of the middle Sydenham River - generally overlapping with *E. t. rangiana*. The wide and fairly even size distribution of *V. fabalis* specimens implies a healthy, reproducing population. Surveys in 1998 proved to be very productive for the third main target species, *L. fasciola*, as live animals were found at an additional 5 sites and fresh shells at 7 sites in four different watersheds. The healthiest population of *L. fasciola* occurs in a 60 km stretch of the upper Grand River above the city of Galt, including the adjoining lower reaches of the Conestoga River. A small, isolated, and possibly non-reproducing population persists in the upper Thames River, whereas only shells were found at a few sites on each of the Sydenham and Ausable Rivers. A healthy population may exist in the Maitland River, as 3 live specimens were found at the single site surveyed.

New information on the distributions of six other target species was also obtained in 1998. Highlights included the discovery of live *Epioblasma triquetra* at 2 sites on the lower Sydenham River. This species is currently ranked SH, i.e., of historical occurrence only, but can now be downlisted to S1. *Obovaria subrotunda*, on the other hand, has declined rapidly throughout its range in recent years, and may now be extirpated from the Sydenham River where it persisted the longest (last seen alive in 1991). *Simpsonaias ambigua* was captured alive at a site on the lower Sydenham River where many fresh shells had been found in 1997, thus validating our previous recommendation (which was based on the presence of very fresh shells at many sites) that the species should be downlisted from SH to S1. The collection of a single fresh valve from the Thames River near London may be evidence of an isolated population in this system. Based on the 1997 surveys, *Obliquaria reflexa* was thought to be restricted to the lower reaches of the Grand River. However, new data collected in 1998 showed that the species also exists (perhaps

at very low densities) in the lower Sydenham and Thames Rivers. A widespread, but low density population of *Ptychobranchius fasciolaris* was found in the main stem of the Sydenham River. The Ausable River also supported this species, but the population was isolated and of higher density. Most live animals from both systems were larger than the maximum size previously reported for this species in Canada. *Pleurobema coccineum* was found alive at 1 site on each of the Grand and Sydenham River in 1997. In 1998, live animals were found at 2 more sites on the Grand River, 1 site on the Thames River, and 4 sites on the Sydenham River, thus significantly extending our knowledge of the distribution of this species. *P. coccineum* was found to be scattered in low numbers throughout the main stem of the Sydenham River and in the lower Grand River, whereas a dense, isolated population inhabits the North Sydenham River. A remnant population (characterized by very large, old animals) was also found in the Middle Thames River.

The Grand, Thames, Sydenham and Ausable Rivers each supported a somewhat unique assemblage of mussel species. The Thames and Sydenham Rivers, which both drain into Lake St. Clair, had the most similar communities; otherwise, the degree of community similarity between rivers decreased with increasing distance apart. Each river except the Thames was found to be an important refuge for one or more of the target species, e.g., the Grand River for *L. fasciola*, the Sydenham River for *E. t. rangiana*, and the Ausable River for *P. fasciolaris*. Although the Thames River supported the largest populations of several S2-ranked species, namely *Actinonaias ligamentina* and *Quadrula pustulosa pustulosa*, it is arguably the least healthy river with respect to its mussel communities. Not only have more mussel species been lost from the Thames than from the other rivers, but many of the species that still occur are represented by remnant, possibly non-reproducing, populations. All rivers, including the Thames, must be properly managed in order to conserve and protect Ontario's native freshwater mussel fauna.

One of the most important requirements for sustaining mussel populations is the presence of healthy densities of the host fishes on which they depend. Unfortunately, the fish host(s) for many mussel species are unknown, or the list is incomplete. Furthermore, many of the host fish species

identified to date occur only in the United States. Of the nine mussel species considered in this report, only five have known hosts that are native to Ontario; these include *S. ambigua*, which uses an amphibian host, the mudpuppy. For the remaining four target species, attempts were made to identify potential fish hosts using data on the distribution patterns of fishes in the watersheds where these mussels are found, as well as host fish information for congeneric mussel species. Results of this exercise emphasized the importance of darter species (*Etheostoma* and *Percina* spp.) in particular, as at least four of the target mussel species (*E. t. rangiana*, *V. fabalis*, *E. triquetra*, and *P. fasciolaris*) are known or presumed to use darters as hosts.

### RECOMMENDATIONS

1. Conduct further surveys in the Maitland River, and possibly other lower Lake Huron drainage rivers, to determine their significance as refugia for rare species of freshwater mussels, including *L. fasciola* and *V. iris*.
2. In view of the updated information on species distributions provided in this report, the provincial conservation status rank for *E. triquetra* should be changed from SH to S1. Revisions to the ranks of 11 other species that were proposed in 1997 still apply. We believe that there is now sufficient information to justify consideration of one or more the following current/proposed S1-ranked species for listing by COSEWIC and COSSARO: *E. triquetra*, *O. reflexa*, *O. subrotunda*, *P. coccineum*, *P. fasciolaris* and *S. ambigua*. The status of *V. iris* requires further investigation.
3. As knowledge of host fish/mussel relationships is essential to fully understand the decline of many mussel species, a more in-depth spatial and temporal analysis of the distributions of mussels and fishes in the studied watersheds is indicated. Once potential fish hosts have been identified, they must be confirmed by artificially exposing glochidia to fish and observing if they survive and metamorphose.



4. The Sydenham River has the most diverse and intact mussel community of any of the rivers investigated, and probably of any river in Canada. It is the major refuge for many rare mussel species, including the first two unionids to be designated as "Endangered" by COSEWIC (anticipated in April 1999). As such, a watershed recovery plan for the Sydenham River is urgently needed to preserve and restore its unique mussel fauna. The Grand River was designated as a Canadian Heritage River System in 1994 and the Thames River has been nominated; thus, conservation management plans are currently being developed for both of these nearby rivers. A recovery plan for the Sydenham River would benefit other imperiled aquatic species, including fishes, crayfishes and turtles.

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**Table 1. Provincial conservation status ranks (Srank) of target mussel species.**

<b>SPECIES</b>	<b>Srank<sup>a,b</sup></b>
<i>Epioblasma triquetra</i>	SH
<i>Obovaria olivaria</i>	SH
<i>Obovaria subrotunda</i>	S1
<i>Epioblasma torulosa rangiana</i>	S1*
<i>Villosa fabalis</i>	S1
<i>Lampsilis fasciola</i>	S1
<i>Ptychobranhus fasciolaris</i>	S1
<i>Simpsonaias ambigua</i>	S1*
<i>Obliquaria reflexa</i>	S1*
<i>Pleurobema coccineum</i>	S1*
<i>Utterbackia imbecillis</i>	S1
<i>Toxolasma parvus</i>	S1*
<i>Truncilla donaciformis</i>	S1*
<i>Cyclonaias tuberculata</i>	S2*
<i>Actinonaias ligamentina</i>	S2
<i>Villosa iris</i>	S2*
<i>Quadrula pustulosa pustulosa</i>	S2
<i>Quadrula quadrula</i>	S2
<i>Ligumia nasuta</i>	S2*
<i>Truncilla truncata</i>	S2S3*
<i>Fusconaia flava</i>	S2S3*

<sup>a</sup>SH - Historical; of only historical occurrence in the province (no occurrences verified in the past 20 years) .

S1 - Extremely rare; usually 5 or fewer occurrences in the province.

S2 - Very rare; usually between 5 and 20 occurrences.

S3 - Rare to uncommon; usually between 20 and 100 occurrences.

S4 - Common; usually more than 100 occurrences.

S5 - Very common; demonstrably secure under present conditions.

<sup>b</sup>Courtesy of D.A. Sutherland, Natural Heritage Information Centre, Peterborough, Ontario.

\*proposed revisions to Srank based on results of the 1997 survey (Metcalf-Smith *et al.* 1998c).



**Table 2. Descriptions of all sites surveyed for freshwater mussels in 1998.**

Site #	Waterbody	Nearest town	Locality description	Diversity (total)	Diversity (live)	Date of Survey (y/m/d)
AR-98-1	Ausable River	Brinsley	2 concessions upstream of Brinsley, N of Ailsa Craig	15	8	19980810
AR-98-2	Ausable River	Exeter	2.8 km due W of Exeter (bridge just N of Hwy 83)	6	3	19980811
AR-98-3	Ausable River	Ailsa Craig	1st bridge N of Ailsa Craig	15	9	19980817
AR-98-4	Ausable River	Hungry Hollow	Hungry Hollow	13	9	19980818
AR-98-5	Ausable River	Arkona	Rock Glen Cons. Area in Arkona; just upstream of Rock Glen Cr.	14	11	19980818
AR-98-6	Ausable River	Arkona	Rock Glen Cons. Area, just upstream of AR-98-5	15	12	19980819
AR-98-7	Ausable River	Nairn	1st bridge S of Nairn	16	13	19980820
AR-98-8	Ausable River	Brinsley	2 concessions upstream of Brinsley, immediately upstream of AR-98-1	14	12	19980820
GR-98-18	Grand River	Innverhaugh	2nd bridge below Inverhaugh (bridge out)	9	7	19980804
GR-98-19	Grand River	Waterloo	Kiwanis Park, off Hwy 22 at N limits of Waterloo	9	4	19980805
GR-98-20	Grand River	Breslau	0.5km downstream of Victoria St. (Hwy 7), W of Breslau	7	4	19980831
GR-98-21	Grand River	York	1.5km downstream of York on west shore (near Mount Healey)	11	10	19980901
GR-98-22	Grand River	Brantford	first bridge below the Brantford Oxbow, at the Newport Bridge	11	9	19980901
GR-98-23	Conestoga River	St. Jacobs	100m upstream of St. Jacobs bridge	9	4	19980902
GR-98-24	Nith River	Drumbo	bridge E of Drumbo	9	7	19980902
MR-98-1	Maitland River	Auburn	bridge at Auburn (Hwy 25)	7	6	19980821
SR-98-10	Sydenham River	Rokeyby	4.5 km NE of Alvinston	18	14	19980824
SR-98-11	Sydenham River	Alvinston	7.5 km NE of Alvinston at bridge crossing, upstream of SR-97-1	18	13	19980825
SR-98-12	Sydenham River	Dawn Mills	Bridge at Dawn Mills	22	20	19980825
SR-98-13	Bear Creek	Brigden	7 km NE of Brigden	8	6	19980826
SR-98-14	Bear Creek	Waubuno	Bridge 2.5 km S of Waubuno	8	5	19980826
SR-98-15	Bear Creek	Petrolia	4.7 km E of Marthaville - just upstream of a driveway bridge	6	5	19980827
SR-98-16	Black Creek	Bradshaw	4 km NE of Bradshaw	2	2	19980827
SR-98-17	Sydenham River	Florence	3.4 km N (& slightly W) of bridge at Florence	26	21	19980828
TR-98-12	North Thames R.	Plover Mills	Bridge at Reg. Rd. 16, just E of Plover Mills	6	4	19980812
TR-98-13	North Thames R.	Science Hill	N of St. Mary's, just W of Science Hill	6	4	19980812
TR-98-14	Thames River	London	Story Book Gardens Park, just d.s. of a 5m high dam, W end of London	11	9	19980813
TR-98-15	Middle Thames R.	Thamesford	N of Thamesford, one concession N off Hwy 2	11	7	19980813
TR-98-16	Middle Thames R.	Cody's Corners	Bridge W of Cody's Corners (W of Woodstock)	8	8	19980814

**Table 3. Numbers of live specimens of each species observed at all survey sites on the Grand River in 1998.**  
**Presence of fresh (F) or weathered (W) shells also indicated; where both F and W shells found, only F are noted.**

SPECIES	18	19	20	21	22	23	24	Total live animals of each species at all sites
<i>Actinonaias ligamentina</i>				14	4			18
<i>Alasmidonta marginata</i>		13	F	26	2	F	28	69
<i>Alasmidonta viridis</i>	W					W	W	
<i>Amblema p. plicata</i>				2	W			2
<i>Anodontoides ferussacianus</i>	1	F					1	2
<i>Cyclonaias tuberculata</i>								
<i>Elliptio dilatata</i>	54	W	F			F	13	67
<i>Epioblasma torulosa rangiana</i>								
<i>Epioblasma triquetra</i>								
<i>Fusconaia flava</i>				W				
<i>Lampsilis fasciola</i>	F	F	2			1	F	3
<i>Lampsilis ovata</i>					2			2
<i>Lampsilis siliquoides</i>	11	1	W		F	1	15	28
<i>Lasmigona c. complanata</i>								
<i>Lasmigona compressa</i>								
<i>Lasmigona costata</i>	162	29	4	32	1	11	35	274
<i>Leptodea fragilis</i>				19	4			23
<i>Ligumia nasuta</i>								
<i>Ligumia recta</i>				24	10			34
<i>Obliquaria reflexa</i>								
<i>Obovaria olivaria</i>								
<i>Obovaria subrotunda</i>								
<i>Pleurobema coccineum</i>			W	1	1			2
<i>Potamilus alatus</i>				4	2			6
<i>Ptychobranchius fasciolaris</i>								
<i>Pyganodon grandis</i>	44	W	65		6	F	3	118
<i>Quadrula p. pustulosa</i>				6				6
<i>Quadrula quadrula</i>								
<i>Simpsonaias ambigua</i>								
<i>Strophitus undulatus</i>	81	8	57			1	26	173
<i>Toxolasma parvus</i>								
<i>Truncilla donaciformis</i>								
<i>Truncilla truncata</i>				5				5
<i>Utterbackia imbecillis</i>								
<i>Villosa fabalis</i>								
<i>Villosa iris</i>	1	W				W		1
<b>Total live animals of all species at each site</b>	354	51	128	133	32	14	121	833
<b>Diversity: Live only</b>	7	4	4	10	9	4	7	
<b>Diversity: Live + Dead</b>	9	9	8	11	11	9	9	

**Table 4. Numbers of live specimens of each species observed at all survey sites on the Thames River in 1998.**  
**Presence of fresh (F) or weathered (W) shells also indicated; where both F and W shells found, only F are noted.**

SPECIES	12	13	14	15	16	Total live animals of each species at all sites
<i>Actinonaias ligamentina</i>						
<i>Alasmidonta marginata</i>	1	1	13	2		17
<i>Alasmidonta viridis</i>				F		
<i>Amblema p. plicata</i>			5			5
<i>Anodontoides ferussacianus</i>						
<i>Cyclonaias tuberculata</i>						
<i>Elliptio dilatata</i>	1	W		11	18	30
<i>Epioblasma torulosa rangiana</i>						
<i>Epioblasma triquetra</i>						
<i>Fusconaia flava</i>				W	4	4
<i>Lampsilis fasciola</i>	1	1		F		2
<i>Lampsilis ovata</i>						
<i>Lampsilis siliquoidea</i>						
<i>Lasmigona c. complanata</i>			10			10
<i>Lasmigona compressa</i>				1	16	17
<i>Lasmigona costata</i>	2	8	37	69	54	170
<i>Leptodea fragilis</i>			10			10
<i>Ligumia nasuta</i>						
<i>Ligumia recta</i>			2			2
<i>Obliquaria reflexa</i>						
<i>Obovaria olivaria</i>						
<i>Obovaria subrotunda</i>						
<i>Pleurobema coccineum</i>				W	2	2
<i>Potamilus alatus</i>			12			12
<i>Ptychobranhus fasciolaris</i>						
<i>Pyganodon grandis</i>				5	12	17
<i>Quadrula p. pustulosa</i>						
<i>Quadrula quadrula</i>			1			1
<i>Simpsonaias ambigua</i>			F			
<i>Strophitus undulatus</i>	W	1	F	19	12	32
<i>Toxolasma parvus</i>						
<i>Truncilla donaciformis</i>						
<i>Truncilla truncata</i>			8			8
<i>Utterbackia imbecillis</i>						
<i>Villosa fabalis</i>						
<i>Villosa iris</i>	W	F		3	1	4
<b>Total live animals of all species at each site</b>	5	11	98	110	119	343
<b>Diversity: Live only</b>	4	4	9	7	8	
<b>Diversity: Live + Dead</b>	6	6	11	11	8	

Table 5. Numbers of live specimens of each species observed at all survey sites on the Sydenham River in 1998.  
 Presence of fresh (F) or weathered (W) shells also indicated; where both F and W shells found, only F are noted.

