NATIONAL WATER RESEARCH INSTITUTE

INSTITUT NATIONAL de RECHERCHE sur les EAUX

ASSESSMENT OF THE CURRENT CONSERVATION STATUS OF RARE SPECIES OF FRESHWATER MUSSELS IN SOUTHERN ONTARIO

J.L. Metcalfe-Smith, S.K. Staton, G.L. Mackie and E.L. West

NWRI Contribution No. 98-019

ASSESSMENT OF THE CURRENT CONSERVATION STATUS OF RARE SPECIES OF FRESHWATER MUSSELS IN SOUTHERN ONTARIO

Janice L. Metcalfe-Smith[1], Shawn K. Staton[1], Gerald L. Mackie[2] and Emma L. West[1]

[1]Aquatic Ecosystem Protection Branch
National Water Research Institute
P.O. Box 5050, 867 Lakeshore Road
Burlington, Ontario, Canada, L7R 4A6

[2]Department of Zoology
University of Guelph
Guelph, Ontario, Canada, N1G 2W1

NWRI Contribution No. 98-019

MANAGEMENT PERSPECTIVE

Freshwater mussels are among the most endangered groups of animals in North America. In the United States, mussels have been protected under endangered species legislation since 1973. In 1994, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) expanded its mandate to include invertebrates. The Mollusc Working Group of the Lepidoptera and Mollusca Subcommittee of COSEWIC was formed in 1995 to develop a list of Canadian mollusc species at risk and prepare status reports on them, thus providing the impetus for assessing the health of Canada's freshwater mussel fauna. Two of the authors of this report (J.L. Metcalfe-Smith and G.L. Mackie) are members of the Mollusc Working Group. The Canadian Biodiversity Strategy requires Environment Canada to participate in and support COSEWIC activities.

In earlier work, a retrospective analysis of historical data on the distributions of mussel species in the lower Great Lakes drainage basin revealed a pattern of species losses and changing community composition throughout the basin. It appears that many unique and ecologically fragile species are being displaced by relatively few pollution-tolerant species. The purpose of the present study was to determine the current conservation status of rare species of freshwater mussels in southern Ontario. Thirty-seven sites on the Grand, Thames and Sydenham Rivers that historically supported these species were intensively surveyed in 1997. Of the 30 species historically known from the study area, 6 have been extirpated and the ranges of 13 others have been reduced. Changes to the official conservation status ranks (Ontario's SRANKS) of 11 species will be recommended to the Natural Heritage Information Centre (OMNR) in Peterborough, ON. Eleven species requiring urgent national status designation by COSEWIC were identified. Funding has been received from COSEWIC and COSSARO (Committee on the Status of Species at Risk in Ontario) for the preparation of national and provincial status reports on three of these species. A scoring system was devised to identify areas of prime mussel habitat, for use by agencies responsible for managing the water and habitat quality of Ontario's rivers. This research was partially funded by a grant from the Endangered Species Recovery Fund.

SOMMAIRE À L'INTENTION DE LA DIRECTION

Les uionidés se classent parmi les groupes d'animaux le plus gravement menacés en Amérique du Nord. Aux États-Unis, ces espèces sont protégées depuis 1973 en vertu d'une loi sur les espèces en danger de disparition. En 1994, le Comité sur le statut des espèces menacées de disparition au Canada (CSEMDC) a élargi son mandat de manière à couvrir également les invertébrés. Le Groupe de travail sur les mollusques, relevant du sous-comité des lépidoptères et mollusques, a été constitué en 1995; il a pour tâche de dresser la liste des mollusques canadiens menacés de disparition et de rédiger des rapports faisant le point sur leur situation, ce qui a pour effet de mettre en branle une évaluation de la situation des uionidés au pays. Deux des auteurs de ce rapport (J.L. Metcalfe-Smith et G.L. Mackie) font partie de ce groupe de travail. La Stratégie canadienne de la biodiversité prévoit qu'Environnement Canada prenne part aux activités du CSEMDC et qu'il les subventionne.

Dans des travaux antérieurs, une analyse rétrospective des données historiques sur les aires de répartition des uionidés dans le basin hydrographique des Grands Lacs d'aval a mis en évidence des tendances à la disparition d'espèces et à une modification de la composition spécifique à l'échelle de ce bassin. Il semble que nombre d'espèces uniques et vulnérables sur le plan écologique soient délogées par un nombre plutôt restreint d'espèces tolérantes à la pollution. La présente étude a pour but de déterminer l'état actuel, sur le plan de leur conservation, d'uionidés rares dans le sud de l'Ontario. En 1997, les auteurs ont procédé à des recensements intensifs de ces espèces à 37 stations situées sur les rivières Grand, Thames et Sydenham, qui les supportaient antérieurement. Des trente espèces dont la présence était attestée dans la région à l'étude, six sont disparues tandis que l'aire de répartition de treize autres espèces a diminué. On recommandera au Centre d'information sur le patrimoine naturel (MRNO) de Peterborough (Ont.) que le statut officiel (Ontario SRANKS) d'onze espèces soit modifié. En outre, il est urgent qu'onze espèces obtiennent un statut national du CSEMDC. Ce dernier et le COSSARO (Committee on the Status of Species at Risk in Ontario) ont versé des subventions pour la rédaction de rapports d'étape nationaux et provinciaux sur trois de ces espèces. Un système d'attribution de cotes a été créé pour le classement des secteurs constituant des habitats de grande qualité pour les uionidés que pourraient employer les agences responsables de la gestion de la qualité de l'eau et de l'habitat des rivières de l'Ontario. Cette recherche a été subventionnée en partie par le Fonds de rétablissement des espèces canadiennes en péril.

ABSTRACT

An earlier retrospective analysis of historical data on the distributions of native freshwater mussels throughout the lower Great Lakes drainage basin had indicated a trend toward species losses over time, and the displacement of many unique and ecologically fragile species by fewer pollution-tolerant species. The purpose of this study was to determine the current conservation status of 21 species that are believed to be at risk in southern Ontario. Thirty-seven sites on the Grand, Thames and Sydenham Rivers that historically supported these species were intensively surveyed in 1997 to determine their true status. Twenty-seven, 41 and 24% of the species historically known from the Grand, Thames and Sydenham Rivers, respectively, were not found alive in these systems in 1997. Six species have been extirpated from all three rivers, and the ranges of an additional 13 species have been reduced. The Sydenham River supported the richest and most productive mussel communities of the three rivers; however, each system sustained a somewhat unique assemblage of mussel species. Based on comparisons of historical and current distributions of the target species, changes to the official conservation status ranks (Ontario's SRANKS) were proposed for 11 species. Six species were recommended for downlisting (*Cyclonaias tuberculata*, *Epioblasma torulosa rangiana*, *Obliquaria reflexa*, *Simpsonaias ambigua*, *Toxolasma parvus* and *Truncilla truncata*), and five species were recommended for uplisting (*Fusconaia flava*, *Ligumia nasuta*, *Pleurobema coccineum*, *Truncilla donaciformis* and *Villosa iris*). Eleven species requiring urgent national status designation by COSEWIC were identified, and COSEWIC (Committee on the Status of Endangered Wildlife in Canada) and COSSARO (Committee on the Status of Species at Risk in Ontario) status reports are in preparation for three of these species (*E. t. 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.

RÉSUMÉ

Une analyse rétrospective antérieure des données historiques sur la répartition des uionidés indigènes dans le bassin hydrographique des Grands Lacs d'aval a mis en évidence des tendances à la disparition d'espèces et au déplacement de nombreuses autres, uniques et vulnérables sur le plan écologique, par un nombre moindre d'espèces tolérantes à la pollution. La présente étude a pour but de déterminer l'état actuel, sur le plan de leur conservation, de 21 espèces du sud de l'Ontario qu'on croit menacées. En 1997, les auteurs ont procédé à des recensements intensifs de ces espèces à 37 stations situées sur les rivières Grand, Thames et Sydenham, qui les supportaient antérieurement, pour déterminer leur statut véritable. Cette année-là, 27 %, 41 % et 24 %, respectivement, des espèces qui avaient historiquement vécu dans ces eaux ne s'y trouvaient plus. Six sont disparues des trois cours d'eau et l'aire de répartition de treize autres a diminué. La rivière Sydenham supporte les communautés les plus riches et les plus productives d'uionidés des trois cours d'eau; cependant, chaque réseau supporte un groupe assez distinct d'uionidés. Au terme de comparaisons entre les répartitions historiques et les répartitions modernes des espèces considérées, les auteurs ont proposé que le statut officiel (Ontario SRANKS), sur le plan de la conservation, d'onze espèces soit modifié. Ils ont recommandé que six espèces soient placées plus bas sur la liste (*Cyclonaias tuberculata, Epioblasma torulosa rangiana, Obliquaria reflexa, Simpsonaias ambigua, Toxolasma parvus* et *Truncilla truncata*), et que cinq autres soient placées plus haut (*Fusconaia flava, Ligumia nasuta, Pleurobema coccineum, Truncilla donaciformis* et *Villosa iris*). Ils ont identifié onze espèces qui doivent obtenir un statut national du CSEMDC. En outre, des rapports sur trois de ces espèces (*E.t. rangiana, Lampsilis fasciola* et *Villosa fabalis*), pour le compte du CSEMDC (Comité sur le statut des espèces menacées de disparition au Canada) et le COSSARO, sont en cours de rédaction. Un système d'attribution de cotes a été créé pour le classement des secteurs constituant des habitats de grande qualité pour les uionidés que pourraient employer les agences responsables de la gestion de la qualité de l'eau et de l'habitat des rivières de l'Ontario.

INTRODUCTION

The world's greatest diversity of freshwater mussels, nearly 300 species, is found in North America (Williams *et al.* 1993). Over the past century, this rich fauna has been decimated by commercial harvesting of mussels (initially for the pearl button industry, and of late for the cultured pearl industry), habitat destruction, water pollution and, most recently, the invasion of the exotic zebra mussel *Dreissena polymorpha* (Biggins *et al.* 1995). In a recent assessment by the American Fisheries Society (Williams *et al.* 1993), 72% of native freshwater mussel species were listed as extinct, endangered, threatened or of special concern and only 24% as currently stable. Similarly, The Nature Conservancy recognizes 55% of the mussel fauna as imperiled, in contrast to only 7% of birds and mammals (Master 1990). No other widespread animal group in North America approaches this level of faunal collapse.

The vulnerability of native freshwater mussels to anthropogenic impacts can be attributed in part to a unique life history trait: they have an intermediate larval stage that is an obligate ectoparasite on fish (Neves 1993). Female mussels brood their young from the egg to the larval stage in their gills, then expel the larvae, termed glochidia, into the water where they must attach to the gills or fins of an appropriate fish host in order to complete their metamorphosis. After a period of encystment ranging from 1 to 25 weeks, depending on the species (Cummings and Mayer 1992), the juvenile mussel detaches from its host and falls to the substrate to complete its development into a free-living adult. Some species may successfully use a variety of fishes, but the majority are host-specific to some degree (Neves 1993). It is largely because of this dependency that mussels are so sensitive to perturbations of the freshwater ecosystem (Bogan 1993). Not only are they threatened by disturbances that impact them directly, but also by those that affect their host fish populations. In several cases, mussel species have become functionally extinct, i.e., known only from non-reproductive populations, due to the disappearance of host fish (Bogan 1993).

In the United States, freshwater mussels have been protected under endangered species legislation since 1973 (Neves 1997). The U.S. Fish & Wildlife Service recently drafted a national strategy for the conservation of native mussels (Biggins *et al.* 1995), and recovery plans are in place for 45 of their 62 listed species (U.S. Fish & Wildlife Service 1996). However, it wasn't until 1994 that the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) expanded its mandate to include invertebrates. The Mollusc Working Group (MWG) of the Lepidoptera and Mollusca Subcommittee of COSEWIC was formed in 1995 to develop a national list of Canadian mollusc species at risk and prepare status reports on them. Two of the authors of this report (G.L. Mackie and J.L. Metcalfe-Smith) are members of the MWG. In 1997, the MWG submitted status reports on two species of gastropods; the Gatineau Tadpole Snail (*Physella parkeri latchfordi*) was designated in the indeterminate category, and the Banff Springs Snail (*Physella johnsoni*) was designated as threatened. The goal of our research is to evaluate the current status of freshwater mussel species at risk in Canada, such that priorities for COSEWIC designation and recovery efforts are based on the best available scientific information.

Our initial efforts focused on the lower Great Lakes drainage basin for two reasons. First of all, this area historically supported the most diverse and unique mussel fauna in Canada; 40 of the 53 Canadian species occur here, and 22 of these species are found nowhere else in Canada (Clarke 1981). Secondly, zebra mussels have decimated native mussel populations in Lake St. Clair (Nalepa *et al.* 1996), western Lake Erie (Schloesser and Nalepa 1994) and the upper St. Lawrence River (Ricciardi *et al.* 1996), leaving the rivers and streams of the drainage basin as the last refuge for many species. In earlier work, species occurrence records dating from 1860 to 1996 were examined to determine if there have been changes over time in the richness and/or composition of freshwater mussel communities throughout the study area. The data revealed a pattern of species losses and changing community composition throughout the basin, particularly in the formerly species-rich Lake Erie and Lake St. Clair drainages. River systems that once supported numerous species characteristic of a wide variety of habitats are now dominated by fewer siltation- and pollution-tolerant species of the Subfamily Anodontinae (Metcalfe-Smith *et al.* submitted). In a related paper, we used a risk factor analysis approach with these data to identify and prioritize a list of candidate species to be recommended for national status designation by COSEWIC (Metcalfe-Smith *et al.* in press).

Historical data such as these can be invaluable for understanding past conditions and long-term ecological processes, and for setting realistic targets for the diversity and productivity of natural systems. However, due to the many limitations of historical data (accuracy, consistency, spatial and temporal coverage, etc.), they are generally of low resolution and should only be used to specify "...qualitative generalizations about past ecosystem states and processes (Steedman *et al.* 1996). In short, the results of retrospective analyses on historical data are best used to direct new, well-focused studies that will clarify our understanding of these processes and their causes.

The objectives of this project were to: (a) determine the current distributions of freshwater mussel species in the lower Great Lakes drainage basin that are believed to be at risk; (b) identify locations where these species still occur such that the populations can be studied and protected; (c) refine the list of species most urgently requiring COSEWIC status designation and recovery efforts, and (d) assign conservation status scores based on freshwater mussel communities to various sites throughout the study area. The latter is expected to be a useful tool for agencies, such as conservation authorities, that are responsible for managing water and habitat quality in the rivers of southern Ontario.

MATERIALS AND METHODS

The Lower Great Lakes Unionid Database

In 1996, all available historical and recent data on the occurrences of freshwater mussel species throughout the lower Great Lakes drainage basin were compiled into a computerized, GIS-linked database referred to as The Lower Great Lakes Unionid Database. Data sources included the primary literature, natural history museums, federal, provincial and municipal government agencies (and some American agencies), conservation authorities, Remedial Action Plans for the Great Lakes Areas of Concern, university theses, and environmental consulting firms. Mussel collections held by six natural history museums in the Great Lakes region (Canadian Museum of Nature, Ohio State University Museum of Zoology, Royal Ontario Museum, University of Michigan Museum of Zoology, Rochester Museum and Science Center, and Buffalo Museum of Science) were the primary sources of information, accounting for over two-thirds of the data acquired. This was the first time that these data had been considered together, as only a fraction had previously been computerized and geo-referenced. The database provides a detailed picture of the historical distributions of the 40 species of freshwater mussels native to the study area, as well as the specific locations where individual species were known to occur in the past.

The database was created using the software program Microsoft® Access Version 7.0, and linked by means of the software program Spansmap® Version 1.4 to 1:250,000 digital base maps of southwestern Ontario that were provided by the Geomatics Office of Environment Canada, Burlington, ON. The database contains fields for information such as data source, name of collector, collection date, name of waterway, description of sampling location, geographical coordinates, species, condition of specimens at time of collection (living or dead), and number of species collected from a given site. Geographical coordinates (latitude and longitude) were assigned to collection sites based on descriptions of site locations. Taxonomy was standardized to the nomenclature most recently adopted by the Freshwater Mussels Subcommittee of the American Fisheries Society Endangered Species Committee (Williams *et al.* 1993). At the time of writing, the database consisted of over 4100 records obtained from approximately 1500 sites between 1860 and 1996 (a record is defined as the occurrence of a given species at a given location on a given date). A more detailed description of the database, and a discussion of the limitations of historical data, are given in Metcalfe-Smith *et al.* (in press).

Selection of Target Species

The most recent conservation status ranks for Ontario unionids were released by the Natural Heritage Information Centre (NHIC), Peterborough, Ontario, in December, 1996 (D.A. Sutherland, NHIC, personal communication, December 1996), and are presented in Table 1. According to these ranks, six of the 40 Ontario species are known only from historical records (i.e., ranked SH), 13 species are considered to be very to extremely rare (S1-S2), 10 species are ranked as rare to uncommon (S3), and only 11 species are categorized as common to very common (S4-S5). The 19 species ranked as SH, S1 or S2 were considered to be most at risk, and were therefore chosen as the target species. These species are: *Epioblasma torulosa rangiana* (northern riffleshell; SH), *Epioblasma triquetra* (snuffbox; SH), *Obliquaria reflexa* (threehorn wartyback; SH), *Obovaria olivaria* (hickorynut; SH), *Simpsonaias ambigua* (salamander mussel; SH), *Toxolasma parvus* (lilliput; SH), *Cyclonaias tuberculata* (purple wartyback; S1), *Lampsilis fasciola* (wavy-rayed lampmussel; S1), *Obovaria subrotunda* (round hickorynut; S1), *Ptychobranchus fasciolaris* (kidneyshell; S1), *Utterbackia imbecillis* (paper pondshell; S1), *Villosa fabalis* (rayed bean; S1), *Truncilla donaciformis* (fawnsfoot; S1/S2), *Truncilla truncata* (deertoe; S1/S2), *Actinonaias ligamentina* (mucket; S2), *Pleurobema coccineum* (round pigtoe; S2), *Pyganodon cataracta* (eastern floater; S2), *Quadrula pustulosa pustulosa* (pimpleback; S2) and *Quadrula quadrula* (mapleleaf; S2). Two changes were made to the list of target species: *Pyganodon cataracta* was excluded because it is an Altantic drainage species that is naturally rare in Ontario but common in the Maritimes, and *Ligumia nasuta* was added because a risk factor analysis that considered its distribution, vulnerability to zebra mussels, degree of host specificity and evidence of decline over time in the study area indicated that it should probably be uplisted from S3 to S2 (Metcalfe-Smith *et al.* in press).

Selection of Survey Sites

The Lower Great Lakes Unionid Database was queried to identify those sites where the target species occurred in the past. In all, 326 sites were identified. The list was reduced to 102 sites by excluding all sites in zebra mussel-infested waters, i.e., sites in the Great Lakes themselves (Lake Ontario, Lake Erie and Lake St. Clair) and their connecting channels (Detroit River, Niagara River, Welland River), where native mussels would no longer occur due to the impact of zebra mussels (Schloesser and Nalpa 1994; Nalepa et al. 1996). The list was further reduced to 45 sites by eliminating all duplicate sites, i.e., sites that had been sampled more than once in the past but that existed as separate entries in the database. As 43 of the 45 sites were located on the Grand, Thames or Sydenham Rivers, these rivers were the focus of the study.

Surveys for unionids had been conducted on all three rivers of interest during the 1990s by other researchers. Mackie (1996) surveyed 70 sites on the Grand River in 1995 with a sampling effort of 1.5 person-hours (p-h)/site, Morris (1996) surveyed 30 sites on the Thames River in 1995 with a sampling effort of 1.0 p-h/site and Clarke (1992) surveyed 16 sites on the Sydenham River in 1991 using a variable sampling effort (0.4-8.0 p-h/site; mean of 2.3 p-h/site). Although the sampling effort used in the present study was generally much more intensive (4.5 p-h/site), these three datasets were considered to be contemporary with the present dataset. Thus, sites that had been sampled by Mackie (1996), Morris (1996) or Clarke (1992) were *not* revisited in 1997 to avoid duplication. An exception to this was that one or several sites on each river were resurveyed for the purpose of determining if the greater sampling effort used in 1997 resulted in more species being encountered. As a result of this exercise, the number of potential survey sites for 1997 was further reduced to 17 sites on the Grand River, 9 sites on the Thames River and 6 sites on the Sydenham River. In addition, several previously-unsurveyed reaches of each river that were located between sites where target species occurred in the past were also selected for survey (1 reach on the Grand River, 4 on the Thames River and 3 on the Sydenham River). Descriptions of all historical sites and reaches selected for survey are given in Table 2. Species lists for each of the 32 historical sites are presented in Appendices I, II and III. This information was used as a reference during field work.

Field Methods

A total of 37 sites, i.e., 17 sites on the Grand River, 11 sites on the Thames River and 9 sites on the Sydenham River, were surveyed between July 23 and September 26, 1997. The sites are described in Table 3, where they are arranged in an upstream to downstream direction for each river. Site locations are shown in Fig. 1 (Grand River) and Fig. 2 (Thames and Sydenham Rivers). A total of 23 sites could be directly matched with historical sites (13 on the Grand, 4 on the Thames and 6 on the Sydenham). An additional 6 sites (1 on the Grand, 4 on the Thames and 1 on the Sydenham) were located in high priority reaches. Thus, approximately 75% of the 40 target sites or reaches were actually sampled. Of the 12 target sites and reaches that were not sampled, 6 were too deep, 2 were too obviously too polluted to support mussels, and 4 could not be accessed for various reasons (Table 2). Although water levels were at their lowest in years in the upper and middle portions of the watersheds due to a lack of rain, water levels in the lower reaches of these rivers were higher than normal due to unusually high water levels in Lake St. Clair and Lake Erie. Water from Lake St. Clair had flooded the lower reaches of the Thames and Sydenham Rivers, rendering them inaccessible. The Grand River is largely protected from this effect by a system of dams. Eight new sites (3 on the Grand, 3 on the Thames and 2 on the Sydenham) were also sampled. Selection of these sites was based on their proximity to other sites where target species were found during the surveys.

Sampling conditions for field work were ideal. Water clarity was better than expected due to the lack of rain, which resulted in reduced runoff of silt to the rivers. Also, there was plenty of sunshine, which greatly enhanced visibility.

The timed search sampling method was used, as this method has been shown to be more effective than the quadrat method for detecting rare species. In a recent paper, Strayer *et al.* (1995) compared the cost, sensitivity and precision of quadrats and timed searches under a wide range of field conditions. They found that a 1 hour timed search could detect a population about 1000 times sparser than 1 hour of quadrat sampling. At most sites, a visual search of the riverbed was conducted by a 3-person team using waders, polarized sunglasses and Waterview™ underwater viewers (a sophisticated version of a glass-bottom bucket) for a period of 1.5 hours, for a total sampling effort of 4.5 person-hours. Exceptions were as follows: At three fairly deep and silty sites in the lower Grand River (sites GR-7, GR-10 and GR-11), garden rakes were drawn through the silt until the tines touched a mussel, at which point the surveyor reached down and picked it up. At 5 sites on the Thames River and 2 sites on the Sydenham River (TR-6, TR-7, TR-8, TR-9, TR-10, SR-6 and SR-7), visibility was very poor (max. depth at which the streambed was clearly visible was < 15 cm). These sites were searched by feel, a technique that we dubbed "raccooning". Sites GR-16 and GR-17 were surveyed by divers for a period of 1 hour, for a total sampling effort of 2.0 person-hours. As diving is a more efficient sampling method, it was assumed that 2 person-hours of diving was roughly equivalent to 4.5 person-hours of searching while wading.