SPECIES	10	11	12	12*	13	14	15	16	17	Total live animals of each species at all sites
<i>Actinonaias ligamentina</i>	10	16	20	10					19	75
<i>Alasmidonta marginata</i>	2	4	F	2*	F				7	15
<i>Alasmidonta viridis</i>	F									
<i>Amblema p. plicata</i>	44	15	5		W		30		26	120
<i>Anodontoides ferussacianus</i>										
<i>Cyclonaias tuberculata</i>	3	5	14	8					10	40
<i>Elliptio dilatata</i>	1								1	2
<i>Epioblasma torulosa rangiana</i>			1	1*					11	13
<i>Epioblasma triquetra</i>				2*					1	3
<i>Fusconaia flava</i>	F	2	2	1			6		2	13
<i>Lampsilis fasciola</i>										
<i>Lampsilis ovata</i>	1	2							W	3
<i>Lampsilis siliquoidea</i>	1	1			1	F	5		1	9
<i>Lasmigona c. complanata</i>	7	2	2	5	65	11	31	11	3	137
<i>Lasmigona compressa</i>										
<i>Lasmigona costata</i>	28	25	4	4	1				35	97
<i>Leptodea fragilis</i>	1	5	7	1	4	4			21	43
<i>Ligumia nasuta</i>										
<i>Ligumia recta</i>	15	8	1						11	35
<i>Obliquaria reflexa</i>				1						1
<i>Obovaria olivaria</i>										
<i>Obovaria subrotunda</i>		F							F	
<i>Pleurobema coccineum</i>	1	2	1			W			2	6
<i>Potamilus alatus</i>			4	1		1			2	8
<i>Ptychobranthus fasciolaris</i>	1	2	4	2					7	16
<i>Pyganodon grandis</i>	4	W	1		12	1	36	21	F	75
<i>Quadrula p. pustulosa</i>				2					2	4
<i>Quadrula quadrula</i>			5	1	2	6			9	23
<i>Simpsonaias ambigua</i>									F	
<i>Strophitus undulatus</i>	F	F	F				F		1	1
<i>Toxolasma parvus</i>										
<i>Truncilla donaciformis</i>			1	4, 8*						13
<i>Truncilla truncata</i>			9	5		F			8	22
<i>Utterbackia imbecillis</i>										
<i>Villosa fabalis</i>	F	F	F						6	6
<i>Villosa iris</i>		F							F	
Total live animals of all species at each site	119	89	81	45, 13*	85	23	108	32	185	780
Diversity: Live only	14	13	16	+4	6	5	5	2	21	
Diversity: Live + Dead	18	18	19	+3	8	8	6	2	26	

\*data are for an additional 1.5 p-h sampling effort at this site, except that data marked with an asterisk were provided by another survey party conducting studies at the same site.

**Table 6. Numbers of sites in the Grand, Thames and Sydenham Rivers, numbers of sites in all three rivers, and numbers of rivers in which each species was found alive in 1997-98. Numbers of sites where fresh (F) and weathered (W) shells were found are shown where no live specimens were found. Numbers of rivers in which each species was found historically is presented for comparison (from Metcalfe-Smith *et al.* 1997).**

	Grand River (24 sites)	Thames River (16 sites)	Sydenham River (17 sites)	TOTAL (57 sites)	Rivers (1997-98)	Rivers (historical)
<i>Actinonaias ligamentina</i>	5	10	12	27	3	3
<i>Alasmidonta marginata</i>	10	14	10	34	3	3
<i>Alasmidonta viridis</i>	1	2F, 1W	1F	1	1	3
<i>Amblema p. plicata</i>	3	8	14	25	3	3
<i>Anodontoides ferussacianus</i>	3	1	1	5	3	3
<i>Cyclonaias tuberculata</i>		6	12	18	2	2
<i>Elliptio dilatata</i>	5	5	8	18	3	3
<i>Epioblasma torulosa rangiana</i>			6	6	1	1
<i>Epioblasma triquetra</i>		1W	2	2	1	3
<i>Fusconaia flava</i>	4	2	8	14	3	3
<i>Lampsilis fasciola</i>	6	3	2F	9	2	3
<i>Lampsilis ovata</i>	6	6	6	18	3	3
<i>Lampsilis siliquoidea</i>	11		7	18	2	3
<i>Lasmigona c. complanata</i>		8	16	24	2	3
<i>Lasmigona compressa</i>	1	2	1	4	3	3
<i>Lasmigona costata</i>	18	16	14	48	3	3
<i>Leptodea fragilis</i>	8	6	14	28	3	3
<i>Ligumia nasuta</i>					0	1
<i>Ligumia recta</i>	7	6	10	23	3	3
<i>Obliquaria reflexa</i>	3	1	1	5	3	2
<i>Obovaria olivaria</i>					0	2
<i>Obovaria subrotunda</i>		3W	4F, 3W		0	3
<i>Pleurobema coccineum</i>	3	1	5	9	3	3
<i>Potamilus alatus</i>	7	7	9	23	3	3
<i>Psychobranhus fasciolaris</i>	3W	2F, 2W	9	9	1	3
<i>Pyganodon grandis</i>	12	2	13	27	3	3
<i>Quadrula p. pustulosa</i>	5	5	3	13	3	3
<i>Quadrula quadrula</i>	5	7	9	21	3	3
<i>Simpsonaias ambigua</i>		1F	1		1	1
<i>Strophitus undulatus</i>	12	4	4	20	3	3
<i>Taxolasma parvus</i>	1			1	1	3
<i>Truncilla donaciformis</i>	1	1F	1	2	2	2
<i>Truncilla truncata</i>	6	7	7	20	3	3
<i>Uterbackia imbecillis</i>	1F		3F		0	2
<i>Villosa fabalis</i>		4W	5	5	1	2
<i>Villosa iris</i>	1	2	3	6	3	3

\*shaded species are those that have disappeared from some rivers or have been extirpated from the study area.

**Table 7. Numbers of live specimens of each species observed at all survey sites on the Ausable River in 1998.**  
**Presence of fresh (F) or weathered (W) shells also indicated; where both F and W shells found, only F are noted.**

SPECIES	1	2	3	4	5	6	7	8	Total live animals of each species at all sites
<i>Actinonaias ligamentina</i>									
<i>Alasmidonta marginata</i>	1		2	1	3	1	12		20
<i>Alasmidonta viridis</i>					F				
<i>Amblema p. plicata</i>	25		120	1	20	42	819*	120*	1147
<i>Anodontoides ferussacianus</i>									
<i>Cyclonaias tuberculata</i>					2	2	F		4
<i>Elliptio dilatata</i>	F		2	1	6	8	14	10	41
<i>Epioblasma torulosa rangiana</i>	W		W	W	F	F	1	1	2
<i>Epioblasma triquetra</i>				W	F	W	W		
<i>Fusconaia flava</i>	2		4				27	11	44
<i>Lampsilis fasciola</i>	W	W	F				F	F	
<i>Lampsilis ovata</i>	1		2	3	15	27	25	6	79
<i>Lampsilis siliquoidea</i>	F	2	8	2	21	31	24	3	91
<i>Lasmigona c. complanata</i>				F		1			1
<i>Lasmigona compressa</i>	1	2					1	F	4
<i>Lasmigona costata</i>	3	1	12	2	22	53	55	32	180
<i>Leptodea fragilis</i>				4	6	1			11
<i>Ligumia nasuta</i>									
<i>Ligumia recta</i>	F		7	2	16	63	26	8	122
<i>Obliquaria reflexa</i>									
<i>Obovaria olivaria</i>									
<i>Obovaria subrotunda</i>									
<i>Pleurobema coccineum</i>									
<i>Potamilus alatus</i>						2			2
<i>Ptychobranchius fasciolaris</i>	1		F				15	11	27
<i>Pyganodon grandis</i>	3	W	30	1	1	F	5	24	64
<i>Quadrula p. pustulosa</i>									
<i>Quadrula quadrula</i>									
<i>Simpsonaias ambigua</i>									
<i>Strophitus undulatus</i>	F		F	F	5	1	1	2	9
<i>Toxolasma parvus</i>									
<i>Truncilla donaciformis</i>									
<i>Truncilla truncata</i>									
<i>Unterbackia imbecillis</i>			F						
<i>Villosa fabalis</i>									
<i>Villosa iris</i>	F	W	F					1	1
<b>Total live animals of all species at each site</b>	37	5	187	17	117	232	1025	229	1849
<b>Diversity: Live only</b>	8	3	9	9	11	12	13	12	
<b>Diversity: Live + Dead</b>	15	6	15	13	14	15	16	14	

\*Note: Abundance of *A. p. plicata* at sites AR-7 and AR-8 are extrapolated values based on collections of 273 and 40 specimens, respectively, in the first 1.5 p-h of sampling effort only.

**Table 8. Numbers of live specimens of each species observed at the survey site on the Maitland River in 1998. Presence of fresh (F) or weathered (W) shells also indicated; where both F and W shells found, only F are noted.**

<b>SPECIES</b>	<b>1</b>
<i>Actinonaias ligamentina</i>	
<i>Alasmidonta marginata</i>	8
<i>Alasmidonta viridis</i>	W
<i>Amblema p. plicata</i>	
<i>Anodontoides ferussacianus</i>	
<i>Cyclonaias tuberculata</i>	
<i>Elliptio dilatata</i>	
<i>Epioblasma torulosa rangiana</i>	
<i>Epioblasma triquetra</i>	
<i>Fusconaia flava</i>	
<i>Lampsilis fasciola</i>	3
<i>Lampsilis ovata</i>	7
<i>Lampsilis siliquoidea</i>	
<i>Lasmigona c. complanata</i>	
<i>Lasmigona compressa</i>	
<i>Lasmigona costata</i>	11
<i>Leptodea fragilis</i>	
<i>Ligumia nasuta</i>	
<i>Ligumia recta</i>	
<i>Obliquaria reflexa</i>	
<i>Obovaria olivaria</i>	
<i>Obovaria subrotunda</i>	
<i>Pleurobema coccineum</i>	
<i>Potamilus alatus</i>	
<i>Ptychobranhus fasciolaris</i>	
<i>Pyganodon grandis</i>	
<i>Quadrula p. pustulosa</i>	
<i>Quadrula quadrula</i>	
<i>Simpsonaias ambigua</i>	
<i>Strophitus undulatus</i>	1
<i>Toxolasma parvus</i>	
<i>Truncilla donaciformis</i>	
<i>Truncilla truncata</i>	
<i>Utterbackia imbecillis</i>	
<i>Villosa fabalis</i>	
<i>Villosa iris</i>	1
<b>Total live animals of all species</b>	<b>31</b>
<b>Diversity: Live only</b>	<b>6</b>
<b>Diversity: Live + Dead</b>	<b>7</b>

**Table 9. Differences in the composition of the mussel communities of the Grand, Thames, Sydenham and Ausable Rivers. For each river, the ten most common species are arranged from most to least dominant based on the numbers of sites where they were found alive in 1997-98\*.**

<b>Grand River (24 sites)</b>	<b>Thames River (16 sites)</b>	<b>Sydenham River (17 sites)</b>	<b>Ausable River (8 sites)</b>
<i>Lasmigona costata</i> (18)	<i>Lasmigona costata</i> (16)	<i>Lasmigona c. complanata</i> (16)	<i>Lasmigona costata</i> (8)
<i>Pyganodon grandis</i> (12)	<i>Alasmidonta marginata</i> (14)	<i>Lasmigona costata</i> (14)	<i>Amblema p. plicata</i> (7)
<i>Strophitus undulatus</i> (11)	<i>Actinonaias ligamentina</i> (10)	<i>Amblema p. plicata</i> (14)	<i>Lampsilis siliquoidea</i> (7)
<i>Alasmidonta marginata</i> (10)	<i>Lasmigona c. complanata</i> (8)	<i>Leptodea fragilis</i> (14)	<i>Lampsilis ovata</i> (7)
<i>Lampsilis siliquoidea</i> (10)	<i>Amblema p. plicata</i> (8)	<i>Pyganodon grandis</i> (13)	<i>Ligumia recta</i> (6)
<i>Leptodea fragilis</i> (8)	<i>Quadrula quadrula</i> (7)	<i>Cyclonaias tuberculata</i> (12)	<i>Pyganodon grandis</i> (6)
<i>Ligumia recta</i> (7)	<i>Potamilus alatus</i> (7)	<i>Actinonaias ligamentina</i> (12)	<i>Elliptio dilatata</i> (6)
<i>Potamilus alatus</i> (7)	<i>Truncilla truncata</i> (7)	<i>Ligumia recta</i> (10)	<i>Alasmidonta marginata</i> (6)
<i>Truncilla truncata</i> (6)	<i>Leptodea fragilis</i> (6)	<i>Alasmidonta marginata</i> (9)	<i>Fusconaia flava</i> (4)
<i>Quadrula quadrula</i> (5)	<i>Cyclonaias tuberculata</i> (6)	<i>P. alatus</i> and <i>P. fasciolaris</i> (9)**	<i>Strophitus undulatus</i> (4)

\*Where more than one species was found at the same number of sites, the species with the greatest total abundance was ranked higher.

\*\*Number of sites where found and abundance were identical for these two species.



**Table 10. Similarity of mussel communities between rivers.**

<b>Rivers compared</b>	<b>Total species in both rivers</b>	<b>Number of species in common</b>	<b>Spearman's rank correl. coeff. (<math>r_s</math>)</b>
Thames and Sydenham	28	21	0.64**
Sydenham and Ausable	27	18	0.48*
Grand and Ausable	29	14	0.42*
Grand and Thames	27	20	0.36
Grand and Sydenham	31	21	0.32
Thames and Ausable	25	15	0.08

\*significant @  $p < 0.05$ ; \*\*significant @  $p < 0.01$ .

**Table 11. Known fish hosts for target species of freshwater mussels.**

Mussel species	Fish host species	# of known host species native to Ontario
<i>E. t. rangiana</i>	<sup>6</sup> bluebreast darter ( <i>Etheostoma camurum</i> ) <sup>6</sup> banded darter ( <i>Etheostoma zonale</i> ) <sup>6</sup> banded sculpin ( <i>Cottus carolinae</i> ) <sup>6</sup> brown trout ( <i>Salmo trutta</i> )	0
<i>V. fabalis</i>	<sup>5</sup> tippecanoe darter ( <i>Etheostoma tippecanoe</i> )	0
<i>L. fasciola</i>	<sup>8</sup> smallmouth bass ( <i>Micropterus dolomieu</i> )* <sup>5</sup> largemouth bass ( <i>Micropterus salmoides</i> )*	2
<i>E. triquetra</i>	<sup>1,2,3</sup> logperch ( <i>Percina caprodes</i> )* <sup>3</sup> banded sculpin ( <i>Cottus carolinae</i> ) <sup>2</sup> blackspotted topminnow ( <i>Fundulus olivaceus</i> ) <sup>2</sup> ozark sculpin ( <i>Cottus bairdii</i> )* <sup>1</sup> blackside darter ( <i>Percina maculata</i> )*	3
<i>O. subrotunda</i>	unknown	0
<i>S. ambigua</i>	<sup>2</sup> mudpuppy ( <i>necturus maculosus</i> )*	1
<i>O. reflexa</i>	<sup>4</sup> common Shiner ( <i>Notropis cornutus</i> )* <sup>4</sup> longnose Dace ( <i>Rhinichthys cataractae</i> )* <sup>4</sup> silverjaw minnow	2
<i>P. fasciolaris</i>	unknown	0
<i>P. coccineum</i>	<sup>7</sup> bluegill ( <i>Lepomis macrochirus</i> )*	1

\* fish species native to Ontario

<sup>1</sup>Hillegass and Hove (1997); <sup>2</sup>Barnhart et al. (1998); <sup>3</sup>Yeager and Saylor (1995); <sup>4</sup>Watters et al. (1998); <sup>5</sup>Watters, G.T., Aquatic Ecology Laboratory, Ohio State University, personal communication, 1998; <sup>6</sup>Watters (1996); <sup>7</sup>Watters (1994); <sup>8</sup>Zale and Neves (1982).

**Table 12. Species of darters and sculpins occurring in the Thames, Sydenham, and Ausable Rivers that may serve as hosts for several rare species of mussels.**

Potential host fish species	Number of records					
	Thames River		Sydenham River		Ausable River	
	ROM <sup>a</sup>	OMNR <sup>b</sup>	ROM	OMNR	ROM	OMNR
greenside darter ( <i>Etheostoma blenniodes</i> )	75	24	37	21	3	-
rainbow darter ( <i>Etheostoma caeruleum</i> )	17	29	1	2	4	18
logperch ( <i>Percina caprodes</i> )	11	1	20	8	1	1
eastern sand darter ( <i>Ammocrypta pellucida</i> )	11	2	9	1	-	-
fantail darter ( <i>Etheostoma flabellare</i> )	35	27	4	1	-	-
least darter ( <i>Etheostoma microperca</i> )	24	20	14	7	2	1
johnny darter ( <i>Etheostoma nigrum</i> )	94	62	81	37	7	24
blackside darter ( <i>Percina maculata</i> )	52	10	54	40	4	-
river darter ( <i>Percina shumardi</i> )	2	-	6	1	-	-
Iowa darter ( <i>Etheostoma exile</i> )	4	-	-	-	8	-
mottled sculpin ( <i>Cottus bairdi</i> )	2	-	1	5	-	-
slimy sculpin ( <i>Cottus cognatus</i> )	1	-	-	-	-	2

<sup>a</sup>Royal Ontario Museum (courtesy of E. Holm, Assistant Curator - Fishes, Centre for Biodiversity and Conservation Biology, ROM, Toronto, ON)

<sup>b</sup>Ontario Ministry of Natural Resources (courtesy of T. Chen, Ontario Fisheries Information System, OMNR, Peterborough, ON)

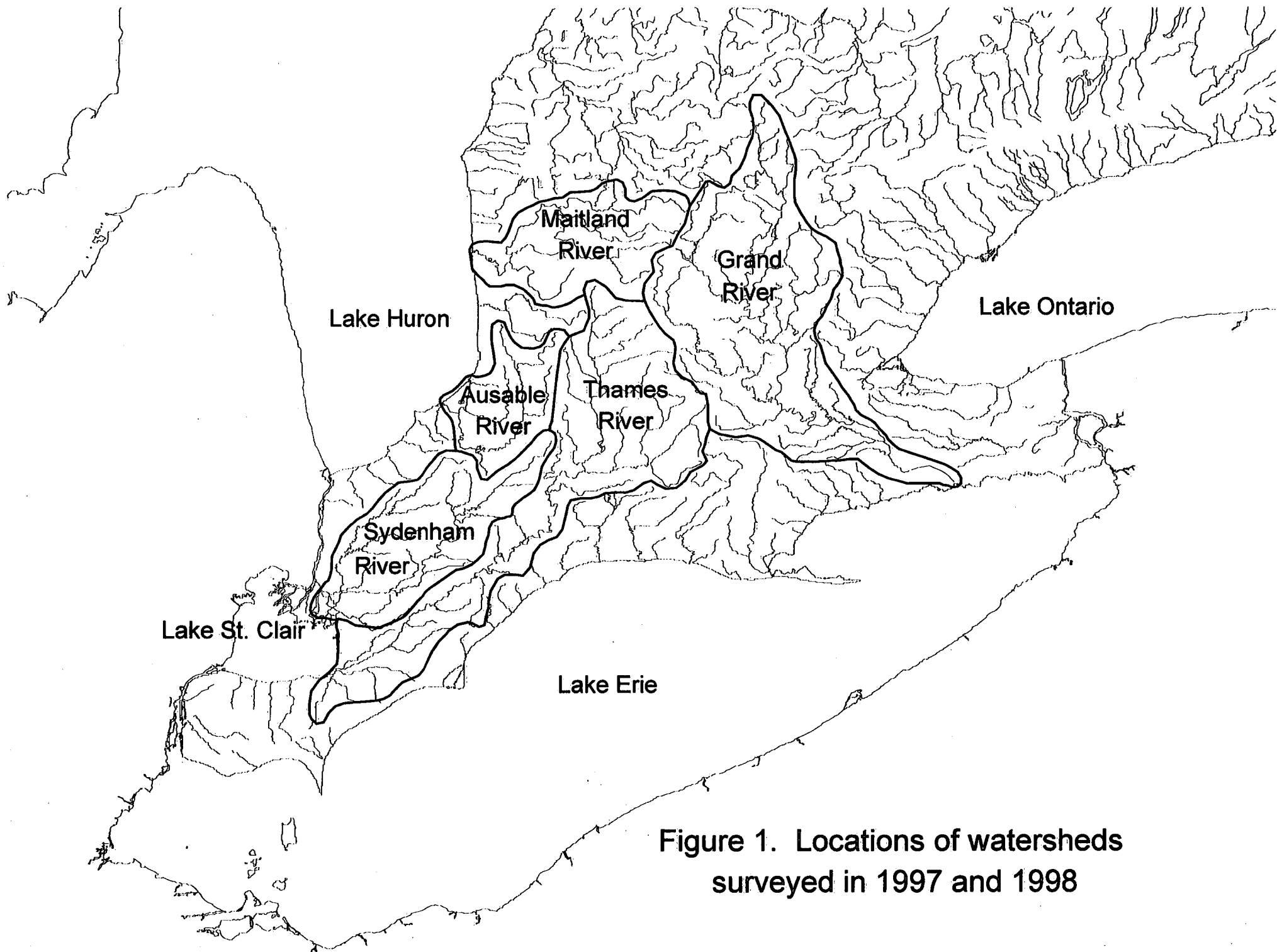
**Table 13. Effect of sampling effort (search time) on the detection of rare, uncommon and common species.**

<b>Category</b>	<b>Number of species/category found for the first time in each time interval</b>			<b>Totals</b>
	<b>First (1.5 p-h)</b>	<b>Second (3.0 p-h)</b>	<b>Third (4.5 p-h)</b>	
Rare (1-5)*	56	36	39	131 (53%)
Uncommon (6-10)	25	3	0	28 (12%)
Common (>10)	78	6	0	84 (35%)

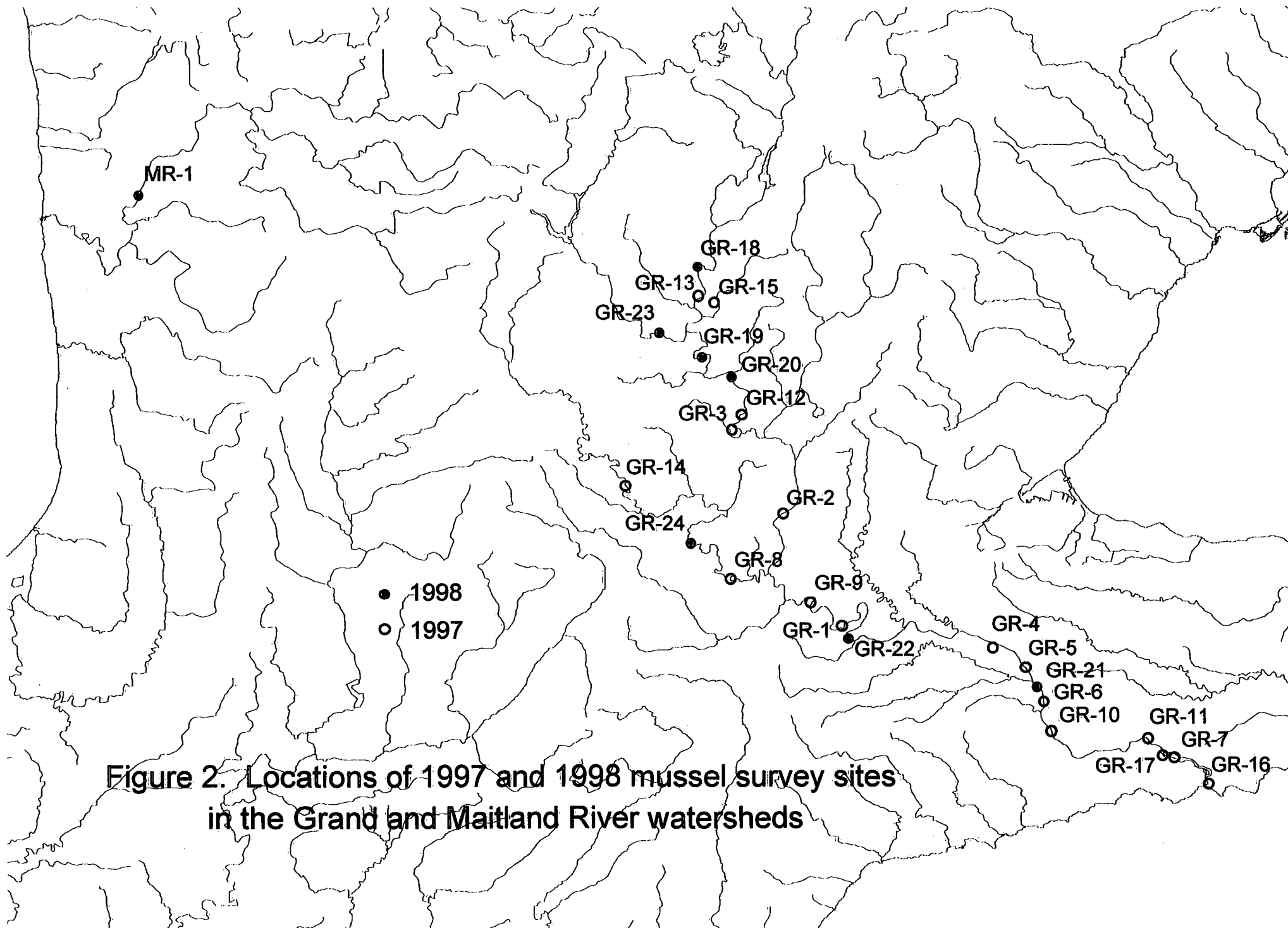
\*numbers in brackets refer to numbers of individuals/site that define each category

**Table 14. Proportions of species (% of total) found in each time interval at each site.**

<b>Site</b>	<b>Diversity</b>	<b>1st interval</b>	<b>2nd interval</b>	<b>3rd interval</b>
SR-16	2	100	0	0
AR-2	3	0	100	0
GR-19	4	50	25	25
GR-20	4	25	75	0
GR-23	4	50	50	0
TR-12	4	25	25	50
TR-13	4	75	0	25
SR-14	5	60	20	20
SR-15	5	100	0	0
MR-1	6	50	0	50
SR-13	6	67	33	0
GR-18	7	86	0	14
GR-24	7	86	14	0
TR-15	7	71	14	15
AR-1	8	75	0	25
TR-16	8	38	25	37
AR-3	9	89	11	0
AR-4	9	22	0	78
GR-22	9	67	11	22
TR-14	9	44	44	12
GR-21	10	90	0	10
AR-5	11	64	18	18
AR-6	12	75	8	17
AR-7	12	92	8	0
AR-8	13	83	17	0
SR-11	13	54	38	8
SR-10	14	29	50	21
SR-12	16	75	6	19
SR-17	21	76	10	14
Mean proportions		63%	21%	16%