All unionids found alive at a given site were placed in mesh diver's bags and kept submerged until the search at that site was completed. At that point, all live specimens were identified to species, counted, and their valve lengths were measured to the nearest mm using vernier callipers. The data on size distributions for individual species will be examined at a later date to assess age structure and recruitment, which are indicators of population health. All live mussels were returned to the riverbed, with the exception of a very few specimens that were sacrificed to obtain their shells for verification by an expert taxonomist. 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. With the exceptions of *Anodontoides ferussacianus* and *Lasmigona compressa*, representatives of all species encountered alive were photographed. Shells were also collected, but not in a quantitative manner. Rather, a few shells of the common species and most or all shells of rare species found at a given site were retained for later examination in the laboratory. The purpose of shell collections was two-fold: first of all, shells were used to confirm species identifications; secondly, where shells of species not found alive were encountered, they provided evidence that those species had occurred at the site, or upstream of it, in the not-too-distant past.

After completing the mussel survey at each site, the site was photographed and characterized. The length and width of 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. Characteristics included bank stability (1=artificially stabilized, 2=stable, 3=moderately stable, 4=highly unstable), stream shading (1=dense, 2=partly open, 3=open), adjacent terrain (1=cultivated, 2=firm pasture, 3=meadow, 4=upland hardwood, 5=swamp hardwood, 6=swamp conifer, 7=shrub marsh, 8=lawn, 9=impervious surface), condition of substrate (degree of siltation: 1=slight, 2=medium, 3=heavy; degree of algal growth: 1=slight, 2=medium, 3=heavy), stream morphology (% riffle, pool, run and flat), substrate type (% of each type) and aquatic vegetation (% submerged and emergent). Any pollution sources observed were noted. The data are presented in Appendix IV. This information may be useful in the future for determining the environmental requirements of the various species.

Lab Methods

Shells obtained from each survey site were sorted by species. Where possible, orphan valves were matched with the corresponding valve from the same individual. All whole (both valves) and half (single valve) shells of each species were counted. Shells were then categorized as either "fresh" or "weathered". Fresh shells were defined as having an intact periostracum, shiny nacre, and little or no signs of wear to the hinge teeth. We submitted shells in this condition to a recognized expert (Dr. D.L. Strayer, Institute of Ecosystem Studies, Millbrook, NY) for examination, and he estimated that the animals from which these shells came would have been alive within the past one to three years. Fresh shells were often found with the ligament intact, and occasionally with remnants of the soft tissues attached. In such cases, even though live specimens could not be found, the presence of numerous fresh shells was considered to be strongly indicative of the presence of live animals. This seemed especially true for the smaller, more fragile-shelled species such as *Simpsonaias ambigua*. 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 be indicative of the presence of live animals. Although these categories are somewhat subjective and may be affected by site-specific factors such as gradient and substrate composition, estimates of the ages of shells found at a given site become important when live specimens cannot be found.

To aid identification, shells were often cleaned with a small brush and water. Specimens with a heavy accumulation of calcium carbonate were soaked in a weak acid solution that did not damage the periostracum or nacre. In general, only the two freshest whole shells of each species were retained; however, in the case of target species, all shells were kept for future reference. Specimens were identified to species using the taxonomic identification keys of Clarke (1981), Cummings and Mayer (1992), Strayer and Jirka (1997) and occasionally Burch (1975). Identifications of rare and unusual specimens were verified by Dr. D.L. Strayer, Institute of

Ecosystem Studies, Millbrook, NY or Dr. D.H. Stansbery, Ohio State University Museum of Zoology, Columbus, OH (Table 4). A voucher collection of specimens will be deposited in the Canadian Museum of Nature, by arrangement with Dr. J.-M. Gagnon, Chief of Invertebrate Collections.

RESULTS AND DISCUSSION

Influence of Sampling Effort on Measures of Diversity and Abundance

The numbers of mussel species and individual animals found during a given survey are related to the amount of effort expended. While the probability of encountering a common species is probably good regardless of the level of effort, the probability of encountering a rare species increases significantly with additional effort. For example, Strayer *et al.* (1996) determined that species with population densities sparser than 0.01-0.1 m^{-2} may escape detection with efforts of up to 10 person-hours (p-h). As the detection of rare species was the main goal of the present study, an intensive sampling effort of 4.5 p-h/site was employed. As previously mentioned, the timed search method was used because it has proven to be more effective than other sampling methods for finding rare species. Mackie (1996), Morris (1996) and Clarke (1992) also used the timed search method in their recent surveys on the Grand, Thames and Sydenham Rivers; however, their sampling efforts were generally less intensive. To determine the influence of sampling effort on estimates of diversity and abundance, data from seven sites surveyed in 1997 were directly compared with data obtained from the same sites during these other contemporary surveys. The results for species diversity are presented in Fig. 3.

In general, a greater sampling effort (in this case, a longer search period) resulted in the discovery of significantly more live species at a given site ($t = 3.08$, $df = 6$, $p = 0.02$). This was also true when data for species represented by dead shells were incorporated. There were no significant differences among surveys in the numbers of species found per hour of effort ($t = -1.63$, $df = 6$, $p > 0.05$), suggesting that the timed search method itself was consistently applied by all surveyors. For six of the sites, the greater sampling effort used in the present study also resulted in more live individuals being found (Appendix V). For example, at site TR-97-6 we found 4.5 times as many mussels as Morris (1996) using 4.5 times the sampling effort (191 vs. 41), and at site GR-97-13 we found 7.5 times as many mussels as Mackie (1996) using 3 times the sampling effort (288 vs. 38). No live mussels were found at site GR-97-2 during the present survey or by Mackie (1996). This site is located 8 km downstream of a sewage treatment plant in Galt, Ontario, that discharges textile mill effluent into the Grand River. The absence of mussels from this site suggests that textile mill effluent may be toxic to mussels or their host fish. Interestingly, we collected 1.5 times as many mussels from site SR-97-3 as Clarke (1992), using slightly less sampling effort (4.5 vs. 5 p-h). Furthermore, we obtained 3 times as many mussels from site SR-97-6 as Clarke (1992), using approximately the same sampling effort (4.5 vs. 4.3 p-h; the latter refers to the combined effort of two days' sampling at the same site). The above results suggest that our surveys were the most thorough. However, a factor contributing to our success was undoubtedly the weather. As previously noted, water levels were at their lowest in years, and water clarity was excellent. It is possible that we were able to access areas that were too deep to be sampled by these other surveyors, or that visibility was significantly better in 1997. A detailed discussion of the results for each river is presented below (see also Appendix V).

At site TR-97-6 on the Thames River, Morris (1996) found 8 live species and we found 11. The three most common species in 1997 were *Actinonaias ligmentina*, *Quadrula p. pustulosa* and *Quadrula quadrula*, and *Cyclonaias tuberculata* was represented by 9 live specimens. None of these species were found by Morris; however, he reported *Lampsilis r. radiata* and *Pyganodon grandis* from this site. The former species was probably *Lampsilis siliquoidea*, as the Thames River is outside the known range of *L. r. radiata*.

Comparisons are available for four sites on the Grand River, and at all sites we recorded more species than Mackie (1996). At site GR-97-13, Mackie found 6 live species and we found 8. Most of the same species were found during both surveys, but we also found *Alasmidonta marginata* and *Anodontoides ferussacianus*, whereas Mackie found *Lasmigona compressa*. At site GR-97-4, Mackie recorded 4 live species and we found 5. Four of the 5 species found by us (*Lampsilis ovata*, *Lasmigona costata*, *Ligumia recta* and *Potamilis alatus*) were not found by

Mackie; however, Mackie found 2 species (*Alasmidonta viridis* and *Quadrula quadrula*) that we did not. At site GR-97-10, we found 4 live species (*Leptodea fragilis, Quadrula p. pustulosa, Quadrula quadrula* and *Truncilla truncata*), whereas Mackie did not encounter any living mussels; however, Mackie found fresh shells of one species (*Lasmigona compressa*) that we did not. Mackie found no live mussels or shells at site GR-97-2, whereas we found fresh or weathered shells of 9 species.

We found many species in the Sydenham River that Clarke (1992) did not find, despite similar sampling efforts in both surveys. At site SR-97-3, we found 15 live species and Clarke found 8. At site SR-97-6, we found 18 live species and Clarke found only 13 over a 2-day period. At both of these sites, we found 6 live species that Clarke did not find, namely, *Elliptio dilatata, Epioblasma torulosa rangiana, Fusconaia flava, Lampsilis ovata, Villosa fabalis* and *Villosa iris*. We also found *Potamilus alatus, Ligumia recta* and *Ptychobranchus fasciolaris* at both sites, whereas Clarke only found them at one site. In addition, we found very fresh shells of *Simpsonaias ambigua* at both sites, and in fact at 6 of our 9 survey sites on this river, whereas Clarke had no record of this species from any of his 16 survey sites. Clarke did, however, observe one live specimen of *Obovaria subrotunda* at site SR-97-6, whereas we found only fresh shells. It is interesting to note that we observed *Strophitus undulatus, Pyganodon grandis*, and *Lasmigona costata* at a greater proportion of our survey sites than did Clarke (33% vs. 6%, 78% vs. 38%, and 89% vs. 38%, respectively). There is evidence to suggest that these species have become much more common in the rivers of southwestern Ontario in recent years (Morris and Corkum 1996; Metcalfe-Smith *et al.* submitted) because they are generally siltation- and pollution tolerant.

The results of these comparisons show that the mussel surveys conducted on the Grand, Thames and Sydenham Rivers during the present study are the most comprehensive surveys to be conducted on these rivers in recent years.

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

A total of 38 species of freshwater mussels have been reported from the Grand, Thames and Sydenham Rivers since the first such data were recorded (Metcalfe-Smith *et al.* submitted). A total of 35 species have been reported from the Grand River since 1885; 32 species have been reported from the Thames River since 1894; and 33 species have been reported from the Sydenham River since 1929. Records for two species are probably incorrect. *Elliptio complanata*, which supposedly occurred in the Grand River, and *Lampsilis radiata radiata*, which supposedly occurred in both the Grand and Thames Rivers, are Atlantic drainage species that should not be found in the Lake St. Clair and Lake Erie drainages. Specimens of *E. complanata* were probably misidentified specimens of *Elliptio dilatata*, whereas specimens of *L. r. radiata* were probably misidentified specimens of *Lampsilis siliquoidea*. Thus, these historical totals should be revised to 36 species overall, with 33 in the Grand River, 31 in the Thames River and 33 in the Sydenham River. In the present study, 30 species were found alive in one or more of these rivers (Table 5). An additional 4 species were represented by fresh or both fresh and weathered shells at some sites. Two species, *Obovaria olivaria* and *Ligumia nasuta*, were not represented by either live specimens or shells. Thus, 16% of the species that were previously known from these rivers were not found alive in 1997.

In 1997, 24 species were found alive and 3 were represented by shells only in the Grand River. For the Thames River, these numbers were 18 and 10, respectively, and for the Sydenham River they were 25 and 5. Thus, 27%, 41% and 24% of the species previously known from the Grand, Thames and Sydenham Rivers were not found alive in these rivers in 1997. As these percentages are greater than the 16% observed for the three rivers combined, it appears that populations of most species still exist but their ranges have been reduced. As shown in Table 5, 13 species now occur in fewer rivers than they did historically, and 6 others appear to have been extirpated. Although fresh shells may indicate the presence of live animals at a given site, the complete absence of live specimens from *all* sites in a particular river strongly suggests that the species is in serious decline in that river.

The mussel communities of the Grand, Thames and Sydenham Rivers differ from each other in terms of diversity, abundance and composition. The numbers of live specimens of each species found at all sites surveyed in 1997, as well as the presence of fresh and/or weathered shells, are presented in Tables 6 (Grand River), 7 (Thames River) and 8 (Sydenham River). As the sampling effort was consistent at all sites, measures of diversity and abundance can be directly compared among systems. This was done using a one-way ANOVA, followed by Tukey's test. Average diversity and abundance per site were greatest in the Sydenham River (13 species and 164 individuals, respectively), intermediate in the Thames River (9 species and 119 individuals) and lowest in the Grand River (6 species and 35 individuals). Diversity and abundance varied significantly among watersheds ($F = 14.72$, $df = 35$, $p < 0.01$ for diversity; $F = 6.31$, $df = 35$, $p = 0.005$ for abundance). Significantly more species were found in the Sydenham River than in the Thames or Grand Rivers (which did not differ significantly from each other), whereas significantly fewer animals were found in the Grand River than in the Thames or Sydenham Rivers (which did not differ significantly from each other). Of the 17 sites that supported 10 or more species, 8 sites were on the Sydenham River, 7 sites were on the Thames River and only 2 sites were on the Grand River. Approximately 2.5 times as many individual mussels were collected from the Sydenham River as from the Grand River, even though only half as many sites were surveyed. Clearly, the Sydenham River supports the richest and most productive mussel communities of the three rivers. This supports an earlier statement by Clarke (1992) that the Sydenham River is "...the richest system for Unionidae in Canada and one of the richest small river systems in North America."

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 least dominant based on the numbers of sites where they were found alive in 1997. Only 3 species were among the 10 most common species in all 3 rivers, namely, *Lasmigona costata*, *Alasmidonta marginata* and *Potamilus alatus*. In addition to these 3 species, 2 species (*Quadrula quadrula* and *Truncilla truncata*) were among the 10 dominant species in both the Grand and Thames Rivers, 2 species (*Pyganodon grandis* and *Leptodea fragilis*) were among the

10 dominant species in both the Grand and Sydenham Rivers, and 4 species (*Actinonaias ligamentina*, *Amblema plicata plicata*, *Lasmigona complanata complanata* and *Cyclonaias tuberculata*) were among the 10 dominant species in both the Thames and Sydenham Rivers. These results clearly show that different rivers may be important refugia for different species and communities of freshwater mussels. Community composition was found to differ greatly among sites in the Grand River, less so in the Thames River and relatively little in the Sydenham River. For example, only 2 species were found at over 50% of the sites on the Grand River, as compared with 12 species on the Thames River and 17 species on the Sydenham River. These differences are quite dramatic and may be related to the numbers of barriers to fish movement on each river. The Grand River has an extensive system of dams and impoundments, whereas there are only a few dams on the Thames River and none on the Sydenham River, with the exception of one small dam in the headwaters of Bear Creek (a major tributary). As a result, some species that are only found in the lower reaches of the Grand River (e.g., *Amblema p. plicata*, *Fusconaia flava*, *Leptodea fragilis*, *Ligumia recta*) are found throughout the Sydenham River.

Four species were found only in the Grand River (*Alasmidonta viridis*, *Obliquaria reflexa*, *Toxolasma parvus* and *Truncilla donaciformis*), and four others were found only in the Sydenham River (*Epioblasma torulosa rangiana*, *Ptychobranchus fasciolaris*, *Villosa fabalis* and *Villosa iris*). The fact that no species was found *only* in the Thames River suggests that it may be the least important refugium for mussels. However, this river supported the largest populations of *Alasmidonta marginata*, *Lampsilis ovata*, *Actinonaias ligamentina* and *Quadrula pustulosa pustulosa*, the latter two of which are species that may require conservation efforts in the future.

Conservation Status of the Target Species

All species occurrence records in the Lower Great Lakes Unionid Database were used to assess the current conservation status of the target species. Data obtained prior to 1990 were considered to be "historical", whereas data obtained after 1990, including all data from the present study, from Mackie (1996), Morris (1996) and Clarke (1992), and from all other collections made during this decade, were considered to be "current." Maps showing the distributions of the target species before and after 1990 were prepared to illustrate the changes over time that have occurred. In preparing these maps, all historical records, whether for live specimens or shells, were assumed to represent "occurrences" of a given species at a given location on a given date. The rationale for this assumption is that even the occurrence of a weathered shell is evidence that a species did at one time occur in that river. All current records, however, are for live animals only. The locations of *all* sites surveyed for live mussels after 1990 (approximately 300 sites) are shown on these maps to indicate whether the historical range of a given species was adequately surveyed in the 1990s. To determine the significance of populations in the Grand, Thames and Sydenham Rivers to the overall survival of a given species, the number of historical records from these systems was compared with the total number of historical records in the Lower Great Lakes Unionid Database and also with the number of records from areas that are now infested with zebra mussels (Table 10). A detailed assessment of the current conservation status of 21 species (the 19 target species, plus 2 others) is given below.

<u>*Epioblasma torulosa rangiana* (SH; Fig. 4)</u>. Prior to 1990, *E. t. rangiana* was found in Lake Erie and the Detroit and Sydenham Rivers, at a total of 10 sites. Its range has since been restricted to the Sydenham River. In our study, all 3 historical sites on the Sydenham River were sampled, with live animals found at 1 of these sites and fresh shells found at the other two. Live *E. t. rangiana* were also found at 3 new sites on the Sydenham River. Although only a few live individuals were collected from each site, the results show that this species is not extirpated as previously thought.

<u>*Epioblasma triquetra* (SH; Fig. 5)</u>. Three-quarters of the historical records for this species were from Lake St. Clair, Lake Erie and the Niagara River, which are now infested with zebra mussels. The remaining records were from the Grand, Thames and Sydenham Rivers. Two historical sites on each of the Sydenham and Grand Rivers, and 1 of 2 historical sites on the Thames River, were surveyed in 1997. No live animals were found at any of these sites, nor was this species reported live from any other survey after 1990. However, it should be noted that a relatively recent half shell was found at a new site on the Sydenham River, suggesting the possibility of an extant population in this reach. A few very weathered half shells were also found at 1 historical site on

each of the Sydenham and Thames Rivers. These findings suggest that *E. triquetra* may be extirpated from the Grand and Thames Rivers, but there is a possibility it may still exist in the Sydenham River.

Obliquaria reflexa (SH; Fig. 6). Before 1990, *O. reflexa* was found in the Grand and Thames Rivers and Lake Erie. Three of 4 historical sites were sampled in the Grand River in 1997, and 1 live animal was found at each of 2 sites. Another site produced a single live specimen, and fresh shells were collected from 3 new sites. No specimens of *O. reflexa* were found in the Thames River. However, the only site where it had occurred historically could not be sampled due to high water. The range of this species has probably been drastically reduced, as 71% of historical records were from zebra-mussel infested waters. *O. reflexa* is now restricted to the lower reaches of the Grand River.

Obovaria olivaria (SH; Fig. 7). The historical range of *O. olivaria* in the lower Great Lakes drainage basin included the Thames, Grand, Detroit and Niagara Rivers, and Lake Erie, and is based on 12 records. Although we were unable to sample the historical sites in the Grand and Thames Rivers (1 in each river), no evidence of this species was discovered at any of our survey sites. In fact, no live animals or shells have been collected from this area since 1963. As most of the historical records for this species (83%) were from zebra mussel-infested waters, *O. olivaria* appears to be extirpated from the lower Great Lakes drainage basin. As *O. olivaria* has likely also been extirpated from the core of its range (the Ottawa and St. Lawrence Rivers) by zebra mussels, the conservation status of this species in Canada is precarious.

Simpsonaias ambigua (SH; Fig. 8). Only 4 historical records exist for *S. ambigua*, and these are from the Detroit and Sydenham Rivers. Although no live animals were seen in the Sydenham River in 1997, fresh shells were found at the 1 historical site surveyed and at 5 new sites. Based on the presence of these very fresh shells (some having remnants of soft tissues and/or with ligaments intact), it seems likely that live animals are present in the Sydenham River. If so, this would be the last remaining refuge for this species in Canada. According to H.D. Athearn, Professor Emeritus, Tennessee Academy of Science (personal communication, September 1997), *S. ambigua* is only found under flat rocks. As this habitat was not adequately searched in 1997, further surveys to determine the status of this species in the Sydenham River are warranted.

Toxolasma parvus (SH; Fig. 9). *T. parvus* is represented historically by only 8 records from the Detroit, Grand and Thames Rivers. Although we were unable to sample the only historical site on the Thames River, no live animals or shells were found elsewhere in the watershed. The 4 historical sites surveyed on the Grand River generated live specimens from only 1 site. This species was also discovered in the Sydenham River in 1991, when Clarke (1992) found a single live specimen at one site. Although the potential exists for a population in the Sydenham River, *T. parvus* has apparently declined in the Grand River and is likely jeopardized in the Detroit River by zebra mussels.

Cyclonaias tuberculata (S1; Fig. 10). *C. tuberculata* was historically found in the Detroit, Sydenham, and Thames Rivers, as well as Lake Erie. Although one historical record exists for the Grand River, this is thought to be spurious and has therefore been disregarded. Live *C. tuberculata* were found at all 3 historical sites on the Thames River, and all 4 historical sites on the Sydenham River in 1997. It was also found live at 3 new sites in each of the Thames and Sydenham Rivers. This species was especially abundant in the Sydenham River where it was the second most common species in terms of total numbers. It therefore seems apparent that *C. tuberculata* has not declined in the Thames and Sydenham Rivers, although it has likely suffered declines elsewhere in its range due to zebra mussels. Approximately 58% of historical records for this species were from the Detroit River and Lake Erie.

Lampsilis fasciola (S1; Fig. 11). *L. fasciola* historically occurred in the Detroit, Grand, Sydenham and Thames Rivers, and Lake Erie. It is primarily a river-dwelling species, with only 14% of historical records occurring in areas now infested with zebra mussels. According to surveys conducted after 1990, its current distribution is limited to the Grand and Thames Rivers. Four of the 6 historical sites on the Grand River were sampled; live animals were found at 2 of these sites, a single fresh shell at another site, and only weathered shells at the fourth site. Live animals were also found at 1 new site, and weathered half shells at 3 others. Although the historical site on the Thames River was not sampled, live animals were located at one new site and fresh shells were collected from 2 others. No live animals were seen in the Sydenham River, but fresh shells were found at 1 of the 2 historical sites and a new site. These results are consistent with Clarke (1992), who found *L. fasciola* to be absent from the Sydenham River in 1991. These findings suggest that the range of *L. fasciola* has been shrinking over time.

Obovaria subrotunda (S1; Fig. 12). Before 1990, there were 40 historical records for *O. subrotunda* from the Detroit, Grand, Sydenham, Thames and Welland Rivers, as well as Lake Erie and Lake St. Clair. It was therefore a relatively common and widespread species at one time. We sampled all 4 historical sites on the Sydenham River and 1 of 2 historical sites on the Grand River, but the 1 historical site on the Thames River could not be accessed. No live specimens of *O. subrotunda* were found anywhere on these rivers in 1997; however, fresh shells were collected from 2 new sites on the Sydenham River. Weathered half shells were also present at 7 sites on the Sydenham and Thames Rivers. These data indicate that this species may be extirpated from both the Grand and Thames Rivers. Although Clarke (1992) found a few live specimens in the Sydenham River in 1991, the decline of *O. subrotunda* in this river is particularly significant because it was the source of 25% of the historical records. Of the remaining sites where *O. subrotunda* was found historically, 62.5% now fall within zebra mussel-infested waters. Overall, it appears that *O. subrotunda* has declined dramatically in recent years.