**Figure 1. Locations of watersheds surveyed in 1997 and 1998**



**Figure 2. Locations of 1997 and 1998 mussel survey sites in the Grand and Maitland River watersheds**

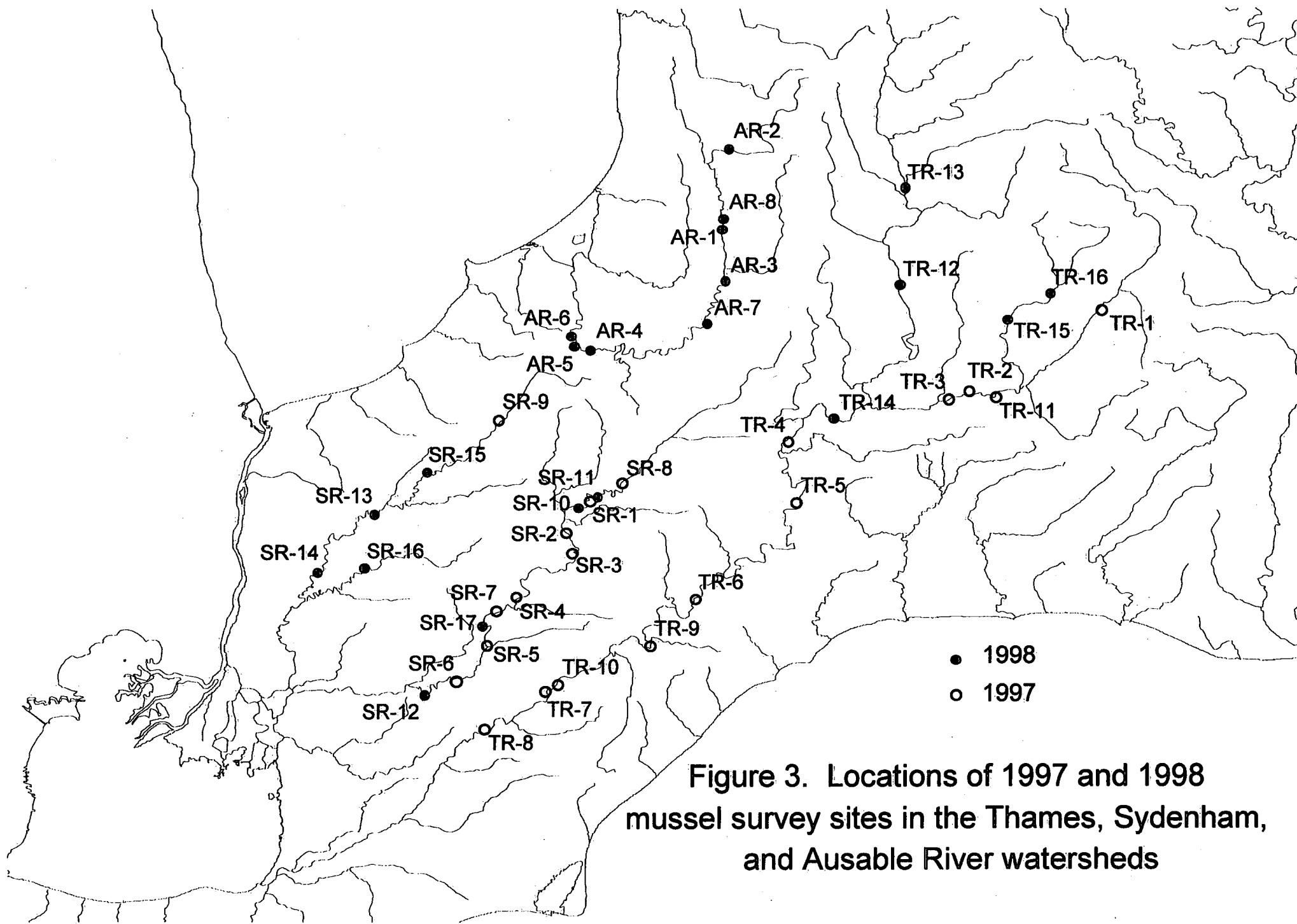
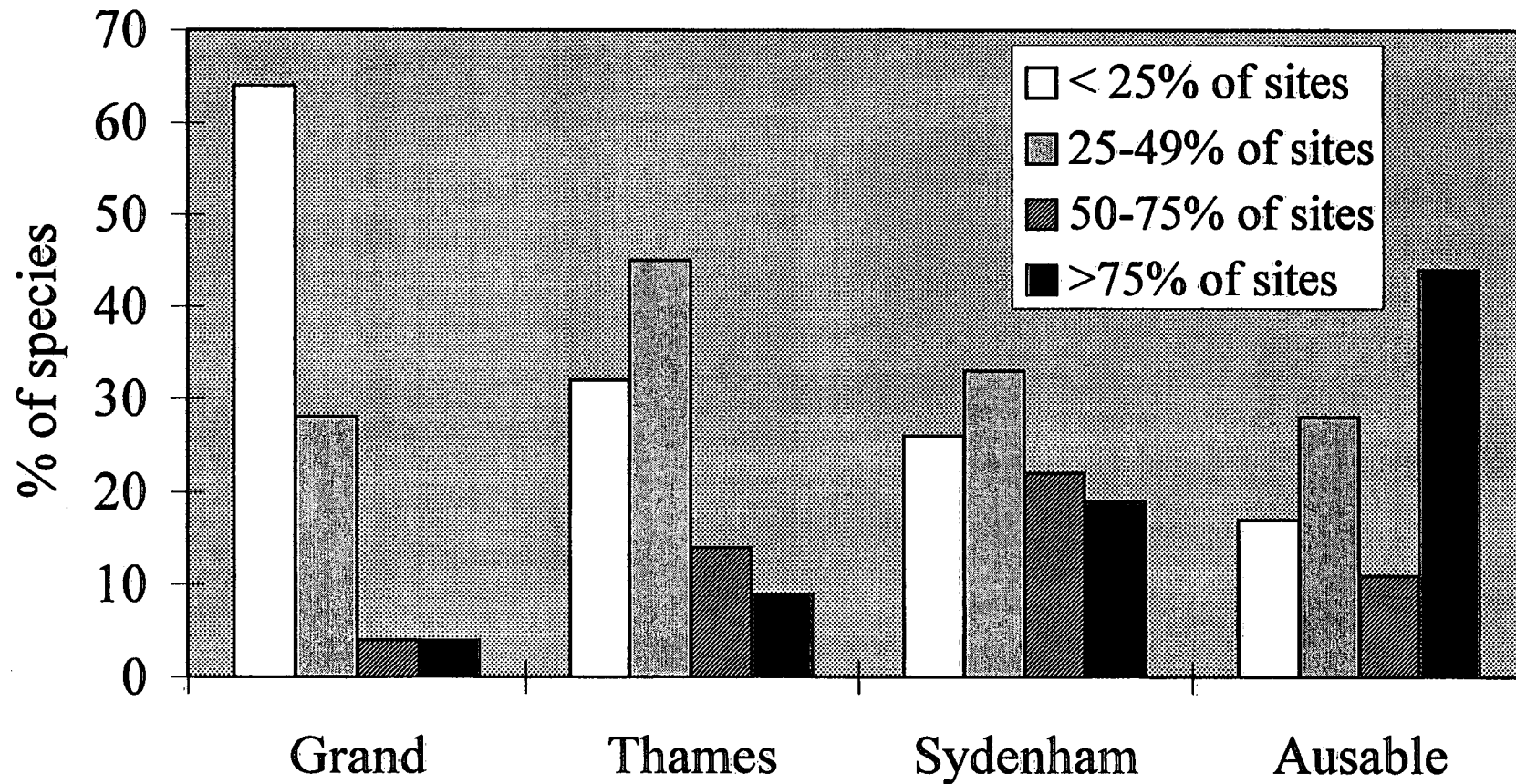


Figure 3. Locations of 1997 and 1998 mussel survey sites in the Thames, Sydenham, and Ausable River watersheds





**Fig. 4. Community similarity among sites within a river system, as determined by the frequency of occurrence of each species at all sites.**

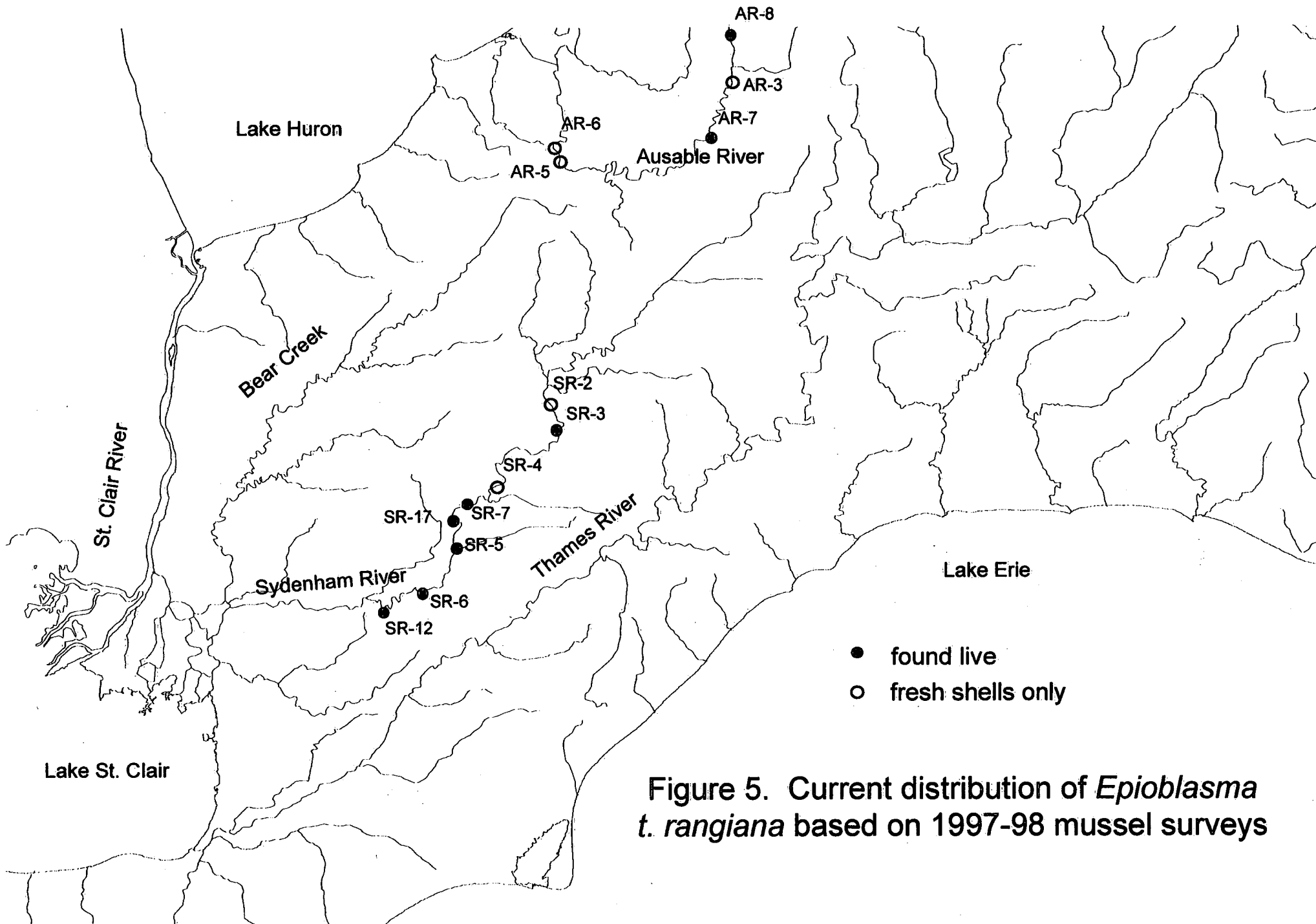
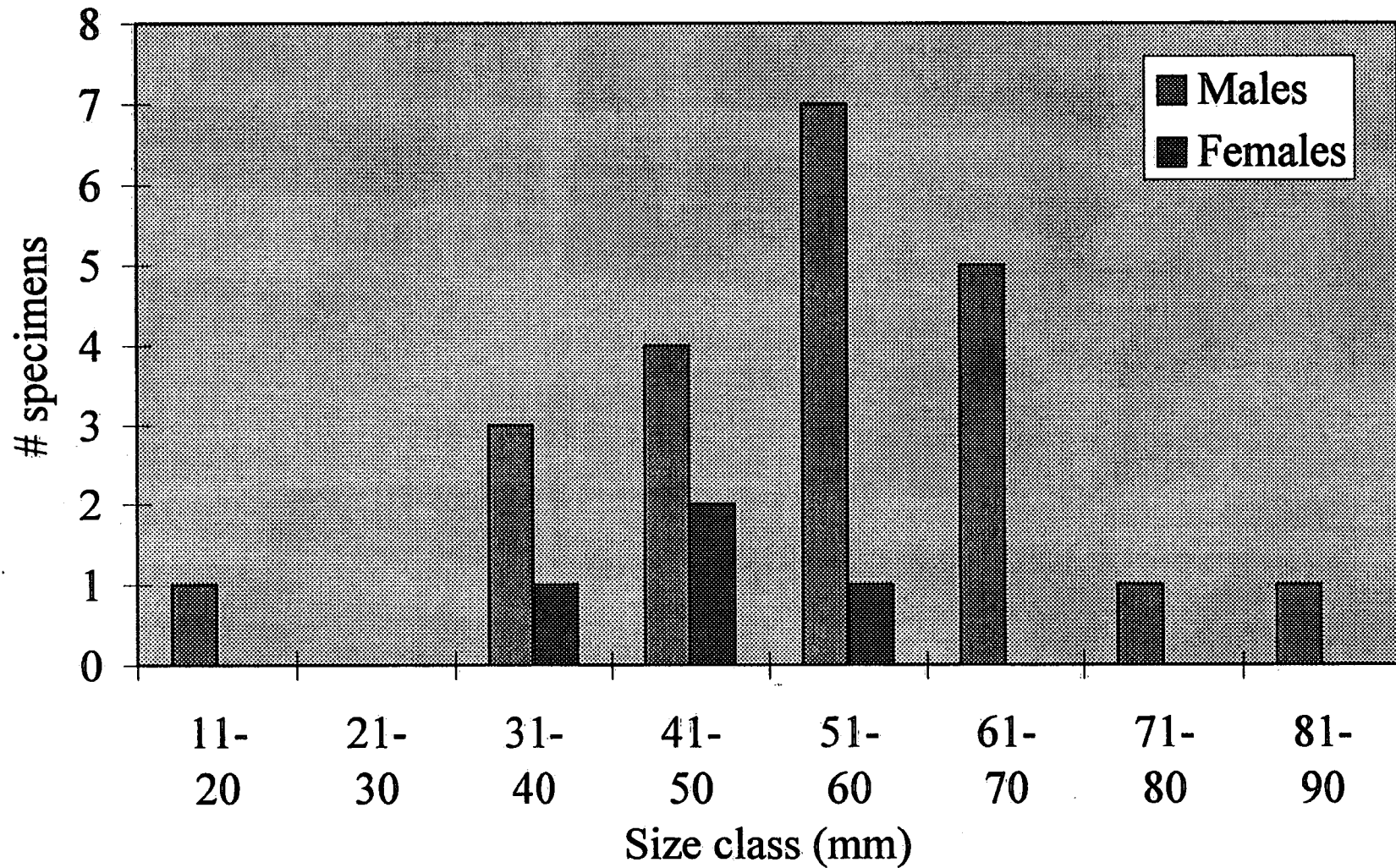
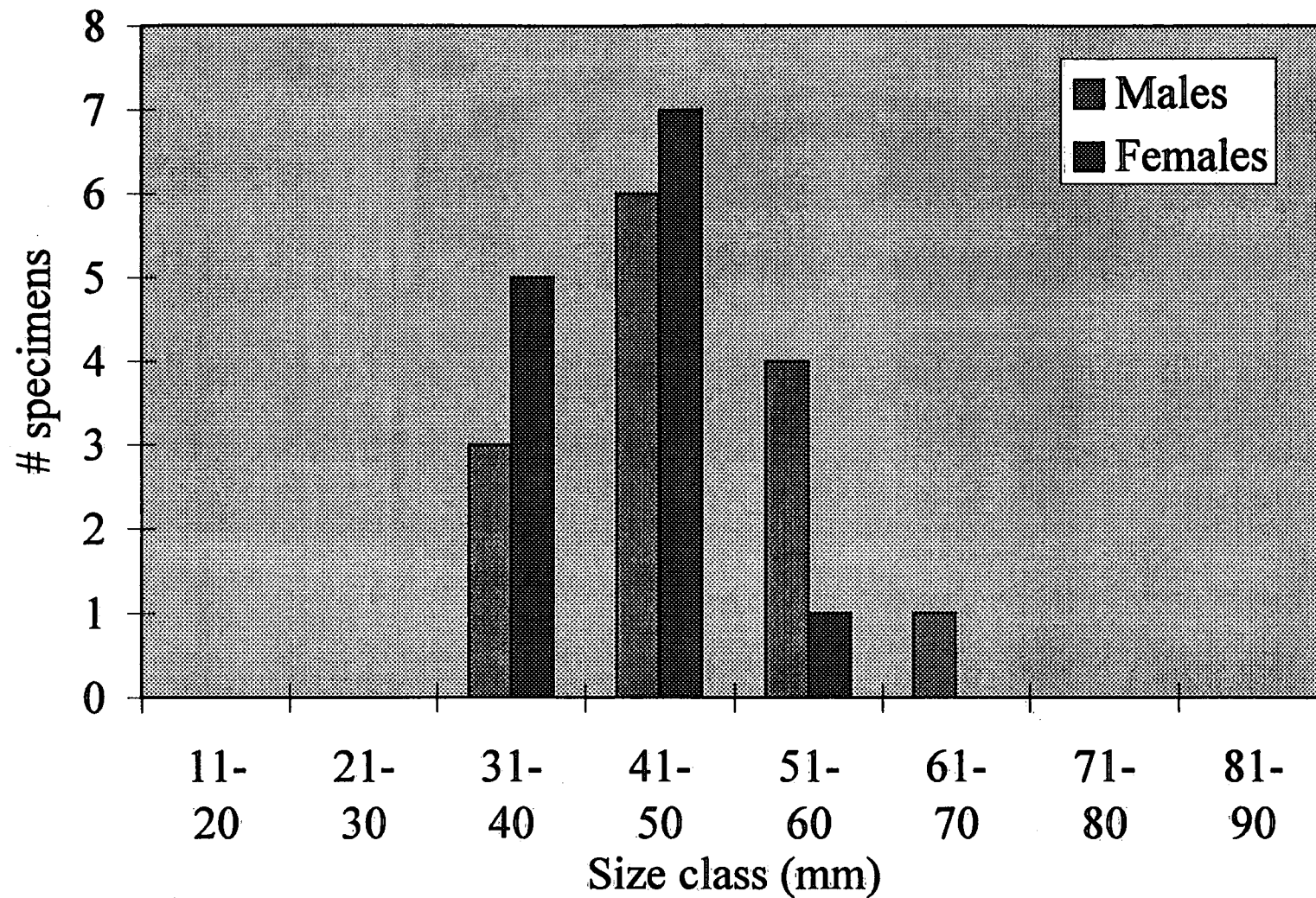