Ptychobranchus fasciolaris (S1; Fig. 13). *P. fasciolaris* was historically known from 57 sites in Lake Erie, Lake St. Clair and the Grand, Niagara, Sydenham, Thames and Welland Rivers. Thus, it was a relatively common species. Sixty percent of these sites are in areas now infested with zebra mussels. In the present study, 4 of 4 historical sites on the Sydenham River, 3 of 4 historical sites on the Grand River, and 0 of 1 historical site on the Thames River were sampled. No live *P. fasciolaris* were found at any site on the Thames River, nor any site on the Grand River. However, fresh shells were found at 2 new sites on the Thames River and weathered shells were found at all historical sites on the Grand River and 3 new sites on the Thames River. Live *P. fasciolaris* were found at 3 of the 4 historical sites, and fresh shells were found at the fourth historical site on the Sydenham River. Live specimens were observed at 2 new sites on the

Sydenham River, and fresh shells were found at 2 other new sites. Since 1990, *P. fasciolaris* has also been reported from the Ausable River (Morris and Di Maio 1997), at 2 sites in Lake Erie (Masteller *et al.* 1993), and at 4 sites on the Sydenham River (Clarke 1992). Based on these results, *P. fasciolaris* appears to have declined over time in the Thames and Grand Rivers.

Utterbackia imbecillis (S1; Fig. 14). Twelve historical records from Lake Erie, Lake Ontario, Lake St. Clair, Lake Simcoe and the Grand River exist for this widely-distributed but never abundant species. Two of 3 historical sites on the Grand River were sampled in 1997, and no live animals were found. However, fresh shells were found at a new site on the Grand River and at 2 new sites on the Sydenham River. Since 1990, live *U. imbecillis* have been found in the Sydenham River (Clarke 1992) and on the Salmon River (Lake Ontario drainage). Although 58% of historical records are from zebra mussel-infested waters, it is possible that this species may still occur in unstudied rivers and streams throughout its broad geographical range. Further surveys should be conducted, particularly in the rivers draining into the Bay of Quinte in eastern Lake Ontario, to confirm the conservation status of this species in Canada.

Villosa fabalis (S1; Fig. 15). *V. fabalis* is known historically from 12 records in Lake Erie, and the Detroit, Sydenham and Thames Rivers. In 1997, no live *V. fabalis* were found in the Thames River; however, the 1 historical site was not sampled. Of the 3 historical sites surveyed on the Sydenham River, 2 supported live *V. fabalis* and one produced fresh shells. Live animals were also found at 2 new sites on the Sydenham River. Weathered shells were found at 1 new site on the Sydenham River and at 4 new sites on the Thames River. As 68% of historical records for this species are in areas now infested with zebra mussels, the Sydenham River appears to be an important refuge for this declining species.

Truncilla donaciformis (S1/S2; Fig. 16). Historically, *T. donaciformis* was found in Lake Erie, Lake St. Clair, and the Grand and Niagara Rivers. With the exception of the Grand River, all of these areas are now infested with zebra mussels. In 1997, we surveyed 2 of 3 historical sites on the Grand River, and found live *T. donaciformis* at 1 site. One fresh half shell was found at a new site on the Thames River. Masteller *et al.* (1993) found 2 live animals at only 1 site in Lake Erie in 1992, even though Lake Erie had been the location of 69% of the historical records for this species. *T. donaciformis* appears to be declining in the Grand River, which is probably its last refuge in Canada.

Truncilla truncata (S1/S2; Fig. 17). The historical distribution of *T. truncata* included the Grand, Sydenham, Thames and Welland Rivers as well as Lakes Erie and St. Clair. It is both a lake and river species, with 45% of historical records in zebra mussel-infested waters and the remaining 55% in the Grand, Thames and Sydenham Rivers. Since 1990, this species has been found in Lake Erie and the Grand, Thames and Sydenham Rivers. In the Thames River, live animals were found at the only one of 3 historical sites that was surveyed, as well as 5 new sites. Fresh shells were found at an additional site. *T. truncata* was also found alive at the only historical site surveyed on the Sydenham River and at 4 new sites; fresh shells were found at another new site. Four of 5 historical sites on the Grand River were surveyed; live *T. truncata* were found at 3 historical sites and 2 new sites, and fresh shells were found at the fourth historical site and at another new site. These results suggest that *T. truncata* is still represented by healthy, self-sustaining populations in the Grand, Thames and Sydenham Rivers.

Actinonaias ligmentina (S2; Fig. 18). Historically, *A. ligamentina* was found in the Detroit, Grand, Moira, Sydenham, and Thames Rivers as well as Lakes Ontario, Erie and St. Clair. Since 1990, this species has been recorded from the Grand, Thames and Sydenham Rivers. In the present study, *A. ligamentina* was found at 3 of the 4 historical sites and 7 new sites on the Thames River. In the Sydenham River, it was found at 3 of the 4 historical sites and at 4 new sites. At the fourth historical site, fresh shells were found. In the Grand River, 8 of 9 historical sites were sampled, and live animals were found at 2 sites as well as at 1 new site. Fresh shells were also found at 3 of the historical sites, and weathered shells were found at the remaining 3 sites. Thus, *A. ligmentina* appears to have declined in the Grand River, but not in the Thames or Sydenham Rivers. Zebra mussels do not constitute a major threat to this species, as only 6% of historical records are from zebra mussel-infested waters.

Pleurobema coccineum (S2; Fig. 19). Prior to 1990, *P. coccineum* had a broad distribution in a number of rivers and lakes including the Detroit, Grand, Niagara, Sydenham and Thames Rivers, as well as Lake Erie and Lake St. Clair. In 1997, we sampled 3 of 5 historical sites on the Thames River, 4 of 4 historical sites on the Sydenham River and 3 of 4 historical sites on the Grand River. Live *P. coccineum* were found at only 1 of the 4 historical sites on the Sydenham River system, and one live animal was found at 1 historical site on the Grand River. Fresh shells were recorded at 1 of the historical sites and 2 new sites on the Grand River. In the Sydenham River, fresh shells were also found at 1 historical site and 2 new sites. Although no live animals were found in the Thames River, a fresh whole shell was found at one historical site. Weathered shells were found at 3 sites on the Grand River, 2 sites on the Sydenham River and 7 sites on the Thames River. In another recent study, this species was found at 2 locations on the Sydenham River (Clarke 1992). In summary, *P. coccineum* was found alive at one-third of the historical sites on the Grand River, one-quarter of the historical sites on the Sydenham River and none of the historical sites on the Thames River. *P. coccineum* is susceptible to the zebra mussel invasion, with 63% of historical sites located in infested waters. This once widespread and relatively common species (59 historical records) appears to have suffered substantial declines in recent years.

Quadrula pustulosa pustulosa (S2; Fig. 20). *Q. p. pustulosa* was historically found in Lake Erie, the Grand River, the Sydenham River, the Thames River, and the Niagara River. Forty-six percent of these historical sites are susceptible to zebra mussels. In studies conducted after 1990, live animals were found in the Grand, Sydenham, and Thames Rivers, as well as Lake Erie. In 1997, this species was found at 2 of 4 historical sites surveyed on the Thames River, and at 3 new sites; weathered shells were found at another new site. One fresh shell was found at the only historical site on the Sydenham River, and one live animal was found at a new site. In the Grand River, 5 of 6 historical sites were surveyed, and live animals were found at 2 of these sites as well as at 2 new sites. Fresh shells were found at 2 historical sites. Thus, the status of *Q. p. pustulosa* in the Grand, Thames and Sydenham Rivers remains unchanged.

Quadrula quadrula (S2; Fig. 21). Before 1990, *Q. quadrula* was known from the Grand, Sydenham, Thames, Niagara and Welland Rivers as well as Lakes Erie and St. Clair. Twenty-five percent of these sites are susceptible to zebra mussels. Since 1990, this species has been found in Lake Erie and the Grand, Thames and Sydenham Rivers. In our study, *Q. quadrula* was found alive at the only one of 4 historical sites surveyed on the Thames River, and at 5 new sites. This species was also found at both historical sites and 2 new sites on the Sydenham River. In the Grand River, *Q. quadrula* was found alive at 5 of the 6 historical sites surveyed. Therefore, the status of this species has not changed over time in the Grand, Thames and Sydenham Rivers. Because 75% of the historical records for this species are from these 3 rivers, its current conservation status in Ontario can be assessed based on its occurrence in these rivers. It should be noted, however, that *Q. quadrula* is also known from the Red-Assiniboine drainage in southern Manitoba, where its current status is not known (James Duncan, Manitoba Conservation Data Centre, personal communication, November 1996). Further surveys should therefore be conducted to determine the conservation status of this species in Canada.

Ligumia nasuta (S3; Fig. 22). Historically, *L. nasuta* was found throughout the lower Great Lakes, in areas such as Lake St. Clair, the Detroit River, Lake Erie, the Grand River, the Niagara River, the Welland River, Lake Ontario and the Moira River. *L. nasuta* is primarily a lake species and is the most susceptible of all Great Lakes species to the zebra mussel invasion (92% of 121 historical sites are located in waters now infested with zebra mussels). We surveyed 1 of the 3 historical sites on the Grand River in 1997 and found no live animals or fresh shells. However, populations were found by the authors in Lake Consecon and East Lake in Prince Edward County in 1996. Only 4% of historical records for this species were from the Grand River. Further surveys must therefore be conducted throughout the historical range of this species before its current conservation status can be determined.

Fusconaia flava (S3; Fig. 23). *F. flava* was not one of the target species in this study, but is included here because we have evidence that its distribution has changed. This species was historically found in the Detroit, Grand, Niagara, Sydenham and Thames Rivers as well as Lakes Erie and St. Clair, and was a significant component of the mussel community. Since 1990, it has been reported from the Grand, Thames and Sydenham Rivers only. Of the 2 historical sites sampled in the Thames River, live animals were found at 1; fresh shells were found at 1 new site and weathered shells were found at 6 new sites. In the Sydenham River, live animals were found at 1 of 5 historical sites surveyed, and fresh shells were found at the other 4 sites. Live animals were also found at 3 new sites in the Sydenham River. Two of 7 historical sites on the Grand River supported live *F. flava*, and two produced fresh shells. Live animals were also found at 2 new sites on the Grand River. This species has most certainly declined throughout much of its range due to zebra mussels (56% of historical sites are in zebra mussel-infested waters), and there is some evidence to suggest that it may also be declining in the Grand, Thames and Sydenham Rivers. This species is also known from the Red-Assiniboine drainage in Manitoba, therefore, further surveys are needed to determine its conservation status in Canada.

<u>Villosa iris (S3; Fig. 24)</u>. *V. iris* was also a relatively common species prior to 1990; it had been found at 75 sites in Lake Erie, Lake St. Clair, the Detroit River, the Grand River, the Moira River, the Niagara River, the St. Clair River, the Sydenham River and the Thames River. Since then it has been found in the Grand, Moira, Sydenham and Thames Rivers. No live animals were found at the 1 historical site or any new sites on the Thames River in 1997. However, fresh shells were found at 2 new sites and weathered shells were found at 2 other new sites. In the Sydenham River, live animals were found at 2 of the 4 historical sites, fresh shells were found at a third historical site, and weathered shells were found at the fourth site. Live animals were also found at a new site on the Sydenham River. No live animals were found at the 7 historical sites surveyed on the Grand River, nor at any new sites. However, fresh shells were found at 1 historical sites. Weathered shells were also found at 2 historical sites and 1 new site. Therefore, no live *V. iris* were found in either the Grand River or the Thames Rivers during our study. In contrast, this species does not appear to have declined in the Sydenham River. Based on decreases in this species in the studied rivers and presumed decreases in areas infested with zebra mussels (43% of historical sites are susceptible), *V. iris* has declined quite significantly throughout much of its range. As 9% of the historical records were from the Moira River in the Lake Ontario drainage, further surveys in this and other nearby rivers are needed to confirm the conservation status of *V. iris*.

The introduction of the zebra mussel to the Great Lakes in the late 1980s (Hebert *et al.* 1989) led to catastrophic declines of native mussels in infested areas (e.g., Gillis and Mackie 1994). As a result, rivers now serve as the last refuge for many species. Unfortunately, factors such as pollution, habitat destruction and dam construction have been causing the decline and extirpation of mussel populations in rivers for many years (Nalepa and Gauvin 1988). Thus, declines of mussel species in major river systems such as the Grand, Thames and Sydenham Rivers, will have a significant impact on the chances of survival for many Canadian species.

The results of the present study revealed that five species historically found in the Grand, Thames and Sydenham Rivers have suffered declines in all three systems (*Epioblasma triquetra*, *Lampsilis fasciola*, *Obovaria subrotunda*, *Pleurobema coccineum*, and *Fusconaia flava*). Declines have been most severe for *E. triquetra* and *O. subrotunda*, which may now be extirpated from the lower Great Lakes region. *L. fasciola* may be extirpated from the Sydenham River, and *P. coccineum* may be extirpated from the Thames River. *Ptychobranchus fasciolaris* has declined in the Thames and Grand Rivers, but appears stable in the Sydenham River; *Villosa iris* also appears stable in the Sydenham River, but may be extirpated from the Grand and Thames Rivers. This species is also known from the Lake Ontario drainage. *Actinonaias ligamentina* has declined in the Grand River, but not in either the Thames or the Sydenham Rivers. *Truncilla truncata*, *Quadrula pustulosa pustulosa* and *Quadrula quadrula* do not appear to have experienced declines in any of the 3 rivers.

Two species were known historically from the Thames and Sydenham Rivers only. *Cyclonaias tuberculata* was found to be quite common in 1997, particularly in the Sydenham River. However, *Villosa fabalis* may be extirpated from the Thames River. Of the three species historically known from the Grand and Thames Rivers only, *Obliquaria reflexa* and *Toxolasma parvus* have declined in both rivers and may be extirpated from the Thames River, whereas *Obovaria olivaria* appears to be extirpated from both rivers.

Epioblasma torulosa rangiana and *Simpsonsias ambigua* were historically known from the Sydenham River only. *E. t. rangiana* was previously thought to be extirpated, but was found alive at several sites in 1997. *S. ambigua* was represented by very fresh shells at 6 sites, and we expect that live animals will be found with sufficient effort. *Utterbackia imbecillis, Ligumia nasuta* and *Truncilla donaciformis* were historically known from the Grand River only, although the former two species are also known from the Lake Ontario drainage. *T. donaciformis* appears to be declining in the Grand River, and may be close to extirpation.

Proposed Changes to Species Conservation Status Ranks

Based on the above assessment of the current conservation status of 21 species of mussels native to the lower Great Lakes basin, we propose that the Ontario conservation status ranks (SRANKS) for 11 species should be revised. The proposed new ranks are presented in Table 11. As most of these species are known in Canada only from southwestern Ontario (i.e., all except *Obovaria olivaria, Fusconaia flava* and *Quadrula quadrula*), these ranks are also applicable nationally.

Four species that were previously ranked SH and thought to be extirpated, i.e., *Simpsonaias ambigua, Epioblasma torulosa rangiana, Obliquaria reflexa* and *Toxolasma parvus*, were revised to S1 status with the confirmation of extant populations. As discussed earlier, a small number of live specimens were collected for three of these species, while the persistence of *S. ambigua* seems highly likely due to the collection of many very fresh shells at several sites in the Sydenham River. Declines in *Pleurobema coccineum* and *Truncilla donaciformis* justified their uplisting to S1 status from S2 and S1S2, respectively. *Villosa iris, Fusconaia flava,* and *Ligumia nasuta* (all previously S3) were uplisted to S2, S2S3, and S2 respectively. Two species were found to be more common than expected and were downlisted: *Cyclonaias tuberculata* from S1 to S2; and *Truncilla truncata* from S1S2 to S2S3.

This year's sampling sites overlapped well with the ranges of many species and thus provide a good indication of the overall conservation status of these species. However, some species are known to exist outside of the Grand, Sydenham, and Thames Rivers and therefore require further investigation before their status ranks can be substantiated. These species include: *Utterbackia imbecillis*, *Ligumia nasuta*, and *Villosa iris*, all of which have recently been found in the Lake Ontario watershed (Metcalfe-Smith *et al.* 1997); *Fusconaia flava* and *Quadrula quadrula*, which also occur Manitoba; and *Obovaria olivaria*, which is also found in the St. Lawrence and Ottawa Rivers. The status of *Toxolasma parvus* requires verification as well. This species was historically found in the lower reaches of the three surveyed rivers, and many of these site could not be accessed in 1997 due to unusually high water levels.

Species Recommended for National Status Designation by COSEWIC

COSEWIC has the mandate to list all species of certain taxonomic groups that are at risk in Canada. Listing extinct and extirpated species is, of course, important because it draws attention to the fact that serious problems exist, may encourage activities to rehabilitate the habitats of these species such that future reintroductions might be possible, and lends urgency to efforts on behalf of species that have not quite reached the critical stage. However, from a practical conservation point of view, we feel that it is more important to focus on officially designating those species for which there may still be time to intervene, i.e., the species ranked S1. With few exceptions, only those species that have been officially listed by COSEWIC are eligible for funding under the Endangered Species Recovery Fund. We therefore recommend that the eleven species with proposed ranks of S1 be given first consideration for national status designation by COSEWIC. These species are: *E. t. rangiana, O. reflexa, S. ambigua, T. parvus, L. fasciola, O. subrotunda, P. fasciolaris, U. imbecillis, V. fabalis, T. donaciformis* and *P. coccineum.* These species would likely fall into the Endangered or Threatened risk categories as defined by COSEWIC. One of the authors of this report (J.L. Metcalfe-Smith) has received approval and funds for the preparation of status reports on three of these species from COSSARO (Alan Dextrase, Ontario Ministry of Natural Resources, personal communication, November 1997) and COSEWIC (Theresa Aniskowicz, Canadian Wildlife Service, personal communication, December 1997). Final reports are due in 1998. Justifications for the three species chosen are presented below:

Epioblasma torulosa rangiana **- Northern Riffleshell**

The Northern Riffleshell is a subspecies that is considered to be very rare globally (G-rank = G2). The other two subspecies of *Epioblasma torulosa* (*E. t. gubernaculum* and *E. t. torulosa*) may be extinct (Williams *et al.* 1993). In 1993, the Northern Riffleshell was listed as endangered under the federal U.S. Endangered Species Act. In the United States, the Northern Riffleshell is known from some Lake Erie tributaries and the Ohio River system, but recent reproduction has only been documented from two locations: the Detroit River (Michigan) and French Creek (Pennsylvania) (U.S. Fish and Wildlife Service 1993). The current distribution of this subspecies represents a range reduction of greater than 95% (U.S. Fish and Wildlife Service 1993). In Ontario, the subspecies is known historically from the Sydenham River, the Detroit River and a few locations in western Lake Erie (Metcalfe-Smith *et al.* 1997). Although ranked SH (no verified occurrences within the last 20 years) in Ontario, an extant population of the Northern Riffleshell was discovered in the Sydenham River in 1997 (Metcalfe-Smith *et al.*, this report). Live specimens ranged from 35 mm to 74 mm in length, suggesting recent recruitment.

As the name implies, the Northern Riffleshell lives in riffles and runs of streams, preferring substrates of firmly packed sand and fine to coarse gravel (Stansbery *et al.* 1982). Until recently the glochidial fish hosts for this species were unknown; however, Watters (1996) has now found the following species to be hosts: Banded Darter, Bluebreast Darter, Brown Trout and Banded Sculpin. As only the Brown Trout (an introduced species) is found in Ontario, the native fish host remains unknown. Impoundments, channelization, water pollution, loss of riparian vegetation and the impacts of siltation from poor land use practices have been important factors in the reduction of the Northern Riffleshell's range in the United States (U.S. Fish and Wildlife Service 1993). The invasion of the zebra mussel (*Dreissena polymorpha*) also poses a significant threat to this subspecies. In the Detroit River, zebra mussels were considered to be such a severe threat that in 1992 rescue efforts were initiated to salvage this and other native species by moving them to captivity (U.S. Fish and Wildlife Service 1993). The Sydenham River is the only refugium for this species in Canada and is therefore important to the global conservation of the Northern Riffleshell, particularly if it supports a reproducing population.

***Villosa fabalis* - Rayed Bean**

The Rayed Bean lives in lakes and in riffles and runs of small to large streams, preferring substrates of sand and gravel. The glochidial fish host for this species is unknown. This species has shown a significant decline in distribution and abundance in recent years (Stansbery 1985), presumably due to the development of impoundments, sedimentation from poor land use practices, and water pollution throughout its range. The Rayed Bean was recently uplisted (February 1997) from very rare (G2) to very to extremely rare (G1G2) globally, and was identified as a species of special concern by Williams *et al.* (1993). This species was previously listed as a Category 2 Federal Candidate under the U.S. Endangered Species Act (Cummings and Mayer 1992), but this listing category has since been abolished. In the United States, the Rayed Bean was formerly known from 11 states (Lake Michigan and Lake Erie drainages, Ohio River and Mississippi River drainages), but is thought to be extirpated from Virginia (Virginia Department of Conservation and Recreation 1997) and Illinois (Illinois Natural History Survey 1997). It is listed as endangered in Kentucky, Michigan and Ohio, and as a species of special concern in Indiana (The Nature Conservancy 1997).

In Ontario, the Rayed Bean is known historically from the Sydenham River, the Thames River, the Detroit River and near Pelee Island in western Lake Erie (Metcalfe-Smith *et al.* 1997). The species is ranked S1 (extremely rare) in Ontario. Recent surveys of sites where the species was historically found revealed only weathered shells in the Thames River, but small numbers of live animals at several sites in the Sydenham River (Metcalfe-Smith *et al.*, this report). It should also be noted that the Sydenham River population showed signs of recent recruitment, with live specimens ranging from 20mm to 37mm in length. As populations in Lake Erie and the Detroit River are threatened by zebra mussels (if indeed they still exist), the Sydenham River may support the only known reproducing population in Canada. The Sydenham River population would therefore be important to the global conservation of this species.

Lampsilis fasciola **- Wavy-rayed Lampmussel**

The Wavy-rayed Lampmussel lives in riffles of medium-sized streams, preferring substrates of gravel (Cummings and Mayer 1992). Only one glochidial fish host, the smallmouth bass (*Micropterus dolomieui*), is known for this species (Hoggarth 1992). The Wavy-rayed Lampmussel is considered to be globally common (G4 - usually more than 100 occurrences). In the United States, the Wavy-rayed Lampmussel is known from 13 states (Lake Michigan, Lake Huron and Lake Erie drainages, Ohio River and Mississippi River drainages), but is uncommon and believed to be declining in the north. It is listed as endangered in Illinois, threatened in Michigan, and a species of special concern in North Carolina, Ohio, and Indiana (The Nature Conservancy 1997). In Ontario, the Wavy-rayed Lampmussel is ranked S1 (extremely rare) and is known historically from the Sydenham River, Thames River, Grand River, Detroit River and several locations in western Lake Erie (Metcalfe-Smith *et al.* 1997). Recent surveys of historical sites in the Sydenham River revealed only a few dead shells, whereas the Thames River yielded four live specimens at a single site (Metcalfe-Smith *et al.*, this report). Surveys of the Grand River were more encouraging, with up to eight live animals observed at three sites.

It is not clear why this species has apparently disappeared from the Sydenham River and declined in the Thames River where other sensitive unionid species have persisted. The Grand River population may still be healthy. The colonization of impoundments in the Grand River by zebra mussels upstream of extant populations of *L. fasciola* would pose a definite threat to the continued existence of this species in Canada. Populations in Lake Erie and the Detroit River, if they still exist, are threatened by zebra mussels.

Conservation Status Scores

In order for watershed managers to make informed decisions regarding the protection of significant mussel habitat, a system for identifying the most valuable habitat areas is needed. Although species diversity is a good indicator of the value of a particular site, it does not take into account the conservation status of the individual species that are present. A community consisting of five common species, for example, would have the same diversity as a community that included three common and two rare species. Thus, we developed a conservation status score system for ranking sites according to the composition of their current (post-1990) mussel communities. The method is as follows: Each species was assigned a conservation value based on its conservation status rank in Ontario, or SRANK. The more at-risk the species, i.e., the lower its SRANK, the higher its conservation value. For example, all S1-ranked species were assigned a value of 5 and all S5-ranked species were assigned a value of 1. Current SRANKs (Table 1) were used for most species; however, proposed new SRANKs were used for 11 species (see Table 11). The conservation values of all species occurring live at a given site were then summed into a conservation status score for that site.

A total of 294 sites in the study area had been surveyed for the presence of live mussels by various researchers between 1990 and the present. Live animals representing between 1 and 18 species were found at 215 of these sites. Conservation status scores were calculated for the 215 sites and plotted in Fig. 25. A total of 30 sites had conservation status scores of 20 or higher (shown in green or red in Fig. 25). With the exception of one site on the AuSable River (Lake Huron drainage; not shown on the map), all of these sites were on the Grand, Thames or Sydenham Rivers. Only 3 of the 30 sites were located on the Grand River, and all were in the lower reaches (max. score = 36). In contrast, there were 10 sites on the Thames River with scores exceeding 20 (max. score = 37), and these were located throughout the middle and upper reaches of the river as well as in one tributary. The Sydenham River contained more than half of the sites with scores over 20, even though the fewest sites had been surveyed on this river. Six sites on the Sydenham River had scores exceeding 40 (shown in red in Fig. 25; max. score = 60). High-scoring sites were located throughout a significant portion (>50 km) of the main stem of the river.

The Canadian Heritage Rivers System recognizes select rivers across Canada for their "...outstanding natural, cultural, and recreational values" (Canadian Heritage Rivers Board, 1997). The Grand River was designated a Canadian Heritage River in 1994, and the Thames

River has been nominated (H. Schraeder, Ontario Ministry of Natural Resources, Aylmer, ON, August 1997). Once a river has been designated, a Conservation Management Plan must be developed to ensure its preservation. We hope that the plans for these rivers will include measures for protecting mussel communities, which are a unique part of our Canadian natural heritage. A conservation status score system, such as the one we have described, may be useful for identifying and prioritizing prime areas of mussel habitat that should be sustained.

CONCLUSIONS

Nearly one-half of the 40 species of freshwater mussels native to the lower Great Lakes drainage basin are presently ranked as SH (known from historical records only), S1 (extremely rare) or S2 (very rare) in Ontario by the Natural Heritage Information Centre in Peterborough, ON. In this study, we determined the current conservation status of 21 species of mussels believed to be at risk in Ontario. As all except three of these species are known in Canada only from Ontario, their status in Ontario reflects their national status. Most of these species are no longer found in the Great Lakes themselves due to the severe impact of the zebra mussel (*Dreissena polymorpha*) on native mussels. The last refugia for many of Canada's native mussel species are the Grand, Thames and Sydenham Rivers in southwestern Ontario.

Thirty-seven sites on the Grand, Thames and Sydenham Rivers that historically supported the target species were intensively surveyed during the summer of 1997 to determine the true status of these species. Current data on species distributions from this and other recent (>1990) surveys in these rivers were combined and compared with the historical data to determine if there have been changes over time. The major findings of this study are as follows:

A comparison of the results of the present survey with the results of three other surveys conducted on the Grand, Thames and Sydenham Rivers in the 1990s revealed that our surveys were the most comprehensive. This could mainly be attributed to our greater sampling effort, although unusually low water levels undoubtedly improved access to the rivers and contributed to our success. Nevertheless, an intensive sampling effort is clearly needed to properly assess the status of rare species. For example, Mackie (1996) surveyed 70 sites on the Grand River in 1995 using a sampling effort of 1.5 person-hours/site and reported a total of 18 live species. In contrast, we surveyed only 17 sites on the Grand River in 1997, but used a sampling effort of 4.5 person-hours/site and reported a total of 24 live species. Sampling effort becomes particularly important when considering changes to species status ranks. For example, Arthur H. Clarke, a leading authority on freshwater mussels in Canada, declared five species extirpated from the Sydenham River based surveys he conducted in 1991. In 1997, we found two of these species to be present at several sites on the river, and provided strong evidence (very fresh shells at numerous sites) that a third species also still occurs.

Although we successfully located more living species on all three rivers than other recent surveyors, we still observed species losses; 27%, 41% and 24% of the species known from the Grand, Thames and Sydenham Rivers, respectively, based on historical records dating back to the late 1800s, were not found alive in 1997. Although 30 of the 36 species historically known from the study area were found alive, 13 of these species now occur in fewer rivers than they did historically. Thus, the ranges of many species have been reduced. The Sydenham River still supports the richest and most productive mussel community of any small river in Canada, with 25 living species, an average diversity of 13 species/site, and an average abundance of over 150 individual mussels based on a sampling effort of 4.5 person-hours. In 1992, Clarke urged "…that the Sydenham River be made an ecological preserve and that its fauna be protected by legislation." To this, we would add that time is of the essence.

The conservation status of 21 species of freshwater mussels was assessed by comparing the current (>1990) distribution of each species with its historical distribution. On the basis of these comparisons, changes to the official conservation status ranks (Ontario's SRANKS) of 11 species were proposed. Three species currently ranked SH were found alive and could therefore be downlisted to S1 (*Epioblasma torulosa rangiana, Obliquaria reflexa* and *Toxolasma parvus*). As the persistence of *Simpsonaias ambigua* is highly likely due to the presence of fresh shells at many sites, this species was also tentatively downlisted to S1. Five species appear to have declined significantly (*Fusconaia flava*, *Ligumia nasuta*, *Pleurobema coccineum*, *Truncilla* *donaciformis* and *Villosa iris*) and are therefore recommended for uplisting. Two other species (*Cyclonaias tuberculata* and *Truncilla truncata*) were more common than expected, and could be downlisted.

We recommend that the 11 species with proposed ranks of S1 be given first consideration for national status designation by COSEWIC, as measures will have to be taken soon to prevent their extirpation. One of the authors of this report (J.L. Metcalfe-Smith) has been commissioned by the Ontario Ministry of Natural Resources to prepare COSSARO (Committee on the Status of Species at Risk in Ontario) status reports on three of these species (*Epioblasma torulosa rangiana*, *Lampsilis fasciola* and *Villosa fabalis*). Funding for the preparation of national status reports on these species will be provided by COSEWIC.

A conservation status score system was devised for identifying and prioritizing areas of prime mussel habitat that should be protected. This system may be a useful tool for agencies that are responsible for managing the water and habitat quality of Ontario's rivers.

RECOMMENDATIONS

(1) Conduct further surveys to more clearly delineate the ranges of the three species recommended for status designation, as well as other high priority species. In addition to further sites in the Grand, Thames and Sydenham Rivers, Bear Creek (a major tributary to the Sydenham River that was historically species-rich and was not adequately surveyed in 1997) and the AuSable and Maitland Rivers (lower Lake Huron drainage), should be the focus of this work.

(2) Populations of these species should be studied to determine their stability, by measuring their sizes, densities, sex ratios, size class distributions, etc., and their environmental requirements. Sites where these species occurred historically but that no longer support them should be characterized (physically, chemically and biologically) and compared with sites that still support them, to determine the probable causes(s) of decline.

(3) Further surveys in the Lake Ontario watershed, particularly in the rivers draining into the highly productive Bay of Quinte region, should be conducted to determine the current distributions of several species that appear to have severely declined in the Lake St. Clair and Lake Erie drainages, namely *Ligumia nasuta*, *Utterbackia imbecillis* and *Villosa iris*.

ACKNOWLEDGEMENTS

The authors wish to thank E. Walker, M. Dahl, T. Breedon and B. Gray, Technical Operations Section, Research Support Branch, National Water Research Institute (NWRI) for their assistance in the field. We also thank M. Brown for her assistance in the laboratory and with report preparation. Dr. D.L. Strayer, Institute of Ecosystem Studies, Millbrook, NY and Dr. D.H. Stansbery, Ohio State University Museum of Zoology, Columbus, OH, kindly verified the taxonomic identifications of voucher specimens. This research was partly supported by a grant to G.L. Mackie from the Endangered Species Recovery Fund, which is co-sponsored by the World Wildlife Fund Canada and the Canadian Wildlife Service of Environment Canada.

REFERENCES

Biggins, R.G., R.J. Neves, and C.K. Dohner. 1995. Draft national strategy for the conservation of native freshwater mussels. U.S. Fish and Wildlife Service, Washington, DC. 26 pages.

Bogan, A.E. 1993. Freshwater bivalve extinctions (Mollusca: Unionoida): a search for causes. American Zoologist 33: 599-609.

Burch, J.B. 1975. Freshwater unionacean clams (Mollusca: Pelecypoda) of North America. Malacoloical Publ. Hamburg, MI. 204p.

Canadian Heritage Rivers Board. 1997. Heritage Riverscapes. Spring 1997.

Clarke, A.H. 1981. The Freshwater Molluscs of Canada. National Museums of Canada, Ottawa, Canada. 446 pages.

Clarke, A.H. 1992. Ontario's Sydenham River, an important refugium for native freshwater mussels against competition from the zebra mussel *Dreissena polymorpha*. Malacology Data Net 3: 43-55.

Cummings, K.S., and C.A. Mayer. 1992. Field Guide to Freshwater Mussels of the Midwest. Illinois Natural History Survey Manual 5. 194 pages.

Gillis, P.L., and G.L. Mackie. 1994. Impact of the zebra mussel, *Dreissena polymorpha*, on populations of Unionidae (Bivalvia) in Lake St. Clair. Canadian Journal of Zoology 72: 1260-1271.

Hebert, P.N.D., B.W. Muncaster, and G.L Mackie. 1989. Ecological and genetic studies on *Dreissena polymorpha* (Pallas): a new mollusc in the Great Lakes. Can. J. Fish. Aquat. Sci. 46:1587-1591.

Hoggarth, M.A. 1992. An examination of the glochidia-host relationships reported in the literature for North American species of Unionacea (Mollusca-Bivalvia). Malacology Data Net 3: 1-30.

Illinois Natural History Survey. 1997. Illinois Natural History Survey web site (http://www.inhs.uiuc.edu/cbd/ilspecies/mollusksplist.html).

Mackie, G.L. 1996. Diversity and status of Unionidae (Bivalvia) in the Grand River, a tributary of Lake Erie, and its drainage basin. Ontario Ministry of Natural Resources, Peterborough, ON. 39p.

Masteller, E.C., K.R. Maleski and D.W. Schloesser. 1993. Unionid Bivalves (Mollusca: Bivlavia: Unionidae) of Presque Isle Bay, Erie, Pennsylvania. J. Penn. Academy of Sci. 67(3): 120-126.

Master, L. 1990. The imperiled status of North American aquatic animals. Biodiversity Network News, Vol. 3, Issue 3.

Metcalfe-Smith, J.L., S.K. Staton, G.L. Mackie and N.M. Lane. 1997. Biodiversity of freshwater mussels in the lower Great Lakes drainage basin. Environment Canada, National Water Research Institute, Burlington, ON. NWRI Contribution No: 97-90.

Metcalfe-Smith, J.L., S.K. Staton, G.L Mackie and N.M. Lane. Selection of candidate species of freshwater mussels (Bivalvia: Unionidae) to be considered for national status designation by COSEWIC. Canadian Field-Naturalist (in press).

Metcalfe-Smith, J.L., S.K. Staton, G.L Mackie and N.M. Lane. Changes in the biodiversity of freshwater mussels in the Canadian waters of the lower Great Lakes drainage basin over the past century. Journal of Great Lakes Research (submitted).

Morris, T.J. 1996. The unionid fauna of the Thames River drainage, southwestern Ontario. Ontario Ministry of Natural Resources, Peterborough, ON. 60p.

Morris, T.J., and L.D. Corkum. 1996. Assemblage structure of freshwater mussels (Bivalvia: Unionidae) in rivers with grassy and forested riparian zones. J. N. Am. Benthol. Soc. 15:576-586.

Morris, T.J., and J. Di Maio. 1997. Current distributions of freshwater mussels (Bivalvia: Unionidae) in rivers of southwestern Ontario. Malacological Review (in press).

Nalepa, T.F., and J.M. Gauvin. 1988. Distribution, abundance, and biomass of freshwater mussels (Bivalvia: Unionidae) in Lake St. Clair. Journal of Great Lakes Research 14: 411-419.

Nalepa, T.F., D.J. Hartson, G.W. Gostenik, D.L. Fanslow, and G.A. Lang. 1996. Changes in the freshwater mussel community of Lake St. Clair: from Unionidae to *Dreissena polymorpha* in eight years. Journal of Great Lakes Research 22: 354-369.

Neves, R.J. 1993. A state-of-the-unionids address. Pages 1-10 In Conservation and Management of Freshwater Mussels, Proceedings of the Upper Mississippi River Conservation Committee Symposium, St. Louis, Missouri. Edited by K.S. Cummings, A.C. Buchanan, and L.M. Koch, Illinois Natural History Survey, Champaign, Illinois.

Neves, R.J. 1997. Keynote address: A national strategy for the conservation of native freshwater mussels. In Conservation and management of freshwater mussels II: initiatives for the future, Proceedings of an Upper Mississippi River Conservation Committee symposium, eds. K.S. Cummings, A.C. Buchanan, C.A. Mayer, and T.J. Naimo, pp.1-10. St. Louis, MO.

Ricciardi, A., F.G Whoriskey and J.B. Rasmussen. 1996. Impact of the *Dreissena* invasion on native unionid bivalves in the upper St. Lawrence River. Can. J. Fish. Aquat. Sci. 53:1434-1444.

Schloesser, D.W., and T.F. Nalepa. 1994. Dramatic decline of unionid bivalves in offshore waters of western Lake Erie after infestation by the zebra mussel, *Dreissena polymorpha*. Canadian Journal of Fisheries and Aquatic Sciences 51: 2234-2242.

Stansbery, D.H., K.G. Borror, and K.E. Newman. 1982. Biological abstracts of selected species of unionid mollusks recovered from Ohio. Unpublished. Prepared for the Ohio Heritage Foundation. Ohio Department of Natural Resources.

Stansbery, D.H. 1985. Ohio State University Museum of Zoology, Columbus, Ohio. Personal communication with D. Lauritsen, Nov. 1985. In: Lauritsen, D. 1987. Element Stewardship Abstract for the Rayed Bean, *Villosa fabalis*. Prepared for The Nature Conservancy. Arlington, Virginia, USA.

Steedman, R.J., T.H. Whillans, A.P. Behm, K.E. Bray, K.I. Cullis, M.M. Holland, S.J. Stoddart and R.J. White. 1996. Use of historical information for conservation and restoration of Great Lakes aquatic habitat. Can. J. Fish. Aquat. Sci. 53(Suppl. 1): 415-423.

Strayer, D.L., S. Claypool. and S.J. Sprague. 1995. Assessing unionid populations with quadrats and timed searches. Proceedings of the upper Mississippi River Conservation Committee Symposium, The Conservation and Management of Freshwater Mussels II: Initiatives for the future. St. Louis, MO. 30p.

Strayer, D.L., S.J. Sprague, and S. Claypool. 1996. A range-wide assessment of populations of *Alasmidonta heterodon*, an endangered freshwater mussel. J. N. Am. Benthol. Soc. 15(3): 308-317.

Strayer, D.L., and K.J. Jirka. 1997. The pearly mussels of New York State. Memoirs of the New York State Museum 26:113 pp. + 27 plates.

The Nature Conservancy. 1997. Current ranks for *Epioblasma torulosa rangiana*, *Villosa fabalis* and *Lampsilis fasciola*, October 23, 1997.

U.S. Fish and Wildlife Service. 1993. Endangered and Threatened Wildlife and Plants; Determination of Endangered Status for the Northern Riffleshell Mussel (*Epioblasma torulosa rangiana*) and the Clubshell Mussel (*Pleurobema clava*).

U.S. Fish and Wildlife Service. 1996. *Endangered Species Bulletin*, Vol. 21(2), March/April 1996. U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC.

Virginia Department of Conservation and Recreation. 1997. Virginia Department of Conservation and Recreation web site (http://www.state.va.us/~dcr/dnh/noinsect.htm).

Watters, G.T. 1996. Hosts for the Northern Riffle Shell (*Epioblasma torulosa rangiana*). Triannual Unionid Report 10:14.

Williams, J.D., M.L. Warren Jr., K.S. Cummings, J.L. Harris, and R.J. Neves. 1993. Conservation status of freshwater mussels of the United States and Canada. Fisheries 18: 6-22.

Table 1. Current conservation status ranks for Ontario species of freshwater mussels (December 1996)*.

SPECIES	SRANK[a]
Actinonaias ligamentina	S2
Alasmidonta marginata	S3
Alasmidonta undulata	S2S3
Alasmidonta viridis	S3
Amblema plicata plicata	S3
Anodontoides ferussacianus	S5
Cyclonaias tuberculata	S1
Elliptio complanata	S5
Elliptio dilatata	S4
Epioblasma torulosa rangiana	SH
Epioblasma triquetra	SH
Fusconaia flava	S3
Lampsilis fasciola	S1
Lampsilis ovata	S4
Lampsilis radiata radiata	S4
Lampsilis siliquoidea	S5
Lasmigona complanata complanata	S3
Lasmigona compressa	S5
Lasmigona costata	S4
Leptodea fragilis	S4
Ligumia nasuta	S3
Ligumia recta	S3
Obliquaria reflexa	SH
Obovaria olivaria	SH
Obovaria subrotunda	S1
Pleurobema coccineum	S2
Potamilus alatus	S3
Ptychobranchus fasciolaris	S1
Pyganodon cataracta	S2
Pyganodon grandis	S5
Quadrula pustulosa pustulosa	S2
Quadrula quadrula	S2
Simpsonaias ambigua	SH
Strophitus undulatus	S4
Toxolasma parvus	SH
Truncilla donaciformis	S1S2
Truncilla truncata	S1S2
Utterbackia imbecillis	S1
Villosa fabalis	S1
Villosa iris	S3

*Courtesy of D.A. Sutherland, Natural Heritage Information Centre, Peterborough, Ontario.

[a] 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.

Table 2. Descriptions of all historical sites and reaches selected for survey in 1997, showing matches to sites actually surveyed.

Site #	Waterbody	Nearest Urban Centre	Description of Survey Site	Match to site surveyed in 1997
GR-A	Grand River	Port Maitland	Port Maitland at the boat launch, east side of river	GR-97-16
GR-B	Grand River	Dunnville	Below the dam	ns*, too deep
GR-C	Sulphur Creek	Byng Park	Byng park below dam at boat launch	GR-97-17
GR-D	Grand River	Byng Park	Byng park just upstream of Sulphur Creek outflow above Dunnville Dam	GR-97-7
GR-E	Grand River	Cayuga	Between Cayuga and Byng Park, 6.5 km northwest of the Dunnville dam	GR-97-11
GR-F	Grand River	York	Between York and Cayuga, 4.5 km north of Cayuga	GR-97-6
GR-G	Grand River	York	Upstream of York about 1.5 mi., along hwy 54 where road is next to the river	GR-97-5
GR-H	Grand River	Caledonia	0.25 mi upstream of bridge in Caledonia at the Caledonia Conservation Area	GR-97-4
GR-I	Grand River	Cayuga	Just downstream of the Hwy 3 bridge at Cayuga; west shore only sampled	GR-97-10
GR-J	Grand River	Glen Morris	Grand River at Glen Morris, at canoe launch area downstream of bridge	GR-97-2
GR-K	Grand River	Galt	In Galt	ns, polluted
GR-L	Grand River	Cambridge	West bank at hwy. 401 bridge	ns, inaccessible
GR-M	Grand River	Kitchener	Grand River at old King St. bridge in Kitchener	GR-97-12
GR-N	McKenzie Ck.	Caledonia	Near Hwy. 6	ns, inaccessible
GR-O	Nith River	Canning	Foot bridge upstream of CNR bridge below Canning	GR-97-8
GR-P	Grand River	West Montrose	At the covered bridge at West Montrose	GR-97-13
GR-Q	Grand River	Brantford	Just below the small dam in Brant Conservation Area in Brantford	GR-97-9
New reach	Grand River	Brantford	The oxbow below Brantford	GR-97-1

Table 2. (cont'd)

Site #	Waterbody	Nearest Urban Centre	Description of Survey Site	Match to site surveyed in 1997
TR-A	Thames River	Chatham	Thames River in Chatham	ns, too deep
TR-B	Thames River	Chatham	3 mi. NE of Chatham	ns, too deep
TR-C	Thames River	Thamesville	5 miles NE of Thamesville, behind a small museum	TR-97-7
TR-D	Thames River	Tate's Corners	Thames River at Tate's Bridge	TR-97-6
TR-E	Thames River	London	South branch of Thames River, east part of London	ns, inaccessible
TR-F	Thames River	Dorchester	Thames River in Dorchester, just downstream of bridge	TR-97-2
TR-G	Thames River	Wookstock	Thames River below Woodstock	TR-97-1
TR-H	Thames River	Thamesford	Below Thamesford	ns, too polluted
TR-I	McGregor Ck.	Chatham	McGregor Creek at Chatham, in cemetary	ns, too deep
New reach	Thames River	Chatham	Lake St. Clair to Chatham	ns, too deep
New reach	Thames River	Kent Bridge	Louisville to Thamesville	TR-97-8
New reach	Thames River	Bothwell	Bothwell to Tate's Corners	TR-97-9, 10
New reach	Thames River	Delaware	Tate's Corners to Delaware	TR-97-5
SR-A	Sydenham River	Florence	Bridge at Florence, just west of town	SR-97-5
SR-B	Sydenham River	Shetland	1.8 mi NE of Shetland, near Shetland Conservation Area	SR-97-4
SR-C	Sydenham River	Alvinston	5 km downstream of Alvinston at bridge crossing	SR-97-3
SR-D	Sydenham River	Alvinston	At hwy 80 crossing of the Sydenham River below Alvinston	SR-97-2
SR-E	Sydenham River	Alvinston	7.5 km northeast of Alvinston at bridge crossing	SR-97-1
SR-F	Bear Creek	Warwick	4 km southwest of Warwick	SR-97-9
New reach	Sydenham River	Florence	Between Florence and Shetland	SR-97-7
New reach	Bear Creek	Wallaceburg	Wallaceburg to Wilkesport	ns, too deep
New reach	Bear Creek	Petrolia	Petrolia to Warwick	ns, inaccessible

*ns = not sampled

Table 3. Descriptions of all sites surveyed for freshwater mussels in 1997.