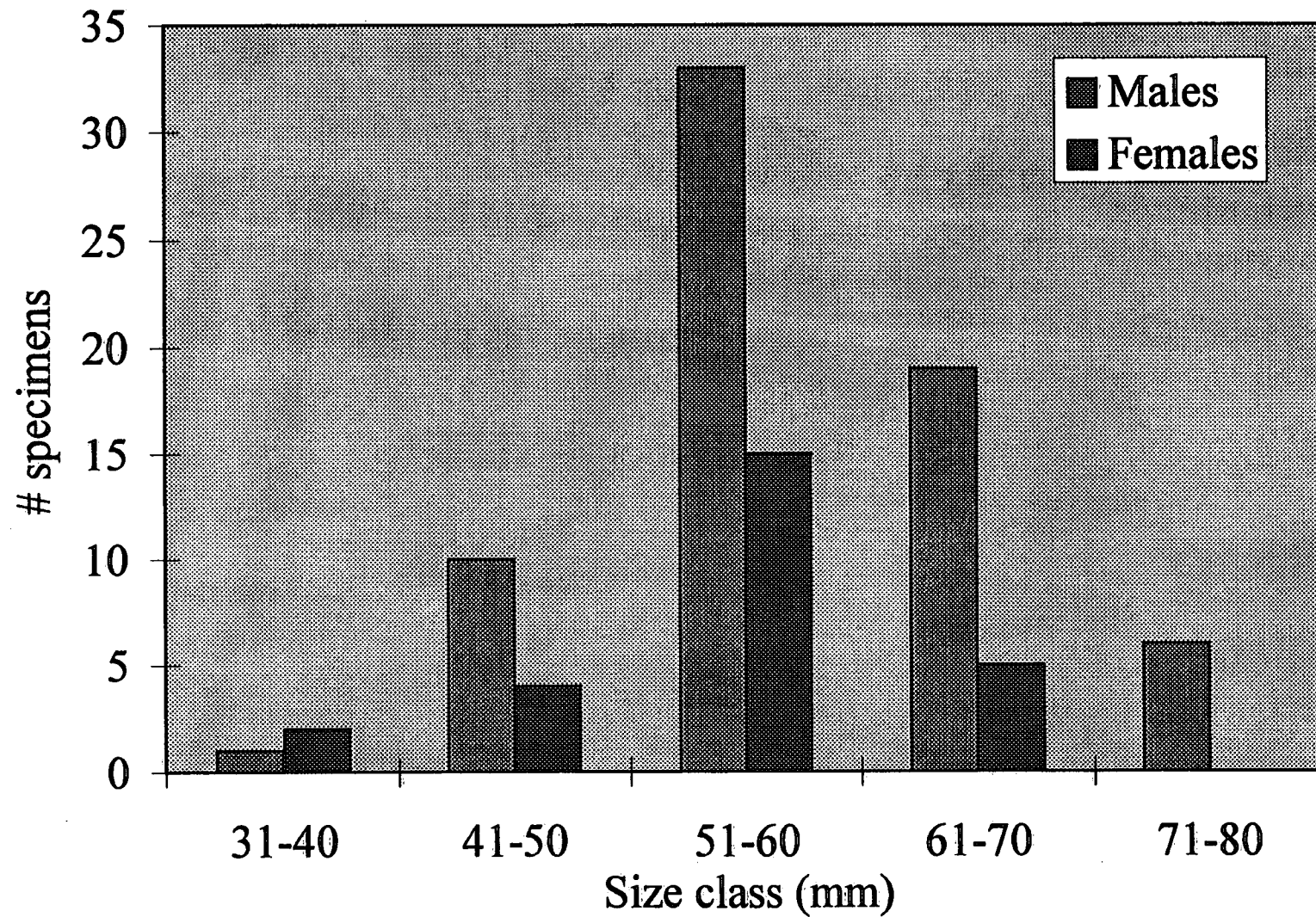
Figure 5. Current distribution of *Epioblasma t. rangiana* based on 1997-98 mussel surveys



**Fig. 6. Size frequency distributions for live *E. t. rangiana* collected from the Sydenham River in 1997-98**



**Fig. 7. Size frequency distributions for shells of *E. t. rangiana* collected from the Sydenham River in 1997-98**



**Fig. 8.** Size frequency distributions for shells of *E. t. rangiana* collected from the Ausable River in 1998

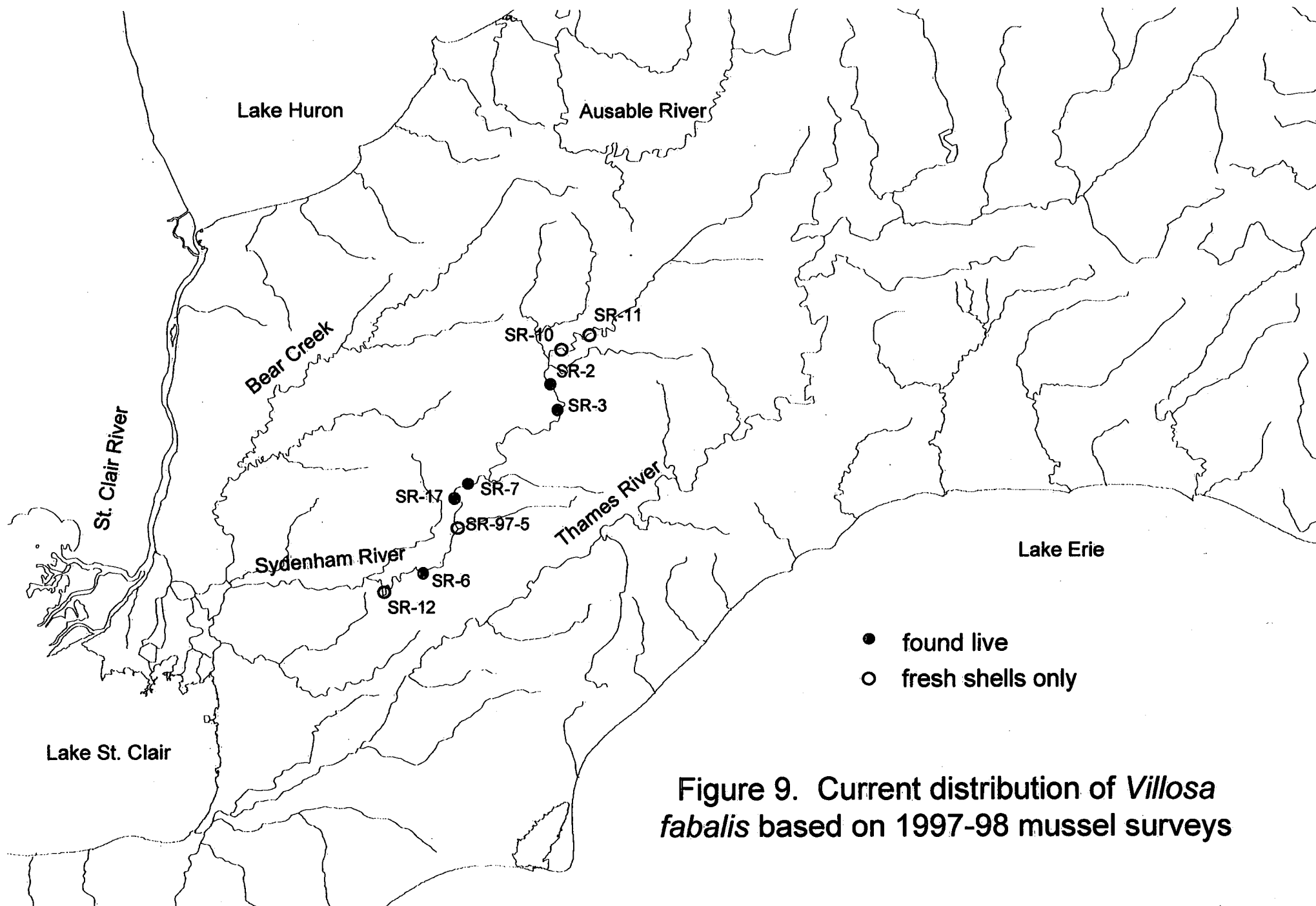
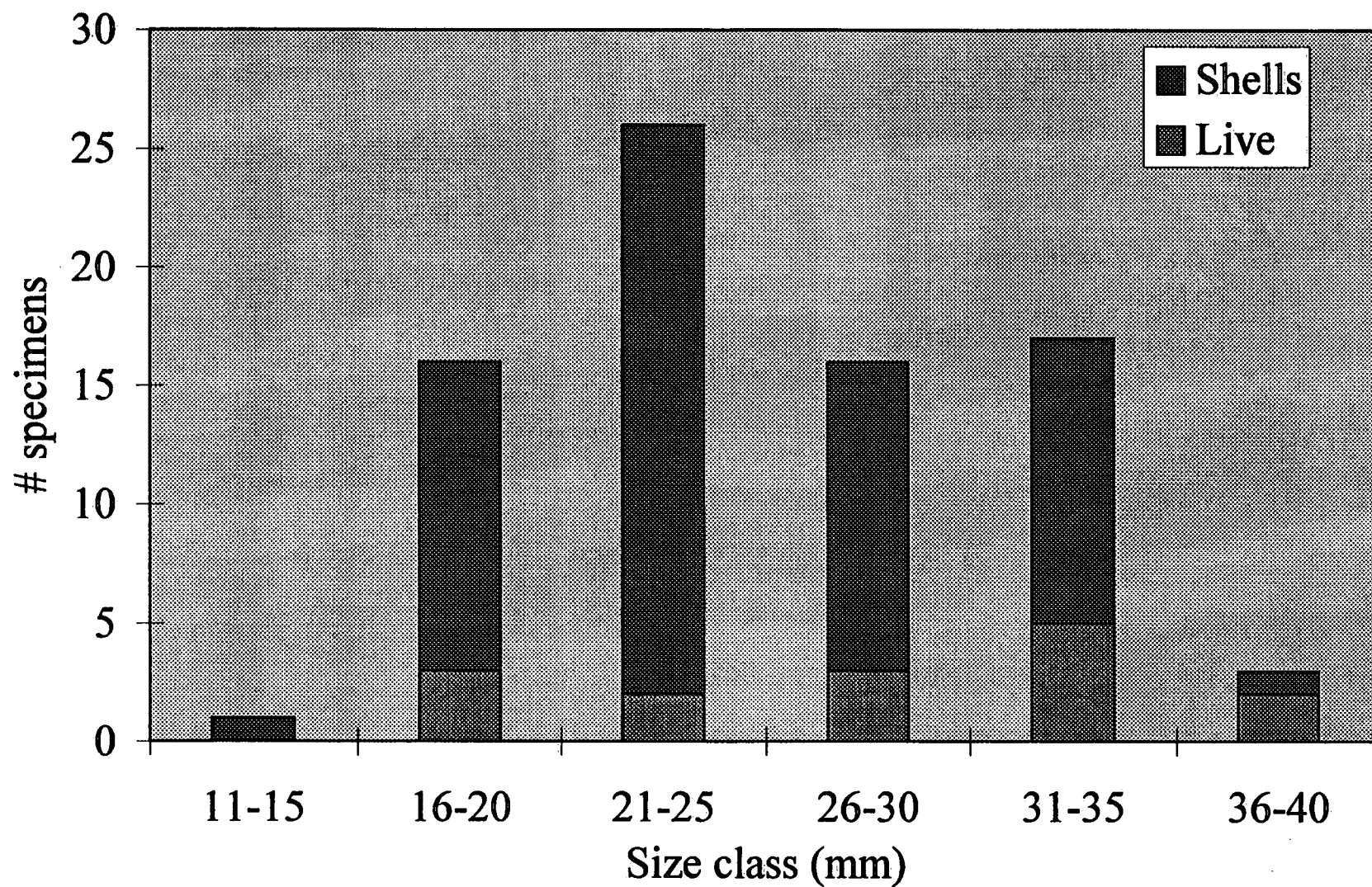


Figure 9. Current distribution of *Villosa fabalis* based on 1997-98 mussel surveys





**Fig. 10. Size frequency distributions for live specimens and shells of *V. fabalis* collected from the Sydenham River in 1997-98**