Site #	Waterbody	Nearest Urban Centre	Description of Survey Site	Date Surveyed (y/m/d)
GR-97-13[a]	Grand River	West Montrose	At the covered bridge at West Montrose	19970807
GR-97-15	Cox Creek	West Montrose	Cox Creek at Hwy 86 near West Montrose	19970916
GR-97-12[a]	Grand River	Kitchener	Grand River at old King St. bridge in Kitchener: "Stonegate Park"	19970807
GR-97-3	Grand River	Kitchener	2 km. upstream of the Kitchener STP, in Doon Heritage Crossroads Corner Area	19970729
GR-97-2[a]	Grand River	Glen Morris	Grand River at Glen Morris, at canoe launch area downstream of bridge	19970724
GR-97-14	Nith River	Plattsville	Nith River at F.H. Montgomery Nature Resource, upstream of iron bridge	19970808
GR-97-8[a]	Nith River	Canning	Foot bridge upstream of CNR bridge below Canning	19970805
GR-97-9[a]	Grand River	Brantford	Just below the small dam in Brant Conservation Area in Brantford.	19970805
GR-97-1[b]	Grand River	Brantford	Grand River below Brantford, 1st bridge above Oxbow	19970723
GR-97-4[a]	Grand River	Caledonia	0.25 mi upstream of bridge in Caledonia at the Caledonia Conservation Area	19970730
GR-97-5[a]	Grand River	York	Upstream of York about 1.5 mi., along hwy 54 where Rd is next to the river	19970731
GR-97-6[a]	Grand River	York	Between York and Cayuga, 4.5 km north of Cayuga	19970731
GR-97-10[a]	Grand River	Cayuga	Just downstream of the Hwy 3 bridge at Cayuga; west shore only sampled	19970806
GR-97-11[a]	Grand River	Cayuga	Between Cayuga and Byng Park, 6.5 km northwest of the Dunnville dam	19970806
GR-97-7[a]	Grand River	Byng Park	Byng park just upstream of Sulphur Creek outflow above Dunnville Dam	19970801
GR-97-17[a]	Sulphur Creek	Byng Park	Byng park below dam at boat launch	19970997
GR-97-16[a]	Grand River	Port Maitland	Port Maitland at the boat launch, east side of river	19970922
TR-97-1[a]	Thames River	Wookstock	Thames River below Woodstock	19970811
TR-97-11	Thames River	Dorchester	First bridge upstream of Dorchester	19970926
TR-97-2[a]	Thames River	Dorchester	Thames River in Dorchester, just downstream of bridge	19970811
TR-97-3	Thames River	London	South branch Thames river between Dorchester and London	19970812
TR-97-4	Thames River	Delaware	South branch Thames river just above Delaware	19970812
TR-97-5[b]	Thames River	Oneida Indian Reserve	Thames River just north of Oneida Indian Reserve	19970813
TR-97-6[a]	Thames River	Tate's Corners	Thames River at Tate's Bridge	19970813
TR-97-9[b]	Thames River	Big Bend	Big Bend Conservaton Area	19970815
TR-97-10[b]	Thames River	Moraviantown	Northern courner of Moravian Indian Reserve 47	19970924
TR-97-7[a]	Thames River	Thamesville	5 miles NE of Thamesville, behind a small museum	19970814
TR-97-8[b]	Thames River	Kent Bridge	3 km NE of Kent Bridge	19970814
SR-97-9[a]	Bear Creek	Warwick	4 km southwest of Warwick	19970925
SR-97-8	Sydenham River	Melwood C.A.	Melwood Conservation Area, a private ranch access	19970925
SR-97-1[a]	Sydenham River	Alvinston	7.5 km northeast of Alvinston at bridge crossing	19970818
SR-97-2[a]	Sydenham River	Alvinston	At hwy 80 crossing of the Sydenham River below Alvinston	19970819
SR-97-3[a]	Sydenham River	Alvinston	5 km downstream of Alvinston at bridge crossing	19970819
SR-97-4[a]	Sydenham River	Shetland	1.8 mi NE of Shetland, near Shetland Conservation Area	19970820
SR-97-7[b]	Sydenham River	Shetland	.8 km west of Shetland	19970821
SR-97-5[a]	Sydenham River	Florence	Bridge at Florence, just west of town	19970820
SR-97-6	Sydenham River	Croton	Upstream of Dawn Mills, 2.3 km downstream of bridge at Croton	19970821

[a] these sites can be directly matched with historical sites; [b] these sites are located in previously-unsurveyed, high priority reaches.

Table 4. List of rare and unusual specimens of freshwater mussels for which taxonomic identifications were verified by experts.

Specimen ID	Species	Verified by*
GR-97-6 (A1)	*Fusconaia flava*	DLS
GR-97-6 (A2)	*Pleurobema coccineum*	DLS
GR-97-7	*Toxolasma parvus*	DLS
TR-97-6 (A,B)	*Actinonaias ligamentina*	DLS, DHS
TR-97-7	*Actinonaias ligamentina*	DHS
SR-97-1 (A1)	*Pleurobema coccineum*	DLS
SR-97-1 (A2)	*Obovaria subrotunda*	DLS
SR-97-1 (B)	*Actinonaias ligamentina*	DHS
SR-97-2 (A1)	*Epioblasma torulosa rangiana*	DLS
SR-97-2 (A2)	*Villosa fabalis*	DLS
SR-97-2 (A3)	*Pleurobema coccineum*	DLS
SR-97-3 (A1)	*Villosa fabalis*	DLS
SR-97-3 (A2)	*Pleurobema coccineum*	DLS
SR-97-3 (B)	*Actinonaias ligamentina*	DHS
SR-97-6 (A1)	*Villosa fabalis*	DLS
SR-97-6 (A2)	*Epioblasma triquetra***	DLS
SR-97-6 (A3)	*Simpsonaias ambigua*	DLS
SR-97-6 (B)	*Ptychobranchus fasciolaris*	DLS
SR-97-6 (C)	*Actinonaias ligamentina*	DHS
SR-97-7 (A1)	*Villosa fabalis*	DLS
SR-97-7 (A2)	*Ptychobranchus fasciolaris*	DLS
SR-97-7 (B1)	*Villosa fabalis*	DLS
SR-97-7 (B2)	*Pleurobema coccineum*	DLS
SR-97-7 (B3)	*Simpsonaias ambigua*	DLS

*DLS = Dr. David L. Strayer, Institute of Ecosystem Studies, Millbrook NY; DHS = Dr. David H. Stansbery, Ohio State University Museum of Zoology, Columbus, OH.

**due to the condition of this specimen, Dr. Strayer could neither confirm nor refute this identification.

Table 5. Numbers of sites in each river, numbers of sites in all rivers, and numbers of rivers in which each species was found alive in 1997. Numbers of sites where fresh (F) and weathered (W) shells were found are also shown. Numbers of rivers in which each species was found historically is presented for comparison (from Metcalfe-Smith *et al.* 1997).

	Grand River (17 sites)	Thames River (11 sites)	Sydenham River (9 sites)	TOTAL (37 sites)	Rivers (1997)	Rivers (historical)
Actinonaias ligamentina	3	10	7	20	3	3
Alasmidonta marginata	6	10	6	22	3	3
Alasmidonta undulata						
Alasmidonta viridis	1	1F,1W		1	1	3
Amblema plicata plicata	2	7	9	18	3	3
Anodontoides ferussacianus	1	1	1	3	3	3
Cyclonaias tuberculata		6	7	13	2	2
Elliptio complanata						
Elliptio dilatata	2	2	6	10	3	3
Epioblasma torulosa rangiana			4	4	1	1
Epioblasma triquetra		1W	1F,1W		0	3
Fusconaia flava	4	1	4	9	3	3
Lampsilis fasciola	3	1	2F	4	2	3
Lampsilis ovata	4	5	4	13	3	3
Lampsilis radiata radiata						
Lampsilis siliquoidea	6		2	8	2	3
Lasmigona c. complanata		7	8	15	2	3
Lasmigona compressa	1	2F	1	2	2	3
Lasmigona costata	11	11	8	30	3	3
Leptodea fragilis	6	5	7	18	3	3
Ligumia nasuta					0	1
Ligumia recta	5	4	6	15	3	3
Obliquaria reflexa	3			3	1	2
Obovaria olivaria					0	2
Obovaria subrotunda		3W	2F, 3W		0	3
Pleurobema coccineum	1	1F, 6W	1	2	2	3
Potamilus alatus	5	6	6	17	3	3
Ptychobranchus fasciolaris	3W	2F, 2W	5	5	1	3
Pyganodon cataracta						
Pyganodon grandis	8	1F, 2W	7	15	2	3
Quadrula pustulosa	4	5	1	10	3	3
Quadrula quadrula	5	6	4	15	3	3
Simpsonaias ambigua			6F		0	1
Strophitus undulatus	6	1	3	10	3	3
Toxolasma parvus	1			1	1	3
Truncilla donaciformis	1	1F		1	1	2
Truncilla truncata	5	6	5	16	3	3
Utterbackia imbecillis	1F		2F		0	2
Villosa fabalis		4W	3	3	1	2
Villosa iris	1F, 3W	2F, 2W	3	3	1	3

Table 6. Numbers of live specimens of each species observed at all survey sites on the Grand River in 1997. Presence of fresh (F) or weathered (W) shells also indicated; where both F and W shells found, only F are noted.

SPECIES	13[a]	15	12[a]	3	2[a]	14	8[a]	9[a]	1[b]	4[a]	5[a]	6[a]	10[a]	11[a]	7[a]	17[a]	16[a]	Total live animals of all species/site
Actinonaias ligamentina								4	1	F	2	F	F		W	W		7
Alasmidonta marginata	6		9	F	F	1	7	10	F	F	7	F	F			F		40
Alasmidonta undulata																		
Alasmidonta viridis	W	4		W	W							W						4
Amblema p. plicata										F	W	1	F	F	1	W		2
Anodontoides ferussacianus	1					F												1
Cyclonaias tuberculata																		
Elliptio complanata																		
Elliptio dilatata	5		W	F	F	W	5	W	W	W	F	W						10
Epioblasma t. rangiana																		
Epioblasma triquetra																		
Fusconaia flava								W		F	1	1	F	3	3			8
Lampsilis fasciola	1		8	8	W	W	F			W	W							17
Lampsilis ovata					W			4	3	2	1							10
Lampsilis r. radiata																		
Lampsilis siliquoidea	5	15	W	F	W	1	F	5	4	F	W	3		W	W	W		33
Lasmigona c. complanata																		
Lasmigona compressa							F				1							1
Lasmigona costata	122[c]	8	23	2	F	6	6	13	4	4	15	7	F			W		88
Leptodea fragilis							1			4	3	3	2			7		20
Ligumia nasuta																		
Ligumia recta								1	4	4	6	1	F			W		16
Obliquaria reflexa											F	1	F		F	1	1	3
Obovaria olivaria																		
Obovaria subrotunda																		
Pleurobema coccineum									W	F	W	1	F					1
Potamilus alatus										2	2	1	F		F	5	1	11
Ptychobranchus fasciolaris										W	W	W						
Pyganodon cataracta																		
Pyganodon grandis	9	24		F	W	1	F	2		F		1	F	1		1	10	49
Quadrula p. pustulosa										F	3	22	3		F	1		29
Quadrula quadrula													1	57	27	15	44	144
Simpsonaias ambigua																		
Strophitus undulatus	139[c]	19	4	2	F	F	2	F	F	F	3							30
Toxolasma parvus															2			2
Truncilla donaciformis																11		11
Truncilla truncata								F		F	5	31	6		F	11	4	57
Utterbackia imbecillis														F				
Villosa fabalis																		
Villosa iris	F						W			W		W						
Total live animals of each species	288	70	44	12	0	9	21	39	16	16	49	73	12	61	33	52	60	594
Diversity: Live only	8	5	4	3	0	4	5	7	5	5	12	12	4	3	4	8	5	
Diversity: Live + Dead	10	5	6	8	9	8	10	11	9	19	19	18	14	6	10	14	5	

[a] direct match with historical site

[b] site located in previously-unsurveyed, high priority reach.

[c] calculated value (see text).

Table 7. Numbers of live specimens of each species observed at all survey sites on the Thames River in 1997. Presence of fresh (F) or weathered (W) shells also indicated; where both F and W shells found, only F are noted.

SPECIES	1[a]	11	2[a]	3	4	5[b]	6[a]	9[b]	10[b]	7[a]	8[b]	Total live animals of all species/site
Actinonaias ligamentina		1	98	36	14	35	64	91	160	81	36	616
Alasmidonta marginata		2	10	10	23	2	4	5	4	2	2	64
Alasmidonta undulata												
Alasmidonta viridis			F	W								
Amblema p. plicata					2	2	6	5	16	6	1	38
Anodontoides ferussacianus		F	1									1
Cyclonaias tuberculata			2	1	W	W	9	F	6	10	2	30
Elliptio complanata												
Elliptio dilatata	F		3	1			W	F	W	W	W	4
Epioblasma t. rangiana												
Epioblasma triquetra										W		
Fusconaia flava	W	W	2	F	W	W			F		W	2
Lampsilis fasciola		F	4	F								4
Lampsilis ovata				W	6	2	W	4	1	F	2	15
Lampsilis r. radiata												
Lampsilis siliquoidea												
Lasmigona c. complanata			1		26	2	2	1	3	3		38
Lasmigona compressa	F		F									
Lasmigona costata	7	39	236[c]	42	53	10	8	2	6	6	11	184
Leptodea fragilis					F		6	7	12	8	7	40
Ligumia nasuta												
Ligumia recta					6	5	W	1	W	5	W	17
Obliquaria reflexa												
Obovaria olivaria												
Obovaria subrotunda						W	W	W				
Pleurobema coccineum	W	W	W				W		W	F	W	
Potamilus alatus					5	2	5	5	8	W	7	32
Ptychobranchus fasciolaris						W	W			F	F	
Pyganodon cataracta												
Pyganodon grandis	W		W								F	
Quadrula pustulosa						W	25	19	21	29	7	101
Quadrula quadrula					1		44	19	17	6	2	89
Simpsonaias ambigua												
Strophitus undulatus			4	F								4
Toxolasma parvus												
Truncilla donaciformis								F				
Truncilla truncata					2	F	18	7	1	1	3	32
Utterbackia imbecillis												
Villosa fabalis			W	W		W					W	
Villosa iris	W	W	F	F								0
Total live animals of each species	7	42	361	90	138	60	191	166	255	157	80	1311
Diversity: Live only	1	3	10	5	10	8	11	12	12	11	11	
Diversity: Live + Dead	7	8	16	12	13	15	17	16	16	17	18	

[a], [b] and [c] as per Grand River

Table 8. Numbers of live specimens of each species observed at all survey sites on the Sydenham River in 1997. Presence of fresh (F) or weathered (W) shells also indicated; where both F and W shells found, only F are noted.

SPECIES	9[a]	8	1[a]	2[a]	3[a]	4[a]	7[b]	5[a]	6	Total live animals of all species/site
Actinonaias ligamentina		5	1	F	5	5	32	31	28	107
Alasmidonta marginata		F	2	6	5	1	2	F	4	20
Alasmidonta undulata										
Alasmidonta viridis										
Amblema p. plicata	44	4	22	25	16	28	57	7	25	228
Anodontoides ferussacianus	4									4
Cyclonaias tuberculata			1	6	3	8	42	14	167	241
Elliptio complanata										
Elliptio dilatata	40		F	3	3	1	7	W	5	59
Epioblasma t. rangiana				F	2	F	5	2	2	11
Epioblasma triquetra			F					W		
Fusconaia flava	21	F	F	F	F	1	13	F	12	47
Lampsilis fasciola				F	F					
Lampsilis ovata		6	F	2	1		2	W	F	11
Lampsilis r. radiata										
Lampsilis siliquoidea	26	F	3	W		W		W		29
Lasmigona c. complanata	61	13	9	1		4	14	11	2	115
Lasmigona compressa	1									1
Lasmigona costata		22	10	57	23	50	90	42	42	336
Leptodea fragilis		8	1	F	8	5	15	7	9	53
Ligumia nasuta										
Ligumia recta		10	F	1	7	1	F	3	1	23
Obliquaria reflexa										
Obovaria olivaria										
Obovaria subrotunda		F	F			W	W	W		
Pleurobema coccineum	14	W	F	F	F			W		14
Potamilus alatus			3		1	2	7	1	3	17
Ptychobranchus fasciolaris		F	F	F	1	1	1	3	4	10
Pyganodon cataracta										
Pyganodon grandis	19	7	3	3	1	1	F	F	1	35
Quadrula pustulosa								F	1	1
Quadrula quadrula						16	16	2	21	55
Simpsonaias ambigua	F				F	F	F	F	F	
Strophitus undulatus	6		F		1		1			8
Toxolasma parvus										
Truncilla donaciformis										
Truncilla truncata			1		F	2	20	1	14	38
Utterbackia imbecillis					F	F				
Villosa fabalis			W	1	1		5	F	2	8
Villosa iris	1		F	1	1	F	F	W	F	4
Total live animals of each species	237	75	56	106	79	126	329	124	343	1475
Diversity: Live only	11	8	11	11	16	15	17	12	18	
Diversity: Live + Dead	12	14	22	19	22	21	22	25	21	

[a] and [b] as per Grand River.

Table 9. Differences in the composition of the mussel communities of the Grand, Thames and Sydenham 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.

Grand River	Thames River	Sydenham River
Lasmigona costata (11)*	*Lasmigona costata* (11)	*Amblema p. plicata* (9)
Pyganodon grandis (8)	*Actinonaias ligamentina* (10)	*Lasmigona c. complanata* (8)
Alasmidonta marginata (6)	*Alasmidonta marginata* (10)	*Lasmigona costata* (8)
Lampsilis siliquoidea (6)	*Amblema p. plicata* (7)	*Actinonaias ligamentina* (7)
Leptodea fragilis (6)	*Lasmigona c. complanata* (7)	*Cyclonaias tuberculata* (7)
Strophitus undulatus (6)	*Cyclonaias tuberculata* (6)	*Leptodea fragilis* (7)
Ligumia recta (5)	*Potamilus alatus* (6)	*Pyganodon grandis* (7)
Potamilus alatus (5)	*Quadrula quadrula* (6)	*Alasmidonta marginata* (6)
Quadrula quadrula (5)	*Truncilla truncata* (6)	*Elliptio dilatata* (6)
Truncilla truncata (5)	*Quadrula p. pustulosa* (5)	*Potamilus alatus* (6)

*values in brackets indicate the numbers of sites where each species was found alive in 1997.

Table 10. Numbers of historical records in the entire Lower Great Lakes Unionid Database, from the study rivers only (Grand, Thames and Sydenham Rivers), and from areas now infested with zebra mussels, for 21 species of freshwater mussels.

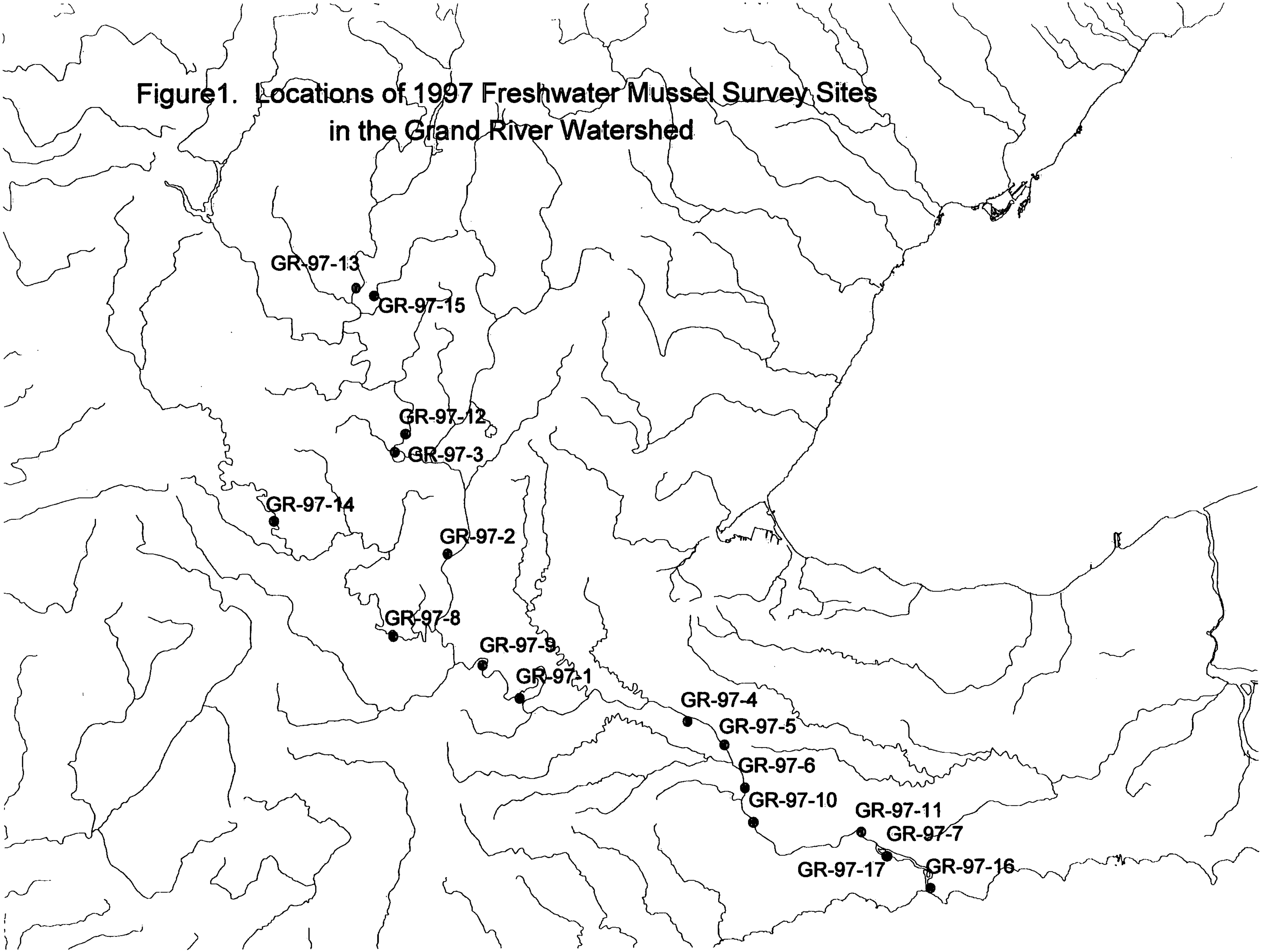
Species	Total # of historical records in database	# of historical records from the study rivers (bracketed value = % of total)	# of historical records in zebra mussel infested areas (bracketed value = % of total)
Epioblasma t. rangiana	10	4 (40.0%)	6 (60%)
Epioblasma triquetra	27	7 (25.9%)	20 (74.1%)
Obliquaria reflexa	31	9 (29.0%)	22 (71.0%)
Obovaria olivaria	12	2 (17%)	10 (83%)
Simpsonaias ambigua	4	2 (50.0%)	2 (50.0%)
Toxolasma parvus	8	7 (87.5%)	1 (12.5%)
Cyclonaias tuberculata	43	17 (39.5%)	25 (58.1%)
Lampsilis fasciola	21	16 (76.0%)	3 (14.3%)
Obovaria subrotunda	40	15 (37.5%)	25 (62.5%)
Ptychobranchus fasciolaris	57	22 (38.6%)	34 (59.6%)
Utterbackia imbecillis	12	4 (33.3%)	7 (58.3%)
Villosa fabalis	12	4 (33.3%)	8 (67.7%)
Truncilla donaciformis	29	7 (24.1%)	22 (75.9%)
Truncilla truncata	58	32 (55.2%)	26 (44.8%)
Actinonaias ligmentina	66	58 (87.9%)	4 (6.1%)
Pleurobema coccineum	59	22 (37.0%)	37 (63.0%)
Quadrula p. pustulosa	48	26 (54.2%)	22 (45.8%)
Quadrula quadrula	56	42 (75.0%)	14 (25.0%)
Fusconaia flava	121	52 (43.0%)	68 (56.2%)
Ligumia nasuta	121	4 (3.3%)	111 (91.7%)
Villosa iris	75	33 (44.0%)	32 (42.7%)

Table 11. Proposed changes to the provincial conservation status ranks (SRANKs) of target mussel species.