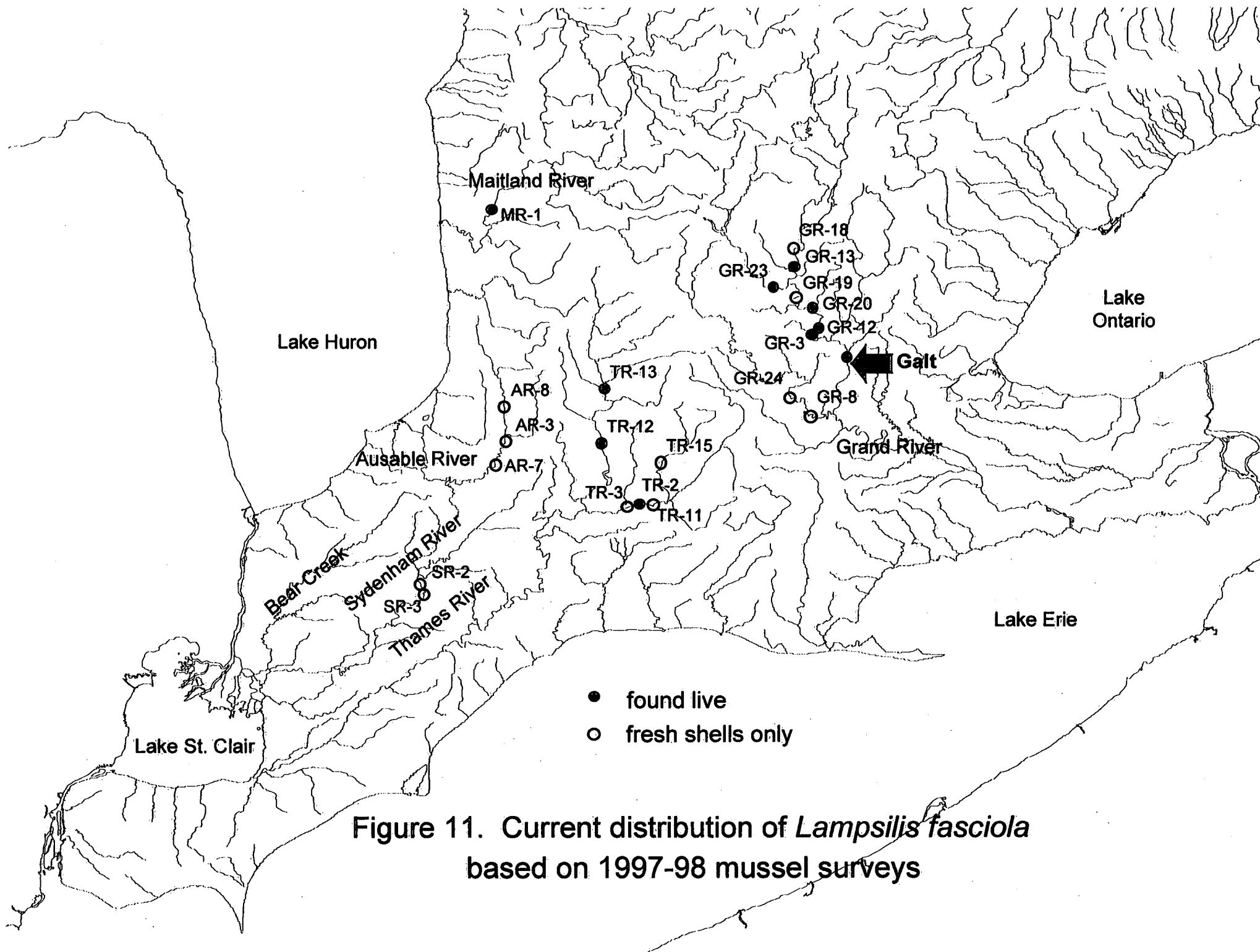
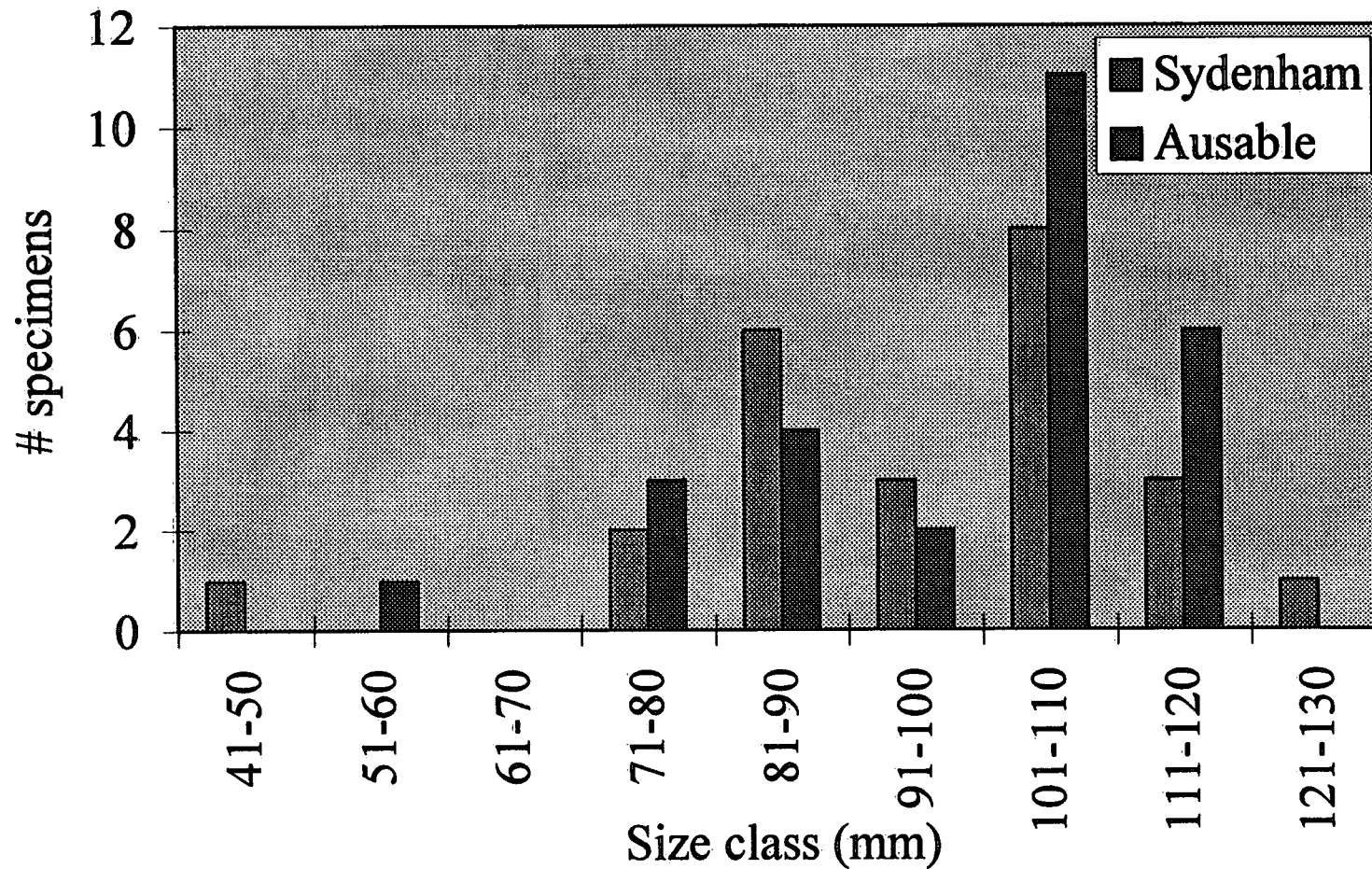
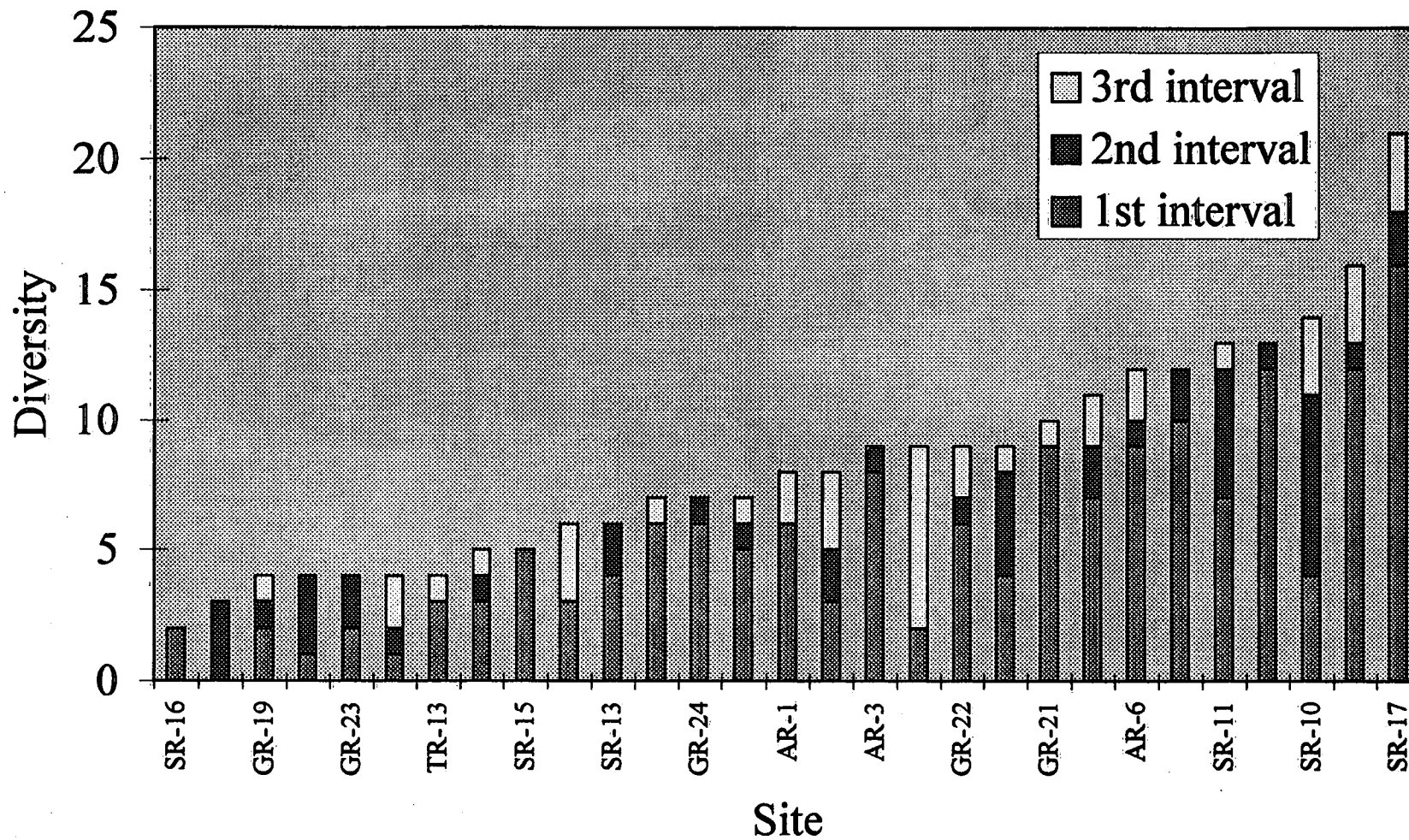


Figure 11. Current distribution of *Lampsilis fasciola* based on 1997-98 mussel surveys



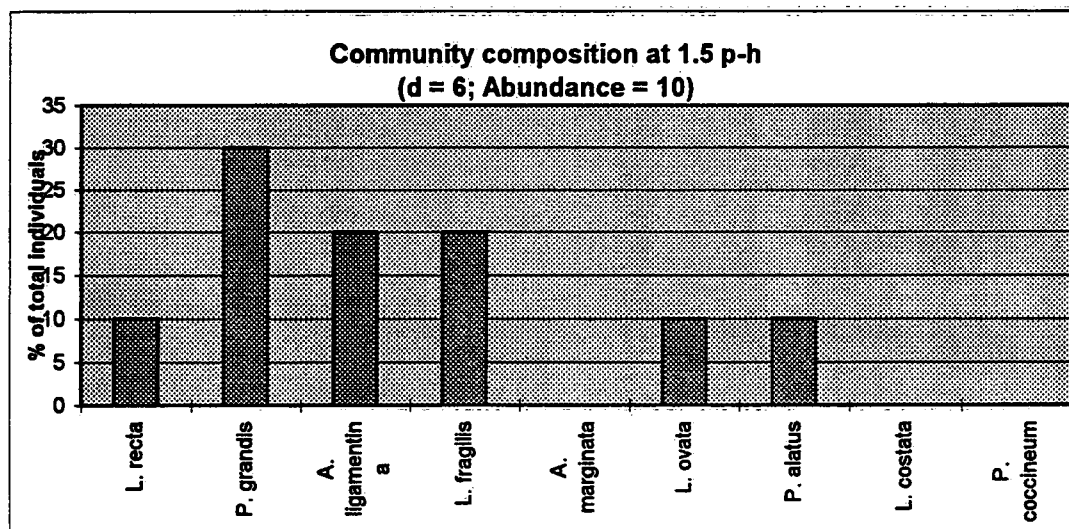
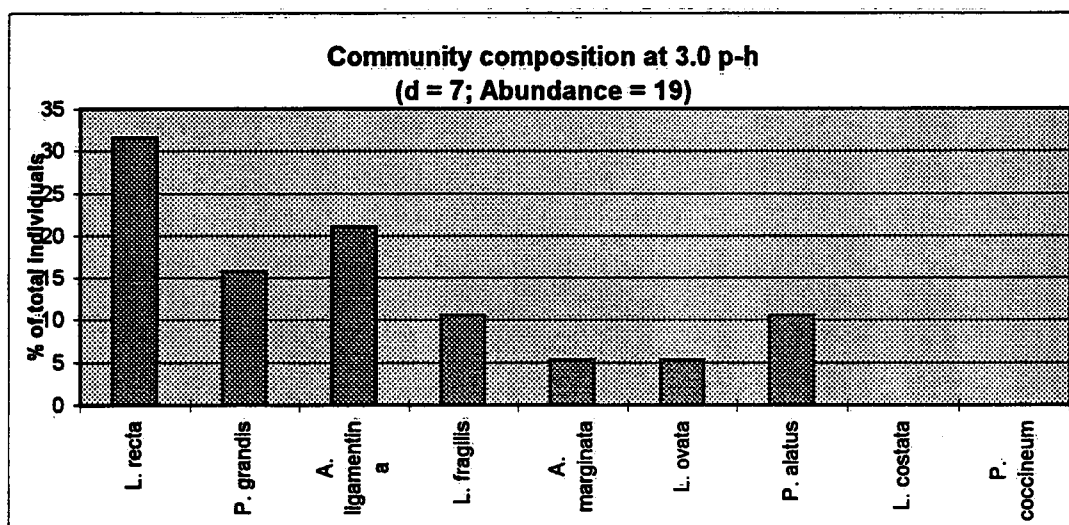
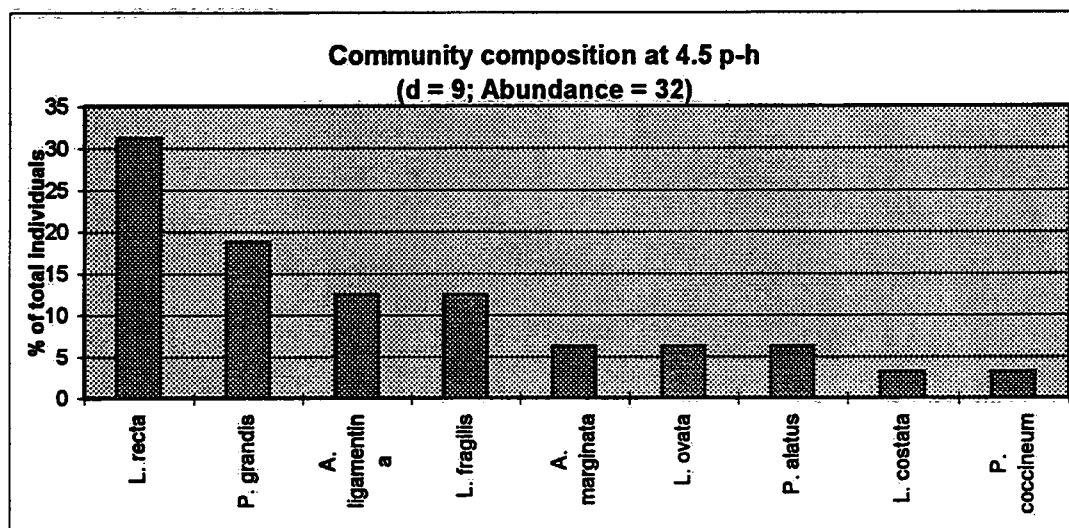


**Fig. 12. Size frequency distributions for live specimens of *P. fasciolaris* collected from the Sydenham and Ausable Rivers in 1997-98**

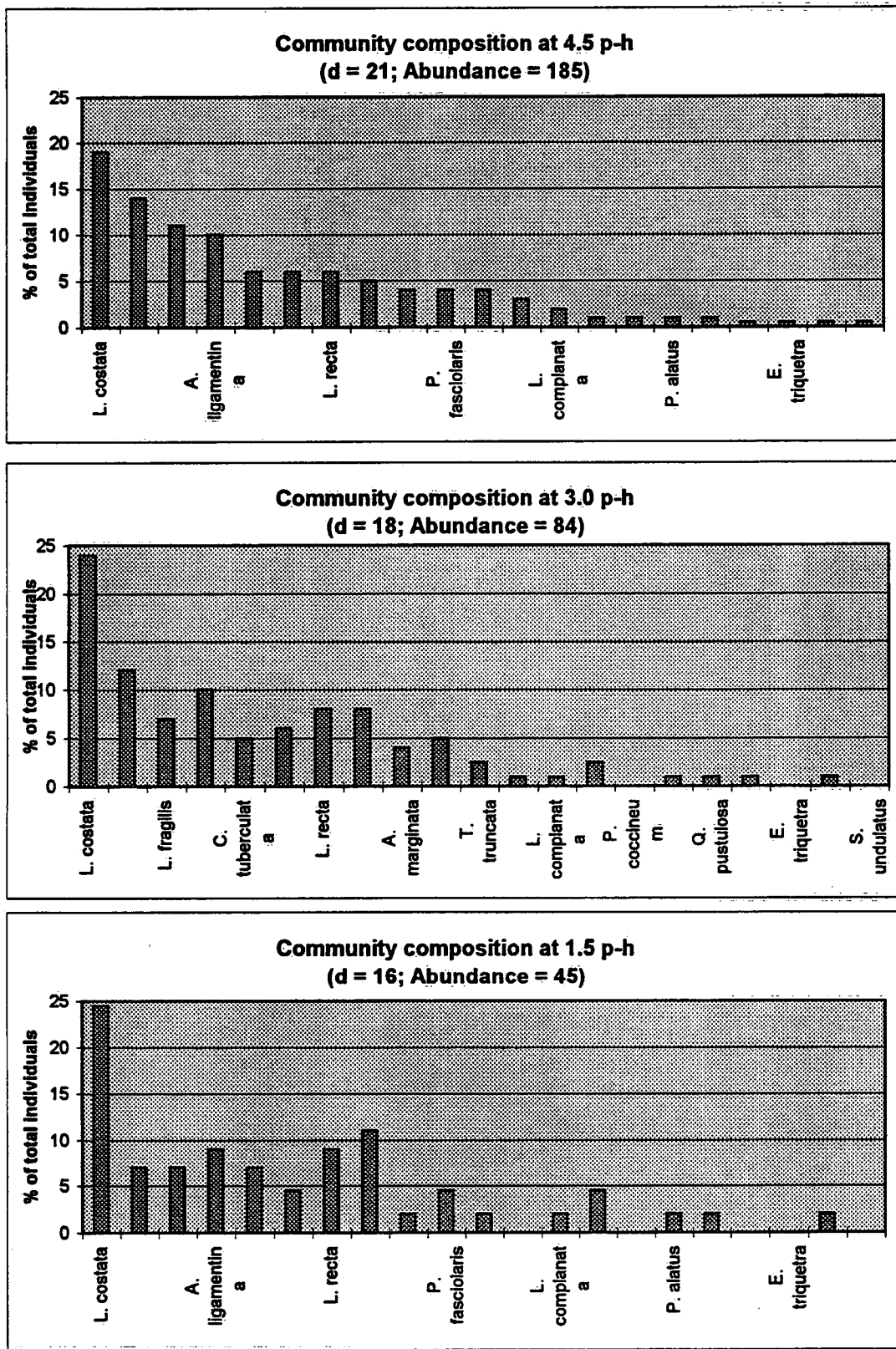


**Fig. 13. Numbers of species found in each time interval at each site.**

**Fig. 14. Changes in the composition of the mussel community with sampling effort at site GR-22 on the Grand River.**



**Fig. 15. Changes in the composition of the mussel community with sampling effort at site SR-17 on the Sydenham River.**



## **APPENDIX I**

**Executive Summary of the COSEWIC Status Report on the Northern Riffleshell,  
*Epioblasma torulosa rangiana***

### **Description**

The Northern Riffleshell, *Epioblasma torulosa rangiana* (Lea, 1837), is unmistakable among Canadian species of freshwater mussels due to its small size and extreme and unique sexual dimorphism. A concise description of the shell characteristics is given by Stansbery *et al.* (1982) as follows: "Shell small to medium size, subcompressed to subinflated, solid; male irregularly ovate, with a wide, shallow sulcus just anterior to the posterior ridge; posterior ridge curves down away from hinge line; occasionally a low ridge down the center of the disc, smooth to faintly nodulous; female obovate, greatly expanded postventrally, expansion very broadly rounded, transversely swollen, beginning about the third year of growth; umbonal sculpture finely double-looped; periostracum brownish yellow to yellowish green with diffuse, fine green rays; cardinal teeth small, lateral teeth fairly short, moderately thick; nacre white, rarely pink." Mature individuals may vary in shell length from 45 to 76 mm. *Epioblasma torulosa rangiana* was originally described by Lea in 1837. The type locality for this subspecies is the Ohio River near Cincinnati, and Yellow Creek of the Mahoning River near Poland, Ohio. Three distinct subspecies of *Epioblasma torulosa*, namely, *E. t. rangiana*, *E. t. torulosa*, and *E. t. gubernaculum* are generally recognized, although many consider *E. t. rangiana* to be the headwater form of *E. t. torulosa*. The current accepted classification of the subspecies is: Phylum Mollusca, Class Bivalvia (Pelecypoda), Subclass Palaeoheterodonta, Order Unionoida, Superfamily Unionacea, Family Unionidae, Subfamily Lampsilinae, Genus *Epioblasma*, Species *Epioblasma torulosa*, Subspecies *Epioblasma torulosa rangiana*.

### **Distribution**

Historically, *E. t. rangiana* was known from Illinois, Indiana, Kentucky, Michigan, Ohio, Pennsylvania, West Virginia and Ontario, and it may once have occurred in New York. It was found throughout the Ohio River system, and in portions of the Lake Erie and Lake St. Clair drainages. It no longer occurs in Illinois or Indiana, and its range has been drastically reduced in all other areas. Its range in Ontario once included western Lake Erie, Lake St. Clair, the Detroit River and the Sydenham River, but is now restricted to the Sydenham River. There are 20 known Canadian records for *E. t. rangiana*. The Northern Riffleshell was listed as "endangered" under the federal U.S. Endangered Species Act in 1993, and a recovery plan was prepared for it in 1994. It is globally ranked as G2T2, and has a subnational rank of S1 in Ontario. This mussel has suffered dramatic declines in North America over the past century, with the current distribution representing a range reduction of greater than 95%.

### **Population Size and Trend**

*Epioblasma torulosa rangiana* is a rare subspecies. Although occasionally abundant, it is usually a minor component of the unionid community. The Allegheny River and French Creek in Pennsylvania support the largest remaining populations in the United States. In Canada, it appears to be restricted to a 40 km reach of the Sydenham River, where it occurs at low densities (2-5 live animals captured/4.5 person-hours of search effort at four of five sites surveyed in this reach in 1997). Abundance in the Sydenham River may have declined by as much as 90% over the past 30 years. Live specimens found in 1997 ranged from 35-74 mm in shell length, suggesting recent recruitment. Twenty years ago, the Sydenham River population was described as the healthiest extant population of *E. t. rangiana* in North America.

### **Habitat**

It is widely accepted that *E. t. rangiana* lives mainly in highly oxygenated riffle areas of rivers and streams of various sizes. It also inhabited shoals in western Lake Erie and Lake St. Clair, where wave action was sufficient to produce continuously moving water. The preferred substrate ranges from rocky, sandy bottoms, to firmly packed sand and fine to coarse gravel. The extent of preferred habitat in the stretch of the Sydenham River where *E. t. rangiana* still occurs is not known. As this reach has a relatively low gradient of about 0.4 m/km, riffle habitat would be expected to constitute only a small proportion of the total habitat. High silt loads, low dissolved oxygen concentrations, runoff of pesticides and fertilizers, and loss of riparian buffer zones associated with intensive agricultural activities have contributed to the destruction of habitat for *E. t. rangiana* and other rare, riffle-dwelling species of mussels in the Sydenham River.

### **Biology**

*Epioblasma torulosa rangiana* is a small to medium-sized sexually dimorphic mussel that tends to live for 15 years or more. It is a long-term brooder (bradyctictic), with a gravid period extending from late summer to the following spring. When the larvae, or glochidia, are ready to be released, the female displays a spongy, pure white mantle lining that can be seen from

several metres away and may function to attract fish hosts. 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 *E. t. rangiana* are morphologically depressed, which indicates an adaptation to fin attachment and predisposes them to low rates of recruitment. The fish host(s) in Canada are presently unknown; however, various species of darters and sculpins have been identified as hosts in the United States. Although the exact food preferences and optimum particle sizes of the adult form of *E. t. rangiana* are unknown, they are probably similar to those of other freshwater mussels, i.e., suspended organic particles such as detritus, bacteria and algae.

### Limiting Factors

The main factor limiting the occurrence of *E. t. rangiana* throughout its range is probably the availability of silt-free, riffle habitat. Increased siltation in the Sydenham River has been correlated with the disappearance of this and other riffle species. Because of its narrow habitat requirements, *E. t. rangiana* is extremely vulnerable to impoundments, siltation and pollution. All rivers in Canada and the United States where *E. t. rangiana* is found are located in areas of intense agriculture and forestry, and are susceptible to siltation and runoff of agricultural chemicals. Access to suitable fish hosts may also be a factor limiting the distribution of this mussel, but it cannot be assessed at present because the fish host(s) for *E. t. rangiana* in Canada are unknown. Predation by muskrats is also a potential limiting factor. There is some evidence that muskrats prefer mid-sized species such as *E. t. rangiana*, and in fact large numbers of this subspecies have been found in muskrat middens, including those on the Sydenham River. The distribution of *E. t. rangiana* in Canada is severely limited by the zebra mussel, *Dreissena polymorpha*, as Lake St. Clair, the Detroit River, and the shoals of western Lake Erie are now heavily infested with these exotic bivalves and, consequently, uninhabitable to native mussels. Populations of *E. t. rangiana* in the Sydenham River are not significantly at risk of exposure to zebra mussels, because the river has no major reservoirs that could support a permanent colony of these organisms should they ever be introduced to the system.

### Protection

Canada does not have federal endangered species legislation at this time. However, Ontario is one of four provinces that have stand-alone Endangered Species Acts. Species classified as Endangered by the provinces are protected from willful destruction under these Acts. The Fisheries Act may represent the most important legislation protecting the habitat of this species. Collection of live mussels is considered "fishing" and therefore falls under the Ontario Fishery Regulations made under the federal Fisheries Act. Laws that protect mussel habitat in Ontario include: the Provincial Policy Statement under Section 3 of The Planning Act, the Ontario Lakes and Rivers Improvement Act, and the voluntary Land Stewardship II program of the Ontario Ministry of Agriculture, Food, and Rural Affairs. Stream-side development in Ontario is managed through flood plain regulations enforced by local Conservation Authorities. Land ownership along the reach of the Sydenham River where *E. t. rangiana* was found alive in 1997 is mainly private, and the lands are in agricultural use. The Nature Conservancy Canada does not own any property on the Sydenham River. In the United States, *E. t. rangiana* is listed as Endangered and is protected under the Endangered Species Act. This Act provides for possible land acquisition, and requires that recovery actions be carried out for all listed species.

### Evaluation and Status Recommendation

*Epioblasma torulosa rangiana* has suffered dramatic declines in North America over the past century, with the current distribution representing a range reduction of greater than 95%. In Canada, the subspecies now occurs only in the Sydenham River, whereas its historical range once included western Lake Erie, Lake St. Clair and the Detroit River. The presence of zebra mussels throughout the Great Lakes precludes the recovery of *E. t. rangiana* throughout much of its original range. The Sydenham River population appears to be of low density and confined to a 40 km stretch of the river, although there is evidence that recruitment is still occurring. This subspecies was listed as "endangered" under the federal Endangered Species Act in the United States in 1993, and is globally ranked as G2T2. Its current sub-national ranks in the United States are SX or S1 in all jurisdictions. As *E. t. rangiana* is expected to face global extinction within the next decade unless measures are taken soon to protect it, the status of "ENDANGERED" is recommended for the Northern Riffleshell, *Epioblasma torulosa rangiana*, in Canada.

### Status assigned by COSEWIC



## Executive Summary of the COSEWIC Status Report on the Rayed Bean, *Villosa fabalis*

### Description

The Rayed Bean, *Villosa fabalis* (Lea, 1831), can be distinguished from other Canadian species of freshwater mussels by its very small size, elliptical shape, crowded wavy green rays, and unusually heavy hinge teeth for the size of the animal. Clarke (1981) describes the shell of *V. fabalis* as follows: "Shell up to 38 mm long, 19 mm high, 13 mm wide, and with mid-anterior shell wall 2.5 mm thick; sub-elliptical, very small, and solid. Females are generally more inflated and more broadly rounded posteriorly than males. Surface with low concentric lines and wrinkles and dark growth rests. Periostracum normally light or dark green and covered with darker green rays. Rays wide or narrow, wavy, and clearly apparent except on old, blackened specimens. Nacre silvery white and iridescent. Beaks narrow, slightly elevated above hinge line, and not excavated. Beak sculpture fine and composed of about 5 crowded double-looped ridges. Hinge teeth relatively heavy; pseudocardinals erect, pyramidal, serrated or ragged, 1 in the right valve and 2 in the left; interdentum thick; laterals short, elevated, straight or a little curved, with diagonal serrations, 1 in the right valve and 2 in the left." Mature individuals may vary in shell length from 25 to 38 mm. *Villosa fabalis* was originally described by Lea in 1831 as *Unio fabalis*. The type locality is the Ohio River. The current accepted classification of *Villosa fabalis* is: Phylum Mollusca, Class Bivalvia (Pelecypoda), Subclass Palaeoheterodonta, Order Unionoida, Superfamily Unionacea, Family Unionidae, Subfamily Lampsilinae, Genus *Villosa*, Species *fabalis*.

### Distribution

In the United States, *V. fabalis* was historically known from Alabama, Illinois, Indiana, Kentucky, Michigan, New York, Ohio, Pennsylvania, Tennessee, Virginia and West Virginia. It was once widely but discontinuously distributed throughout the Ohio and Tennessee River systems, in western Lake Erie and its tributaries, and in tributaries to Lake St. Clair and the St. Clair River. It no longer occurs in Illinois or Virginia, and its range has been significantly reduced in all other areas. Its range in Ontario once included the Detroit River, the Sydenham and Thames Rivers in the Lake St. Clair drainage, and western Lake Erie, but is now restricted to the Sydenham River. There are 30 known Canadian records for *V. fabalis*. It is currently listed as endangered in Kentucky, Michigan and Ohio, as a species of special concern in Indiana, and is proposed as endangered in New York. Its global rank was uplisted from G2 to G1G2 in 1997, and it is currently ranked SX, S1 or S2 in all jurisdictions, including Ontario (S1).

### Population Size and Trend

*V. fabalis* is typically a rare species, although it can sometimes be abundant. Comparisons of historical and recent records indicate that *V. fabalis* is becoming more rare, although its rarity may be more apparent than real because it is a small species that burrows deeply into the substrate and can be easily overlooked. It is difficult to quantify population trends for *V. fabalis*, as many studies note only its presence or absence. However, studies in Michigan and New York indicate that the species is now very rare and/or its population size is declining. The majority of previously known populations in the state of Tennessee are now inundated by reservoirs. In the United States, *V. fabalis* is now found most frequently in the Ohio River drainage. In Canada, it appears to be restricted to a 45 km reach of the Sydenham River, where it occurs at low densities and is probably declining. Live specimens found in 1997 ranged from 20-37 mm in shell length, suggesting that recruitment may still be occurring.

### Habitat

*Villosa fabalis* tends to inhabit the headwaters and smaller tributaries of river systems, where it is found in sand and gravel in or near riffle areas. It is occasionally reported from shallow water areas of lakes and large rivers. It is usually found deeply buried in the substrate, among the roots of aquatic vegetation. Live specimens encountered in the Sydenham River in 1997 were found buried in stable substrates of sand or fine gravel, generally in low flow areas along the margins of the river or the edges of small islands. The historical distribution of *V. fabalis* in Canada falls within a region that is heavily impacted by human activities. Agriculture accounts for 80-85% of the land use in the Thames and Sydenham River watersheds, and the upper Thames River also supports a large urban population. High silt loads; low dissolved oxygen concentrations; runoff of pesticides, fertilizers and manure; loss of riparian buffer zones; and inputs of toxic chemicals have likely contributed to the loss of 25% and 50% of the native mussel fauna of the Sydenham and Thames Rivers, respectively.



## Biology

*Villosa fabalis* is a small, sexually dimorphic unionid. It is a long term brooder (bradyctictic) that holds its larvae, or glochidia, over winter for spring release. Female mussels brood their young from the egg to the larval stage in their gills, using the posterior portions of their outer gills as marsupia. 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 *V. fabalis* are rounded, but with a straight hinge line; they are higher than long, which indicates an adaptation to gill attachment. Only one fish host, the Tippecanoe darter (*Etheostoma tippecanoe*), is known for *Villosa fabalis*. As this species of fish is not found in Canada, the host fish for *V. fabalis* in Canada is not known. Although *V. fabalis*'s exact food preferences and optimum particle sizes are unknown, they are probably similar to those of other freshwater mussels, i.e., suspended organic particles such as detritus, bacteria and algae.