SPECIES*	Current SRANK**	Proposed SRANK
Epioblasma torulosa rangiana	**SH**	**S1**
Epioblasma triquetra	SH	SH
Obliquaria reflexa	**SH**	**S1**
Obovaria olivaria	SH	SH
Simpsonaias ambigua	**SH**	**S1**
Toxolasma parvus	**SH**	**S1**
Cyclonaias tuberculata	**S1**	**S2**
Lampsilis fasciola	S1	S1
Obovaria subrotunda	S1	S1
Ptychobranchus fasciolaris	S1	S1
Utterbackia imbecillis	S1	S1
Villosa fabalis	S1	S1
Truncilla donaciformis	**S1S2**	**S1**
Truncilla truncata	**S1S2**	**S2S3**
Actinonaias ligamentina	S2	S2
Pleurobema coccineum	**S2**	**S1**
Quadrula pustulosa pustulosa	S2	S2
Quadrula quadrula	S2	S2
Fusconaia flava	**S3**	**S2S3**
Ligumia nasuta	**S3**	**S2**
Villosa iris	**S3**	**S2**

*changes in SRANKs are proposed for species shown in boldface type.
**see Table 1 for definitions of SRANKs.

Figure1. Locations of 1997 Freshwater Mussel Survey Sites in the Grand River Watershed



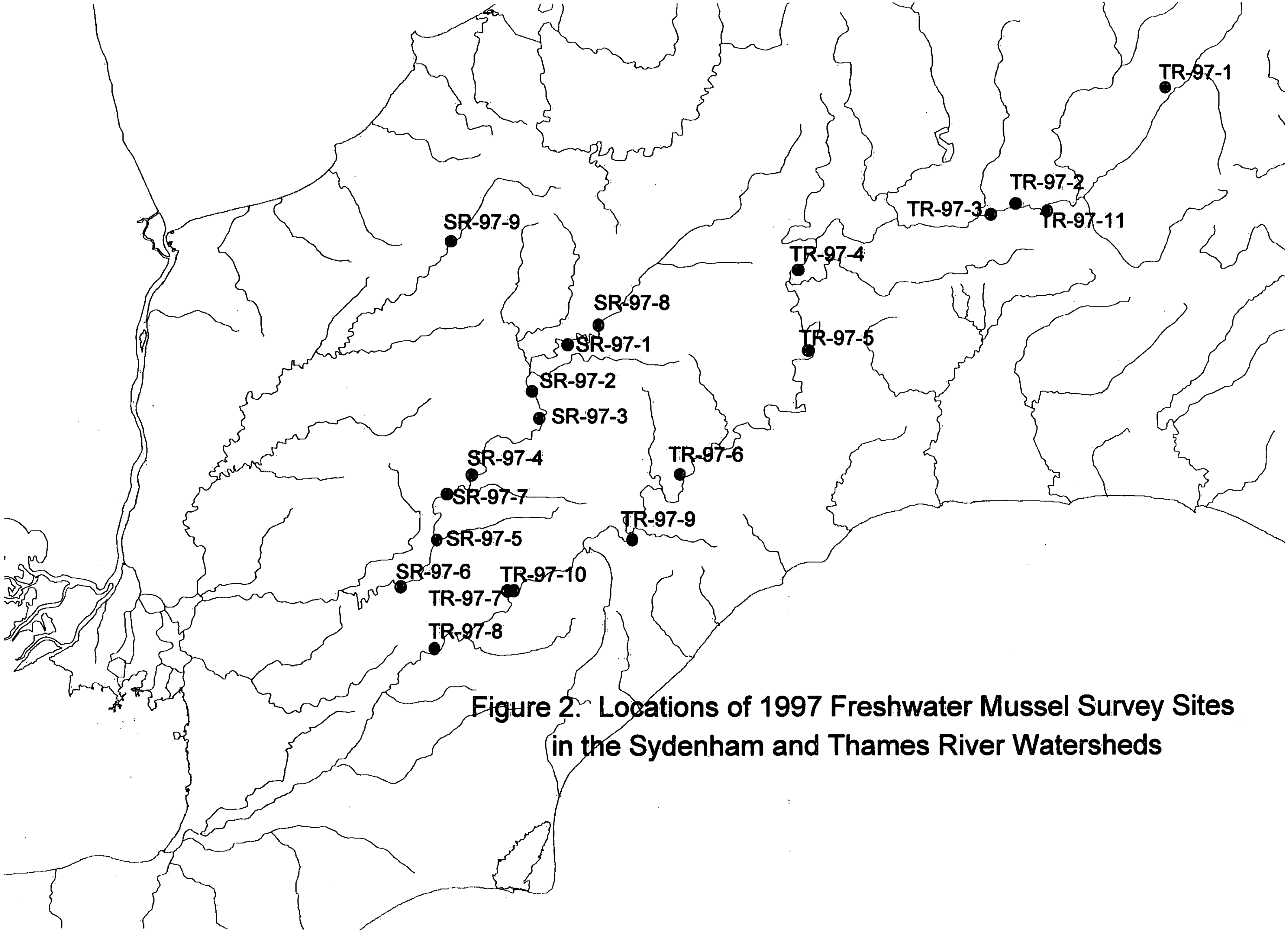


Figure 2. Locations of 1997 Freshwater Mussel Survey Sites in the Sydenham and Thames River Watersheds

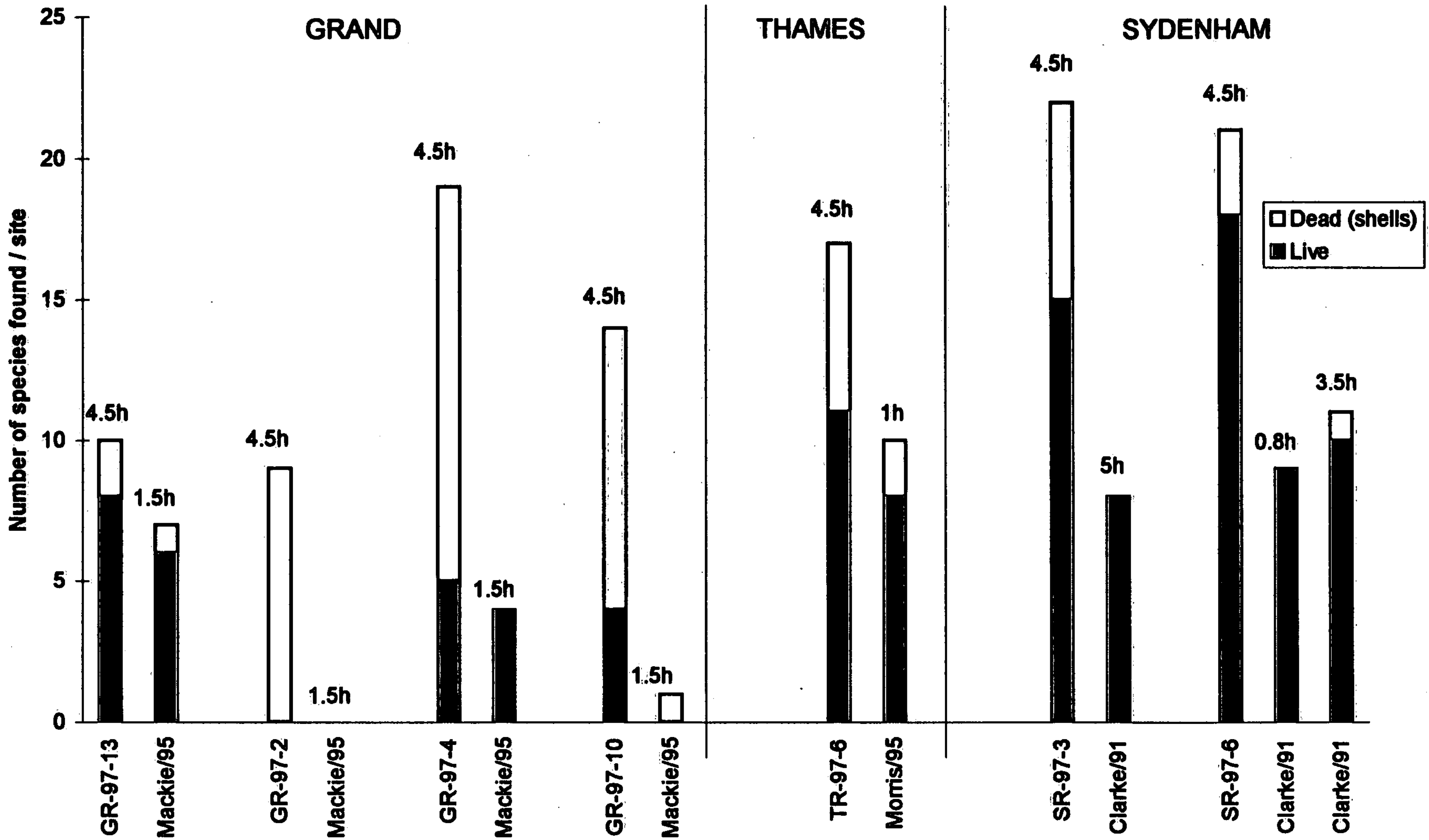


Fig. 3. Comparisons of numbers of species found (live and dead) using 4.5 person-hours of effort during the present study, with numbers of species found using different sampling efforts during other surveys conducted in the 1990s at the same sites.