## Limiting Factors

The main factor limiting the occurrence of *V. fabalis* throughout its range is probably the availability of shallow, silt-free, riffle habitat. Access to suitable fish hosts may also be a factor, but it cannot be assessed for Canadian populations until the host species have been identified. Poor agricultural and forestry practices cause siltation, which can bury mussels, interfere with their feeding, and expose them to pollutants. Due to its burrowing habits, *V. fabalis* may be more directly exposed to sediment-associated contaminants than most other mussel species. There is some evidence that species of the genus *Villosa* may be very sensitive to environmental contaminants. The remaining populations of *V. fabalis* in Canada are found in the Sydenham River, which is located in an area of intensive agricultural activity. Thus, the distribution and abundance of this mussel may be limited by agricultural chemicals, including fertilizers and pesticides, in addition to siltation. The added stress of point source pollution from urban centres, and manure and physical destruction due to livestock farming, may have extirpated the species from the Thames River. Although zebra mussels now infest a large portion of the former range of *V. fabalis* in Ontario (the Detroit River and western Lake Erie) they are unlikely to be a threat to this mussel due to its burrowing habits.

## Protection

*Villosa fabalis* is currently listed as endangered in Kentucky, Michigan and Ohio, and is therefore afforded protection in these states. Canada does not have federal endangered species legislation at this time. However, Ontario is one of four provinces that have stand-alone Endangered Species Acts. Species classified as Endangered by the provinces are protected from willful destruction under these Acts. The federal Fisheries Act may represent the most important legislation protecting the habitat of this species. Collection of live mussels is considered "fishing" and therefore falls under the Ontario Fishery Regulations made under the federal Fisheries Act. Laws that protect mussel habitat in Ontario include: the Provincial Policy Statement under Section 3 of The Planning Act, the Ontario Lakes and Rivers Improvement Act, and the voluntary Land Stewardship II program of the Ontario Ministry of Agriculture, Food and Rural Affairs. Stream-side development in Ontario is managed through flood plain regulations enforced by local Conservation Authorities. Land ownership along the reach of the Sydenham River where *V. fabalis* was found alive in 1997 is mainly private, and the lands are in agricultural use. The Nature Conservancy Canada does not own any property on the Sydenham River.

## Evaluation and Status Recommendation

*Villosa fabalis* was once widely, but discontinuously distributed throughout its original range in North America. There is a general consensus that the species has significantly declined in distribution and abundance in recent years, although population trends are difficult to quantify due to the paucity of numerical data. As *V. fabalis* is more difficult to find than most other species of unionids due to its very small size and burrowing habits, it is possible that its distribution and abundance have been somewhat underestimated. Its global rank was recently uplisted from G2 to G1G2, and its current sub-national ranks are SX, S1 or S2 in all jurisdictions. There are only a few recent references to the continued existence of "reasonably healthy" populations of *V. fabalis*, and these are for several sites in western New York and northwestern Ohio. In Canada, *V. fabalis* now occurs only in the Sydenham River, whereas its historical range once included the Detroit River, the Thames River, and western Lake Erie. The Sydenham River population appears to be of low density and confined to a 45 km stretch of the river, although there is evidence that recruitment is still occurring. As the species is at continued risk of extirpation due to siltation and pollution associated with intensifying agricultural activities in the Sydenham River watershed, the status of "ENDANGERED" is recommended for the Rayed Bean, *Villosa fabalis*, in Canada.

## Status assigned by COSEWIC

## Executive Summary of the COSEWIC Status Report on the Wavy-rayed Lampmussel, *Lampsilis fasciola*

### Description

The Wavy-rayed Lampmussel, *Lampsilis fasciola* (Rafinesque, 1820), is readily distinguished 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) describes the shell morphology of this species as follows: "Shell...with mid-anterior shell wall about 7.5mm 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. Periostracum yellowish, greenish yellow or yellowish brown, and covered with crowded, narrow and wide, interrupted, wavy rays. Many of the wide rays are composed of closely aligned, very narrow rays. 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." The maximum shell length is 75-100 mm. Sexual dimorphism is pronounced, with the female having a distended shell shape.

### 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, the upper Allegheny River drainage in New York, 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. It has declined substantially in the northeastern United States, and is uncommon in Canada. Canadian populations are limited to Ontario, and once included Lake Erie, Lake St. Clair, and the Ausable, Maitland, Detroit, Grand, Nith, Sydenham and Thames Rivers. It is now restricted to the upper Grand River, and limited sections of the Ausable, Thames, and possibly the Sydenham Rivers. There are 35 known Canadian records for *L. fasciola*. *Lampsilis fasciola* is globally ranked as G4. It currently ranks S1 in North Carolina, New York and Ontario; S2 in Illinois, Indiana and Michigan; S4 in Pennsylvania and Virginia; and S4S5 in Kentucky. No ranks are available for the remaining jurisdictions.

### Population Size and Trend

*Lampsilis fasciola* is an uncommon species throughout its range, with seldom more than 1 to 5 specimens found in a day's search at any location. Even in optimal habitats, it accounts for only 2-4% of the mussel community in terms of abundance. Comparisons of historical and recent data show that the species has declined in numbers and/or range in Illinois, Michigan, New York, Ohio, Tennessee, Virginia and Ontario. *Lampsilis fasciola* has presumably been lost from western Lake Erie, Lake St. Clair and the Detroit River due to zebra mussels. Its distribution in the Grand River has contracted; whereas it once occurred in the upper and middle reaches of the river, it is now restricted to a 40+ km reach of the upper river above Kitchener, ON. It appears that *L. fasciola* has always been rare in the Thames and Sydenham Rivers. Based on live animals or fresh shells found during surveys in 1997, populations of *L. fasciola* may still survive in an 8 km reach of the upper Thames River near Dorchester, ON and a 5 km reach of the upper Sydenham River near Alvinston, ON. It may also exist in the Ausable River.

### Habitat

*Lampsilis fasciola* inhabits clear, hydrologically stable (i.e., having steady flows and stable substrates) rivers and streams of a variety of sizes, where it is typically found in gravel or sand substrates in and around riffle areas. It is most abundant in small (2<sup>nd</sup> to 4<sup>th</sup> order) to medium-sized (5<sup>th</sup> to 7<sup>th</sup> order) streams. It is invariably found at sites that support a great diversity of other mussel species, suggesting that it cannot tolerate sub-optimal conditions. Habitats in Ontario where live *L. fasciola* were observed in 1997 were generally characterized as clean sand/gravel substrates, often stabilized with cobble or boulders, in steady currents at depths of up to 1 metre. Water and habitat quality have declined throughout a significant portion of the species' former range in Canada, namely, the Grand, Thames and Sydenham Rivers in southwestern Ontario. Habitats in Great Lakes waters are now heavily infested with zebra mussels and can no longer be utilized.

### 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 (bradytic); spawning occurs in August, and glochidia (larvae) are released the following July to 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, were both observed in the Grand River in 1997. 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, then the conservation status of this/these species would 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, 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; however, there may be other hosts and the specific host(s) in Canada are not presently known. Although *L. fasciola*'s exact food preferences and optimum particle sizes are unknown, they are probably similar to those of other freshwater mussels, i.e., suspended organic particles such as detritus, bacteria and algae.

### Limiting Factors

The main factor limiting the occurrence of *L. fasciola* throughout its range is probably the availability of clean, silt-free, riffle/run habitat. Increased siltation in the Sydenham River has been correlated with the disappearance of this and other riffle-dwelling species. Siltation could also limit *L. fasciola* in the Grand and Thames Rivers, because agriculture accounts for 80-85% of the land use in all three basins. Agricultural activities are intensifying, and urban expansion is continuing at a rapid rate, especially in the Grand River basin. Thus, runoff of sediment, pesticides, fertilizers and livestock manures from surface and tile drainage, the continued loss of riparian vegetation, the physical destruction of streambeds by livestock, and the input of pollutants and pathogens from sewage treatment plants and stormwater runoff all threaten *L. fasciola* throughout its current range in Canada. The glochidia of this species are known to be very sensitive to copper, and copper concentrations in water often exceed federal aquatic life guidelines in both the Grand and Thames Rivers. Muskrat predation could potentially be a severe threat to small populations of this species, as muskrats tend to prey on medium-sized mussels and there is evidence that they prefer *L. fasciola* over other mussel species. Although zebra mussels have displaced native mussels throughout much of the lower Great Lakes drainage, they do not presently threaten existing populations of this river-dwelling species. However, the extensive system of dams on the Grand River may increase the susceptibility of downstream populations of *L. fasciola* if zebra mussels ever become established in the reservoirs. Recreational activities such as canoeing may be destroying sensitive mussel habitat in the upper Grand River.

### Protection

In the United States, *L. fasciola* is listed as endangered in Illinois, threatened in Michigan and New York, and of special concern in Indiana, Ohio and North Carolina, and is therefore afforded legal protection in these states. Canada does not have federal endangered species legislation at this time. However, Ontario is one of four provinces that have stand-alone Endangered Species Acts. Species classified as Endangered by the provinces are protected from willful destruction under these Acts, but there is currently no protection for Threatened or Vulnerable species. The federal Fisheries Act may represent the most important legislation protecting the habitat of this species. Collection of live mussels is considered "fishing" and therefore falls under the Ontario Fishery Regulations made under the federal Fisheries Act. Laws that protect mussel habitat in Ontario include: the Provincial Policy Statement under Section 3 of the Planning Act, the Ontario Lakes and Rivers Improvement Act, and the voluntary Land Stewardship II program of the Ontario Ministry of Agriculture, Food and Rural Affairs. Stream-side development in Ontario is managed through flood plain regulations enforced by local Conservation Authorities. Land ownership along the reaches of the Grand and Thames Rivers where *L. fasciola* was found alive in 1997 is mainly private, and the areas that are protected are too small to have any significance for the protection of this species. The Nature Conservancy Canada does not own any property on the Grand or Thames Rivers.

### Evaluation and Status Recommendation

*Lampsilis fasciola*'s historical range spanned thirteen states and the Province of Ontario. Although always an uncommon species, there is convincing evidence that it has declined significantly in distribution and abundance in recent years, particularly in the upper Midwest. In Ontario, *L. fasciola* has been found alive at only six sites in the Grand, Thames and Ausable Rivers since 1990. Its global rank is G4, and it currently ranks S1 or S2 in 50% of northeastern North American jurisdictions with ranks available, including Ontario. Although healthy populations still exist in the upper Grand River, it is unlikely that populations in the Thames River are sustainable due to pollution. The status of populations in the Ausable and Sydenham River remain unclear. Zebra mussels have likely eliminated the species from the remainder of its range in Canada. *Lampsilis fasciola* is believed to be very sensitive to toxic chemicals. It is found only at sites supporting diverse mussel communities, suggesting that it cannot tolerate sub-optimal conditions. It is restricted to areas of high water clarity, perhaps to successfully attract fish hosts, and it prefers stable substrates of sand or fine gravel in or near riffle areas, which are becoming more rare. Based on these factors, the status of "THREATENED" is recommended for the Wavy-rayed Lampmussel, *Lampsilis fasciola*, in Canada.

### Status assigned by COSEWIC

**Appendix II. Occurrences of target species at historical sites selected for survey.**

Srank	Species	Historical data for sites surveyed in 1998					
		AR-4 <sup>1</sup>	AR-1,8 <sup>2</sup>	AR-7 <sup>2</sup>	MR-1 <sup>3</sup>	SR-12 <sup>4</sup>	SR-12 <sup>5</sup>
S1	<i>Epioblasma t. rangiana</i>					1	
SH	<i>Epioblasma triquetra</i>	X				1	
S1	<i>Obliquaria reflexa</i>						
SH	<i>Obovaria olivaria</i>						
S1	<i>Simpsonaias ambigua</i>						
S1	<i>Toxolasma parvus</i>						
S2	<i>Cyclonaias tuberculata</i>					14	2
S1	<i>Lampsilis fasciola</i>		1		X		
S1	<i>Obovaria subrotunda</i>					18	2
S1	<i>Ptychobranhus fasciolaris</i>		3	3		5	
S1	<i>Utterbackia imbecillis</i>						
S1	<i>Villosa fabalis</i>					1/2d	
S1/S2	<i>Truncilla donaciformis</i>						
S2/S3	<i>Truncilla truncata</i>					19	2
S2	<i>Actinonaias ligamentina</i>					41	18
S1	<i>Pleurobema coccineum</i>					3	
S2	<i>Quadrula p. pustulosa</i>					1	1
S2	<i>Quadrula quadrula</i>					1	1
S2	<i>Ligumia nasuta</i>						
S2	<i>Villosa iris</i>	X			X	1d	

<sup>1</sup> 1950 data from I.G. Reimann (University of Michigan Museum of Zoology records)

<sup>2</sup> 1993-94 data from Morris and Di Maio (1997)

<sup>3</sup> 1935 data from J.P. Oughton (Royal Ontario Museum records)

<sup>4</sup> 1973 data from C.B. Stein (personal records)

<sup>5</sup> 1991 data from Clarke (1992)

**Appendix III. Diversity and abundance of live mussels found at all 66 survey sites in southwestern Ontario rivers in 1997 & 1998.**

Site	Grand River		Thames River		Sydenham River		Ausable River		Maitland River	
	Diversity	Abundance	Diversity	Abundance	Diversity	Abundance	Diversity	Abundance	Diversity	Abundance
1	5	16	1	7	11	56	8	37	6	31
2	0	0	10	361	11	106	3	5		
3	3	12	5	90	16	79	9	187		
4	5	16	10	138	15	126	9	17		
5	12	49	8	60	12	124	11	117		
6	12	73	11 (14)	191	18 (19)	343	12	232		
7	4	33	11	157	17	329	13	1025		
8	5 (8)	21	11	80	8	75	12	229		
9	7	39	12	166	11	237				
10	4	12	12	255	14	119				
11	3	61	3	42	13	89				
12	4 (5)	44	4	5	16 (20)	81				
13	8	288	4	11	6	85				
14	4 (5)	9	9	98	5	23				
15	5	70	7	110	5	108				
16	5	60	8	119	2	32				
17	8	52			21	185				
18	7	354								
19	4	51								
20	4	128								
21	10	133								
22	9	32								
23	4	14								
24	7	121								
Mean	5.79	70.33	7.88	118.13	11.82	129.24	9.63	231.13	-	-
Standard Deviation	2.9	86.12	3.5	95.13	5.25	93.18	3.2	333.78	-	-
Total species	25		23		29		18		-	-
Total abundance	1688		1890		2197		1849		-	-

**Note:** Diversity values in brackets include data for new species found alive at 1997 sites revisited in 1998, and for species found during additional sampling effort at 1998 sites. These values will be used in Table 6, but will not be used to statistically compare mean diversity and abundance among rivers.



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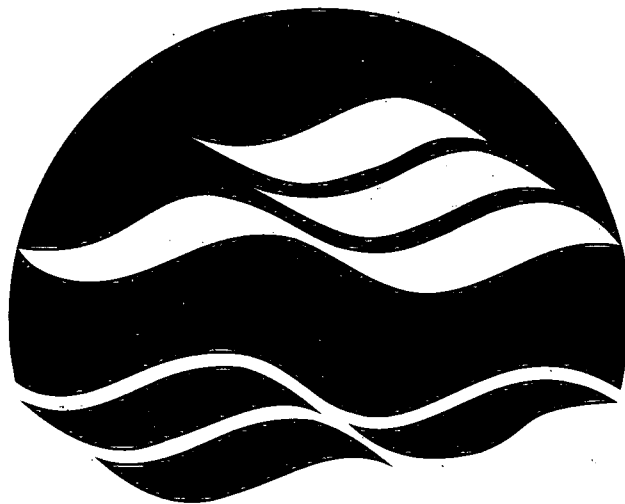
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