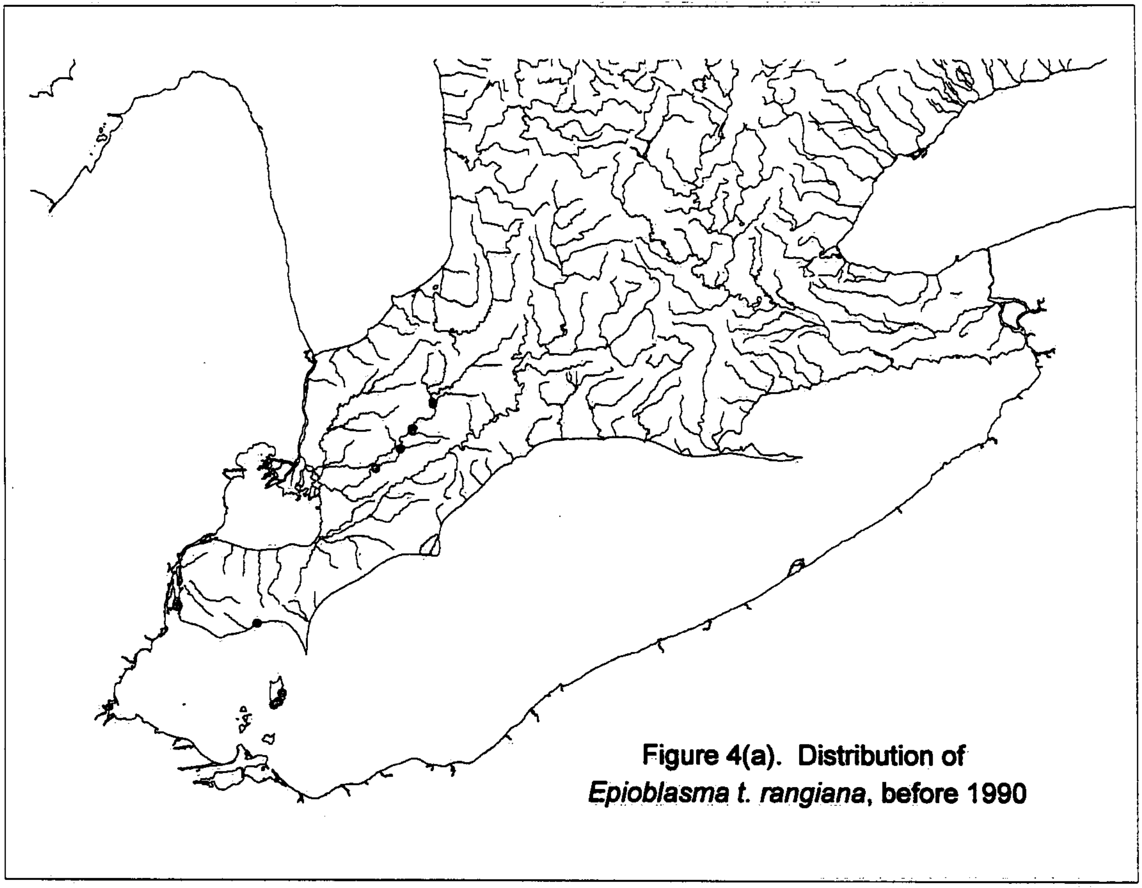


Figure 4(a). Distribution of *Epioblasma t. rangiana*, before 1990

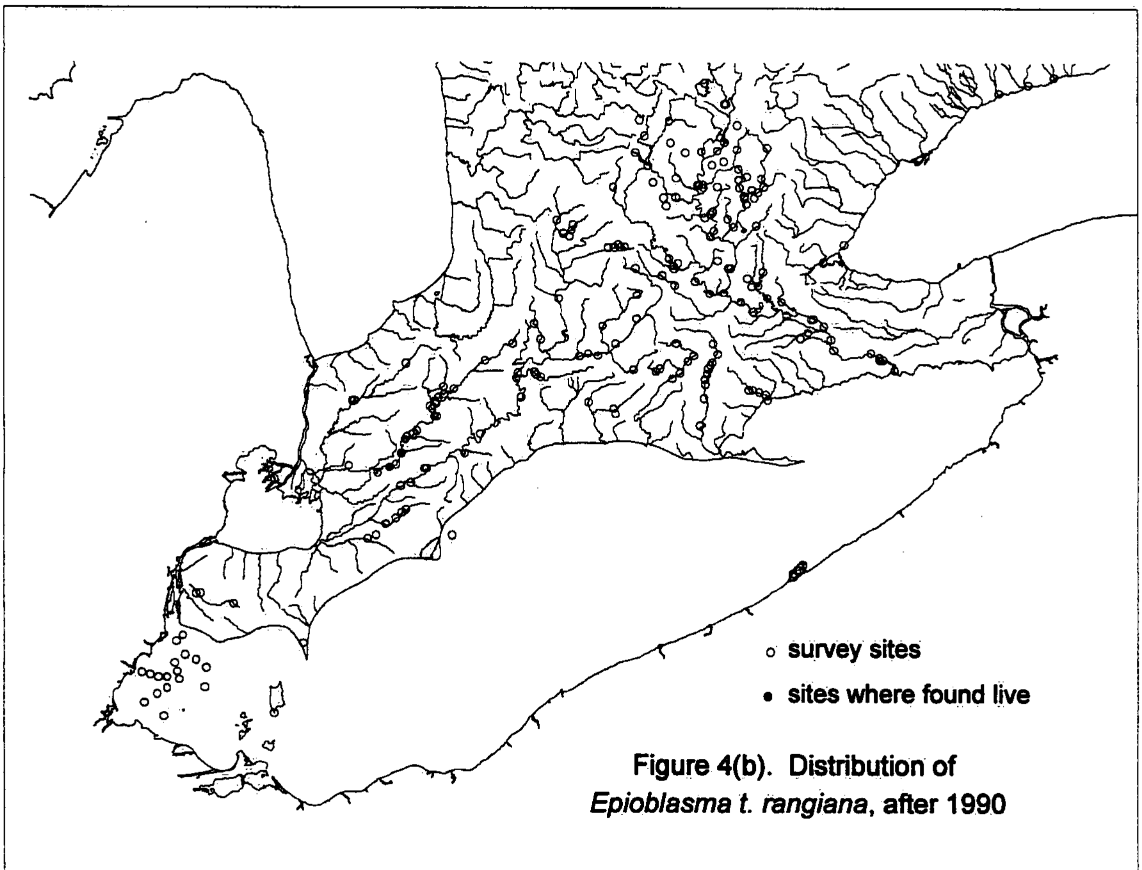


Figure 4(b). Distribution of *Epioblasma t. rangiana*, after 1990

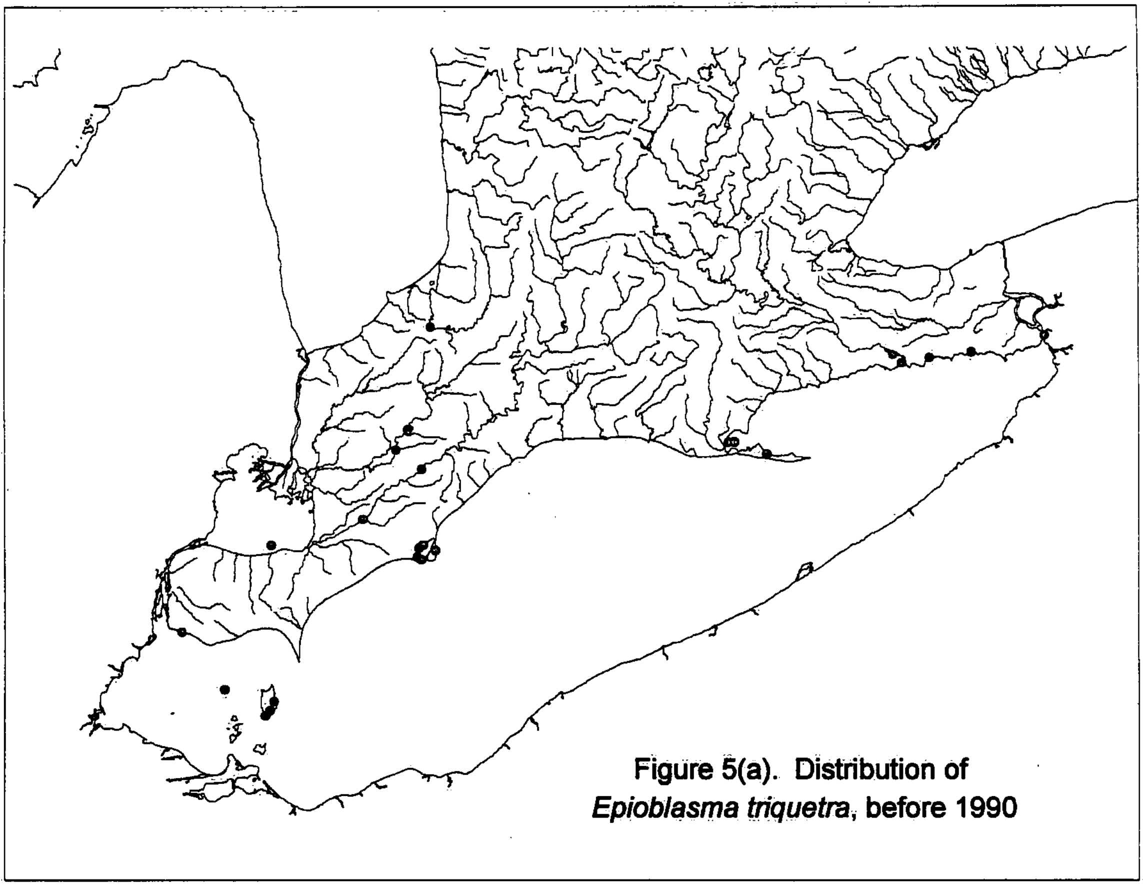


Figure 5(a). Distribution of *Epioblasma triquetra*, before 1990

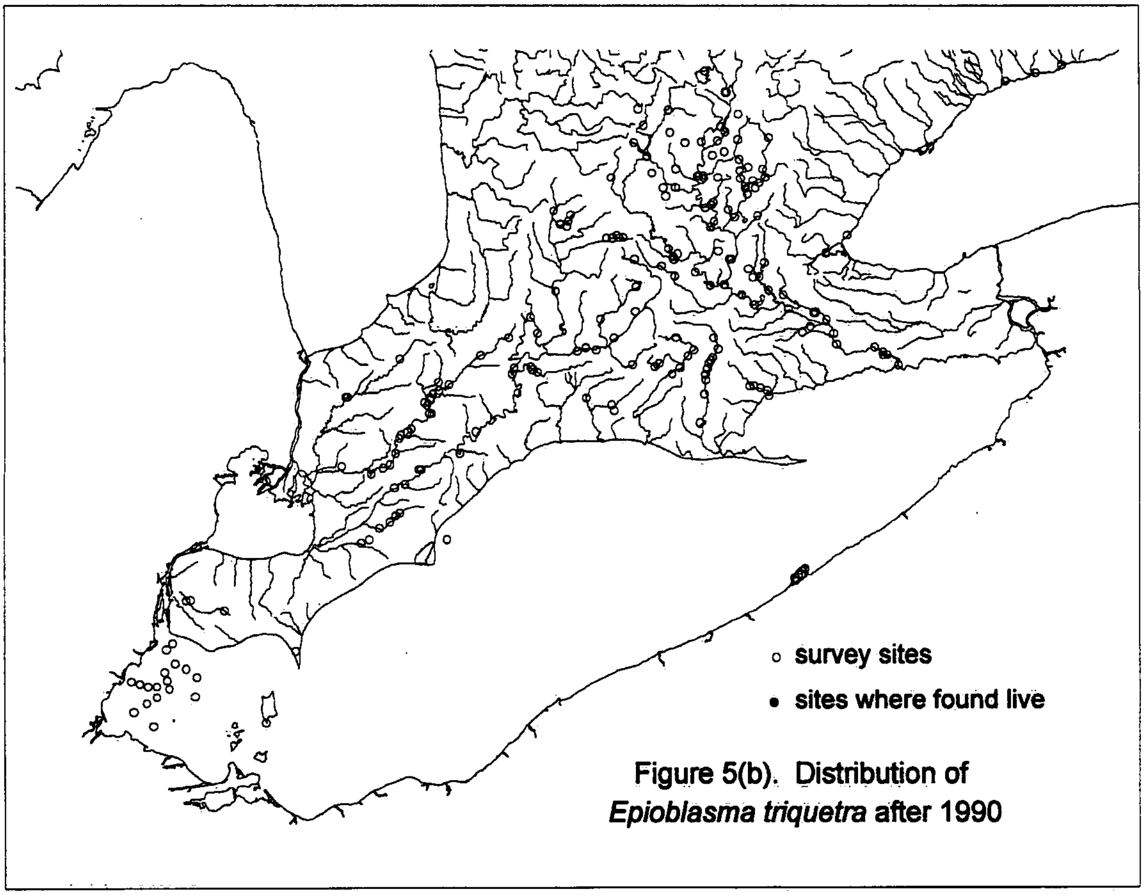


Figure 5(b). Distribution of *Epioblasma triquetra* after 1990

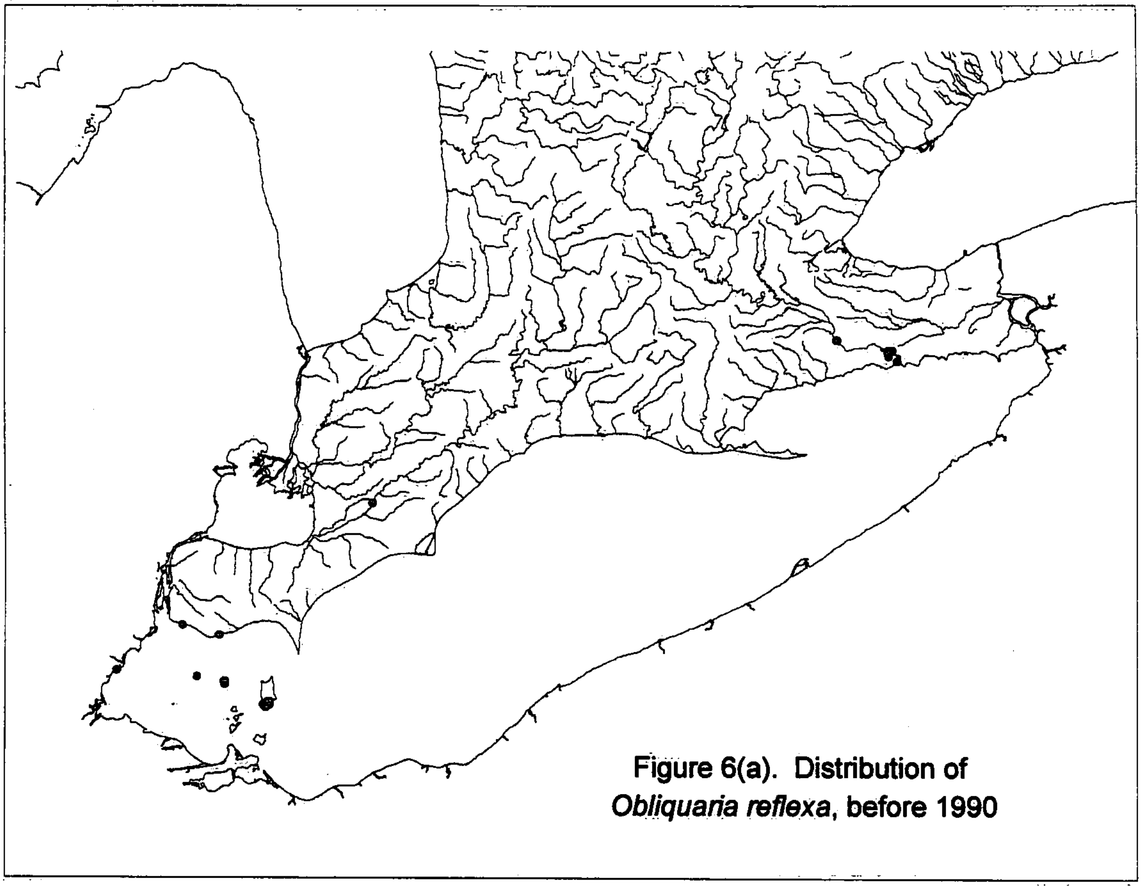


Figure 6(a). Distribution of *Obliquaria reflexa*, before 1990

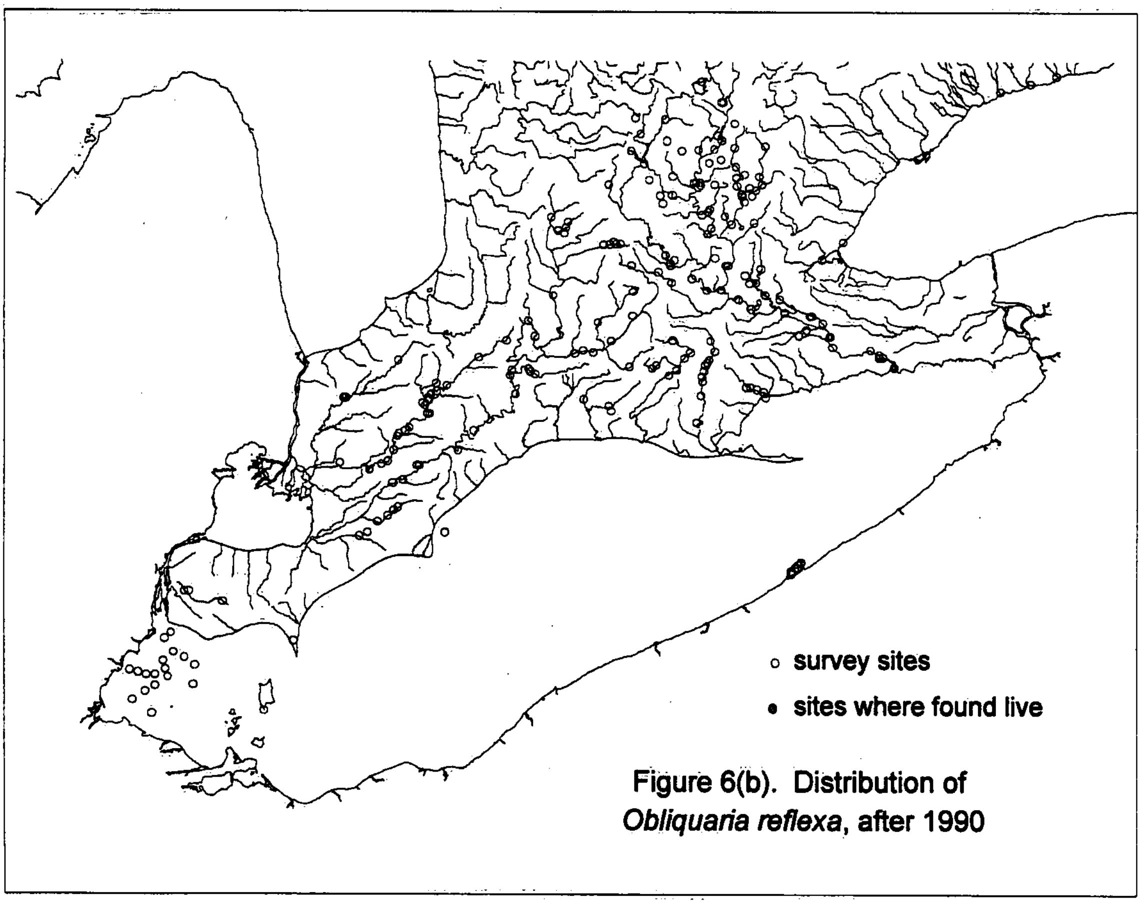


Figure 6(b). Distribution of *Obliquaria reflexa*, after 1990

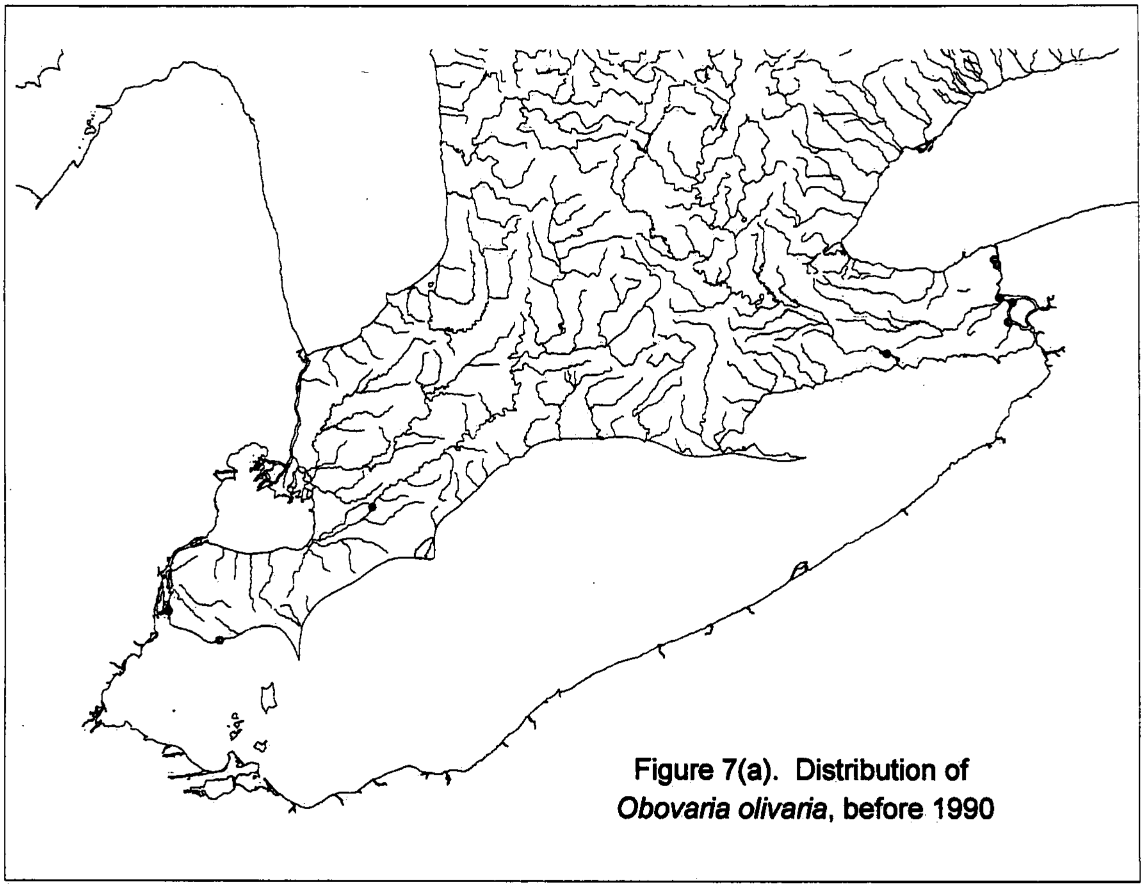


Figure 7(a). Distribution of *Obovaria olivaria*, before 1990

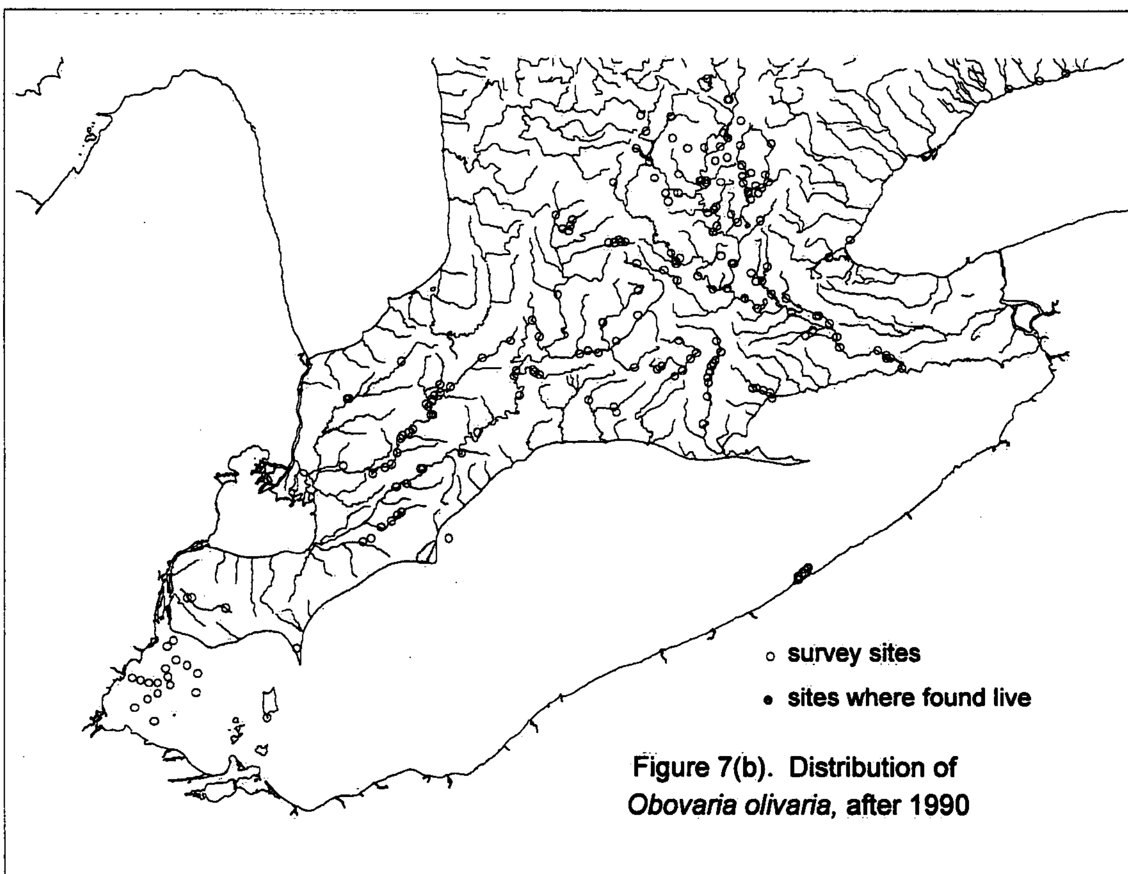


Figure 7(b). Distribution of *Obovaria olivaria*, after 1990

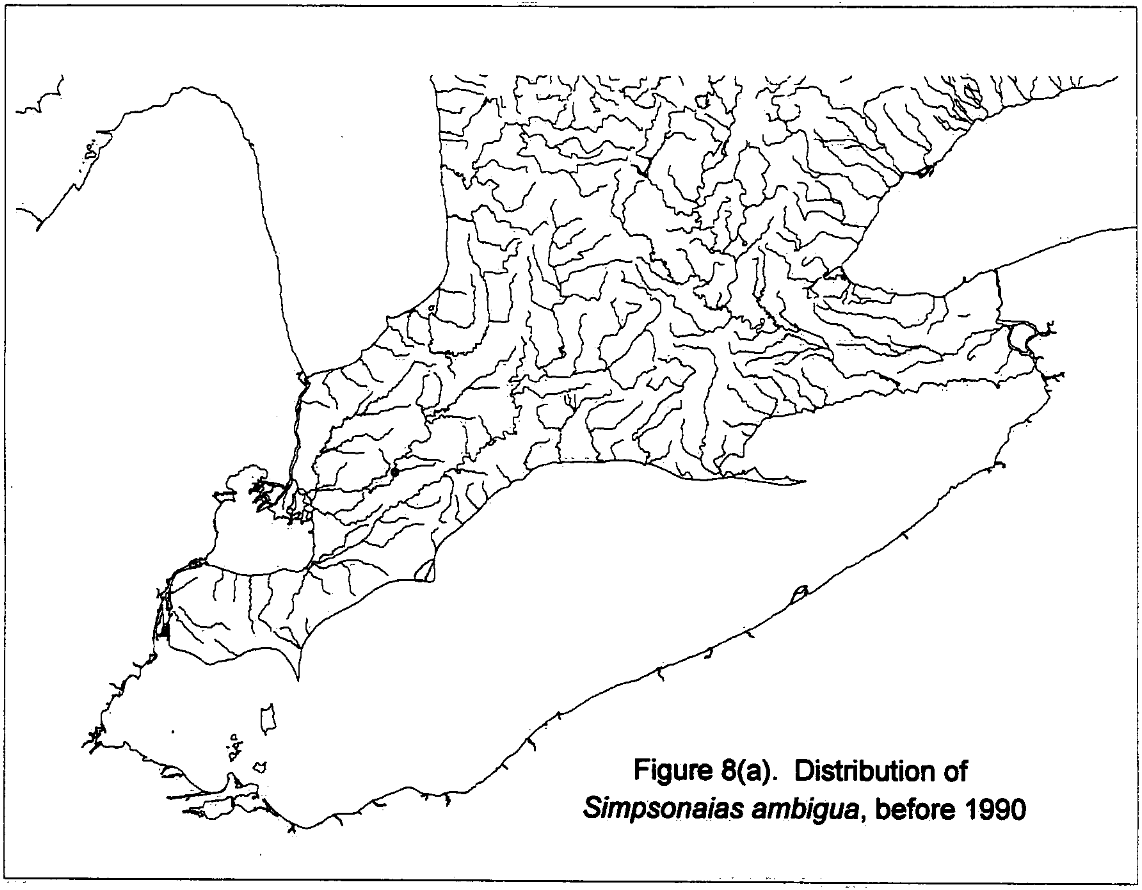


Figure 8(a). Distribution of *Simpsonaias ambigua*, before 1990

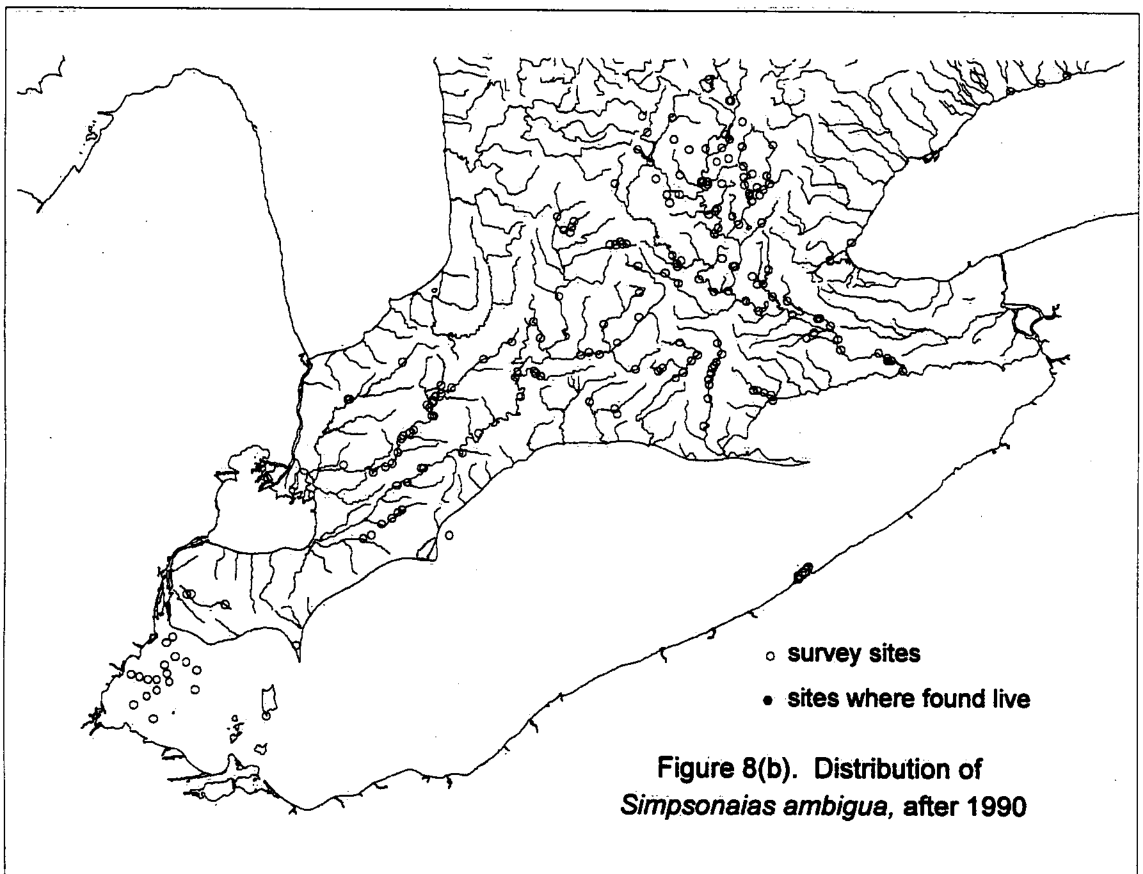


Figure 8(b). Distribution of *Simpsonaias ambigua*, after 1990

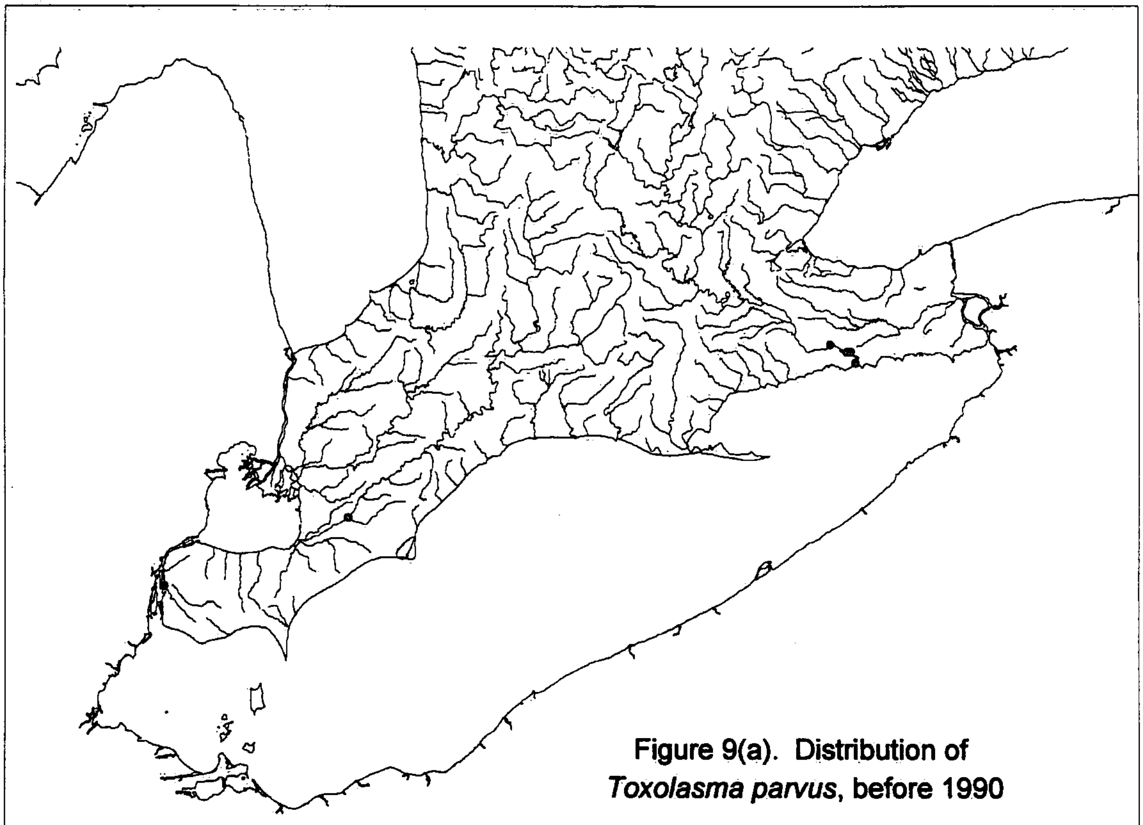


Figure 9(a). Distribution of *Toxolasma parvus*, before 1990

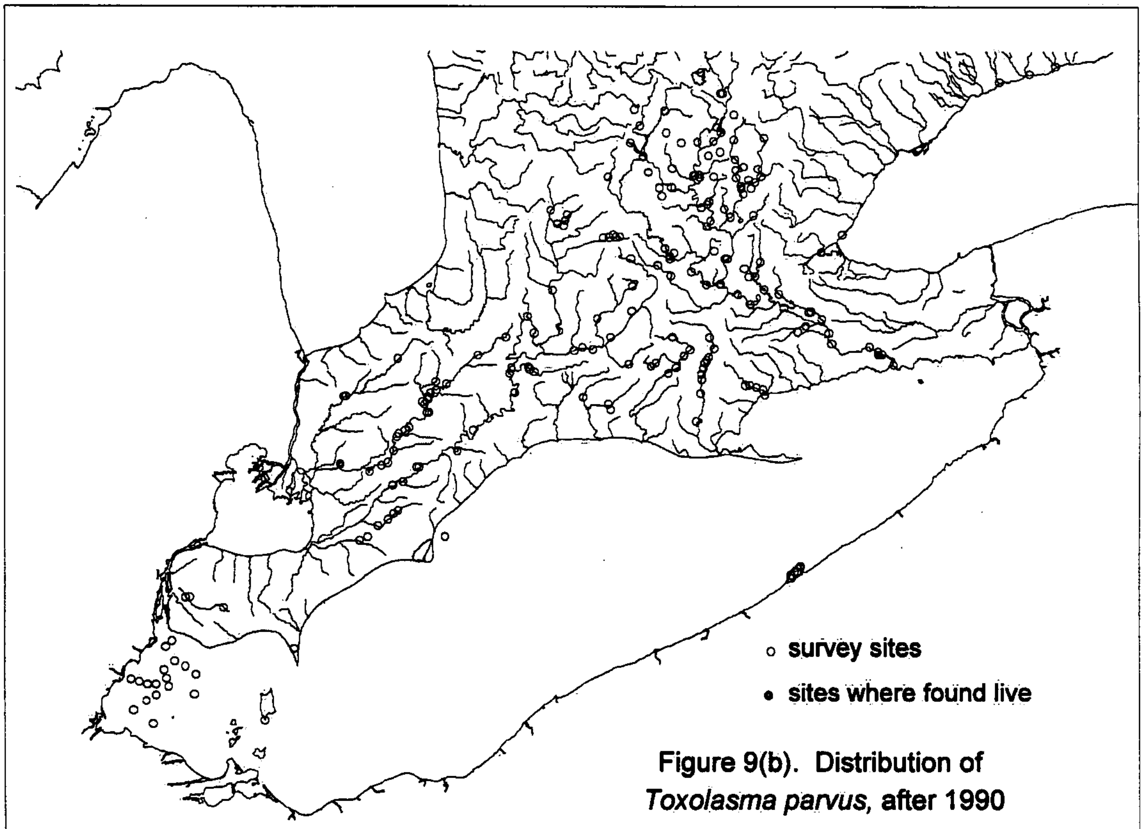


Figure 9(b). Distribution of *Toxolasma parvus*, after 1990

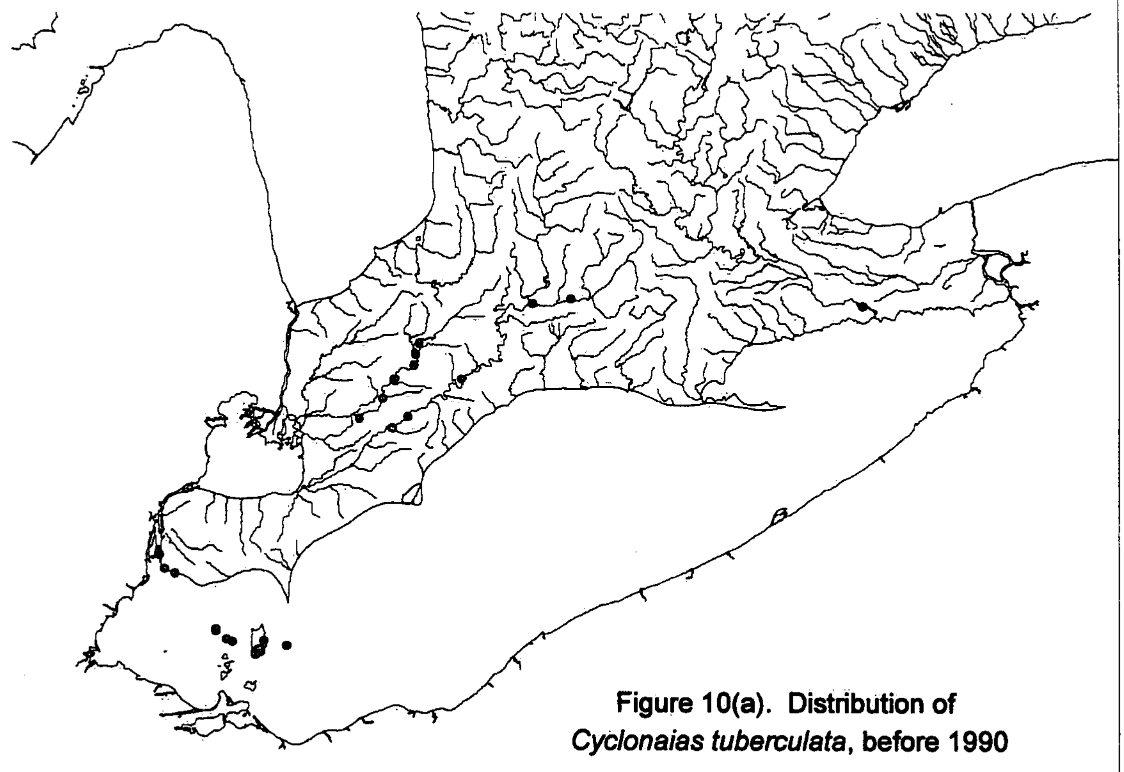


Figure 10(a). Distribution of *Cyclonaias tuberculata*, before 1990

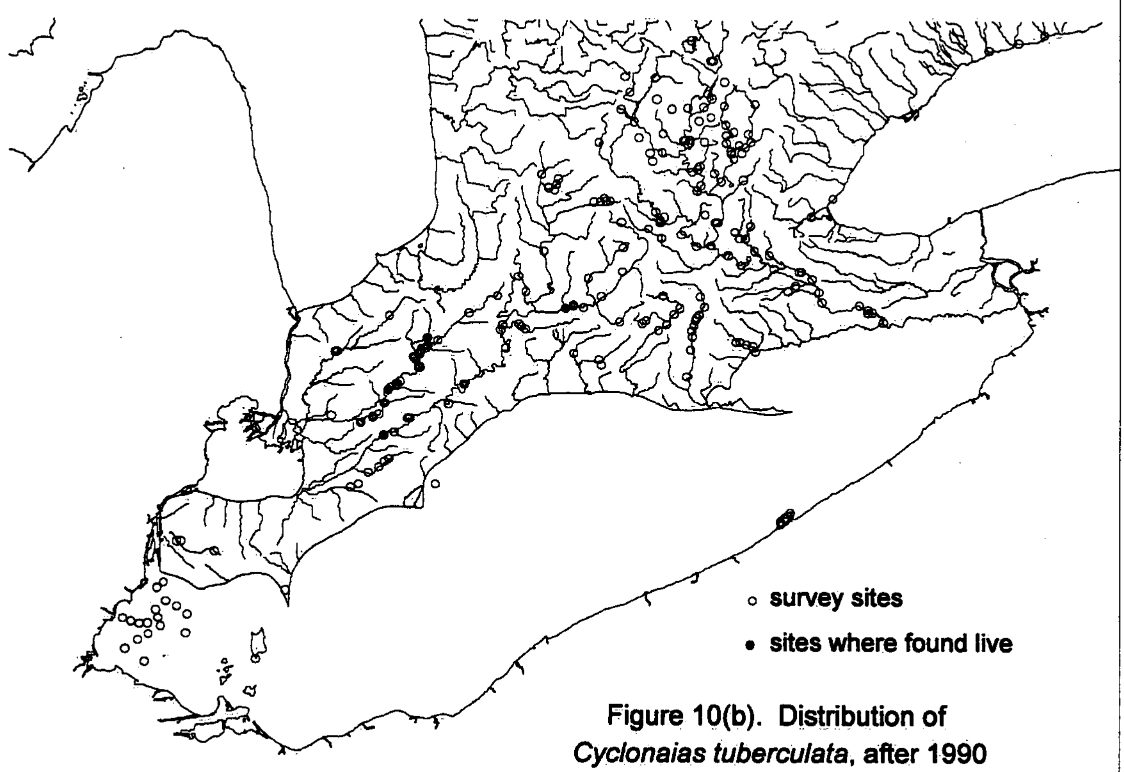


Figure 10(b). Distribution of *Cyclonaias tuberculata*, after 1990

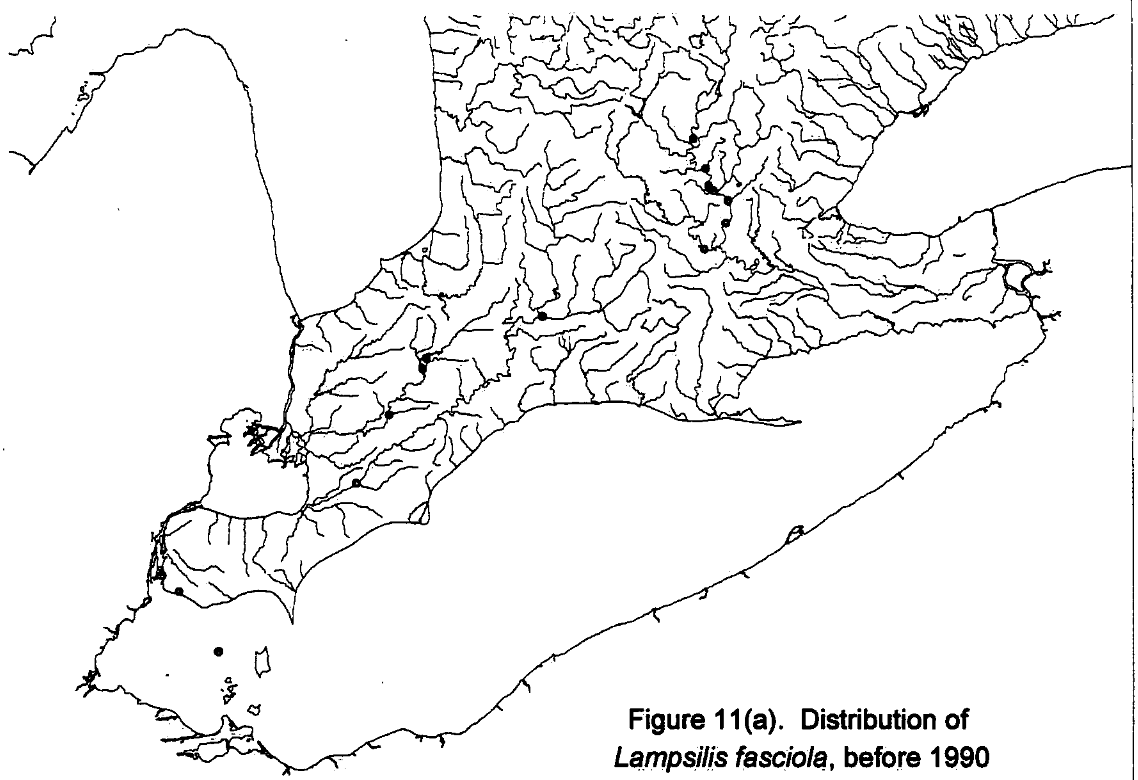


Figure 11(a). Distribution of *Lampsilis fasciola*, before 1990

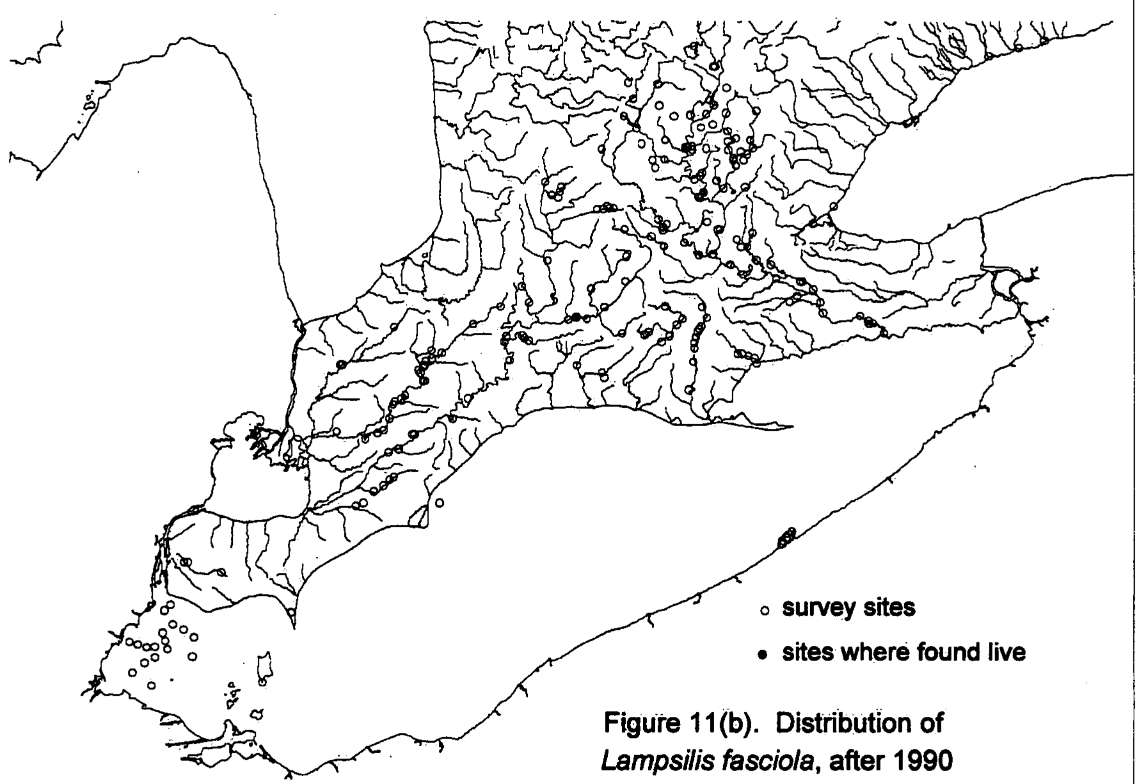


Figure 11(b). Distribution of *Lampsilis fasciola*, after 1990

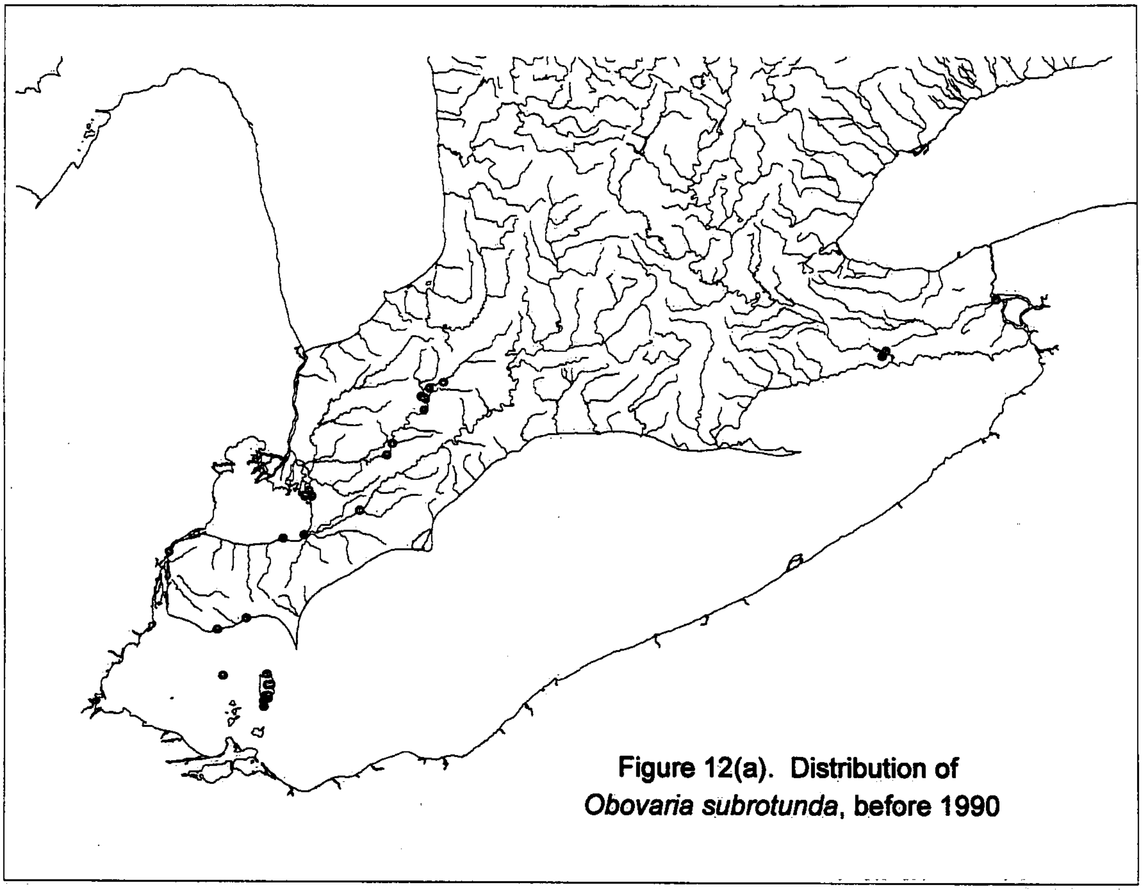


Figure 12(a). Distribution of *Obovaria subrotunda*, before 1990

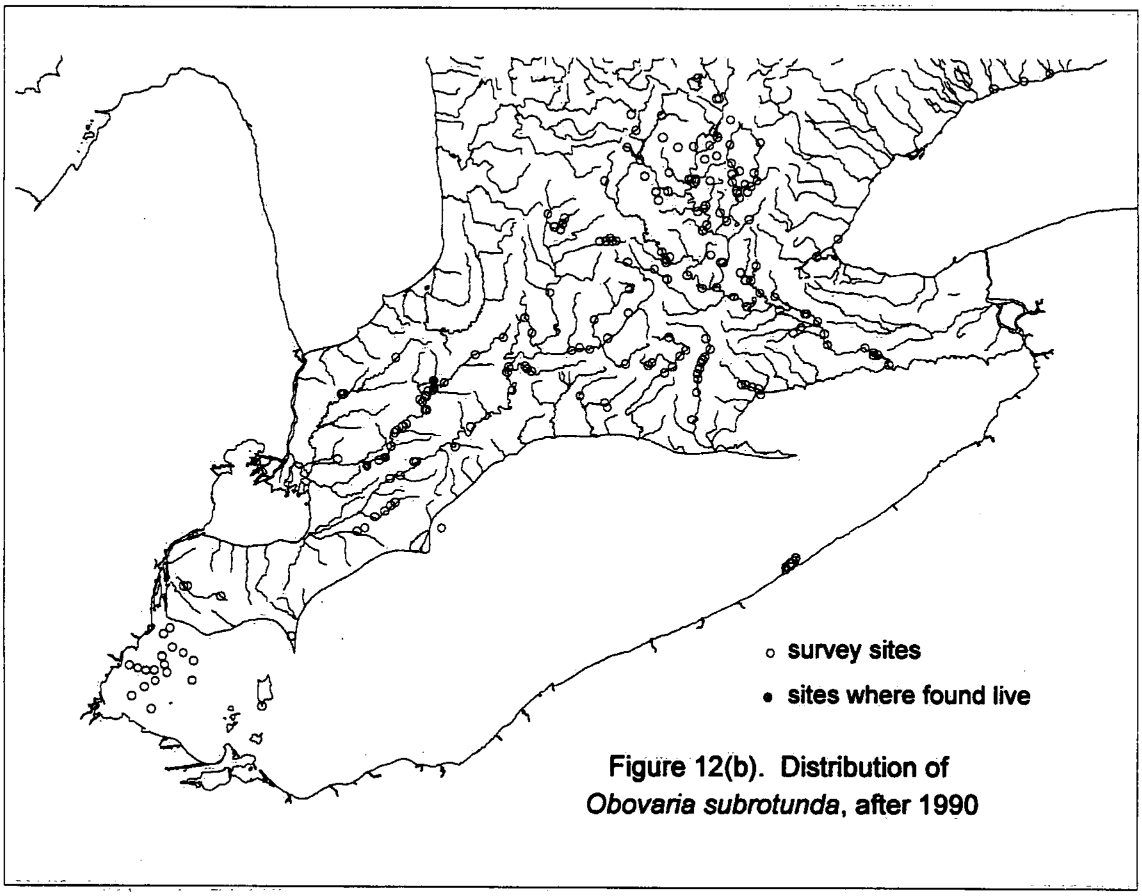


Figure 12(b). Distribution of *Obovaria subrotunda*, after 1990

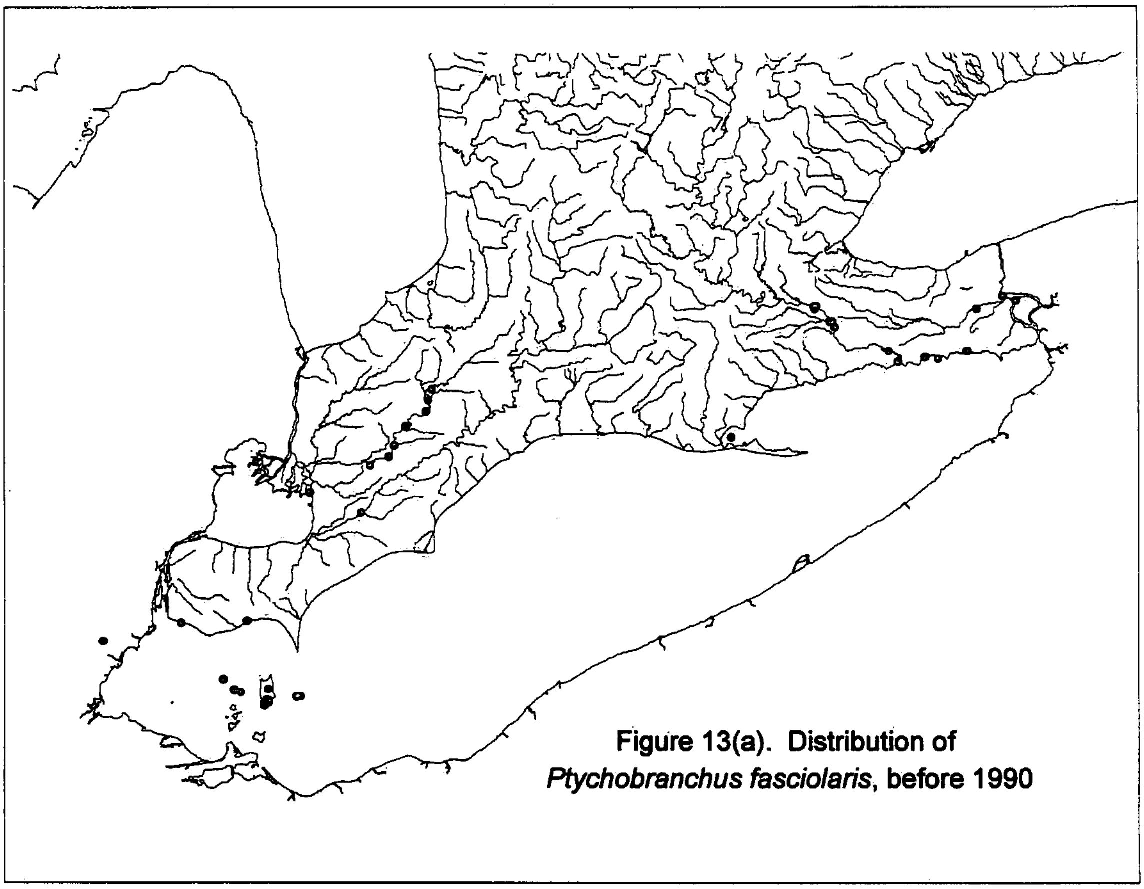


Figure 13(a). Distribution of *Ptychobranchus fasciolaris*, before 1990

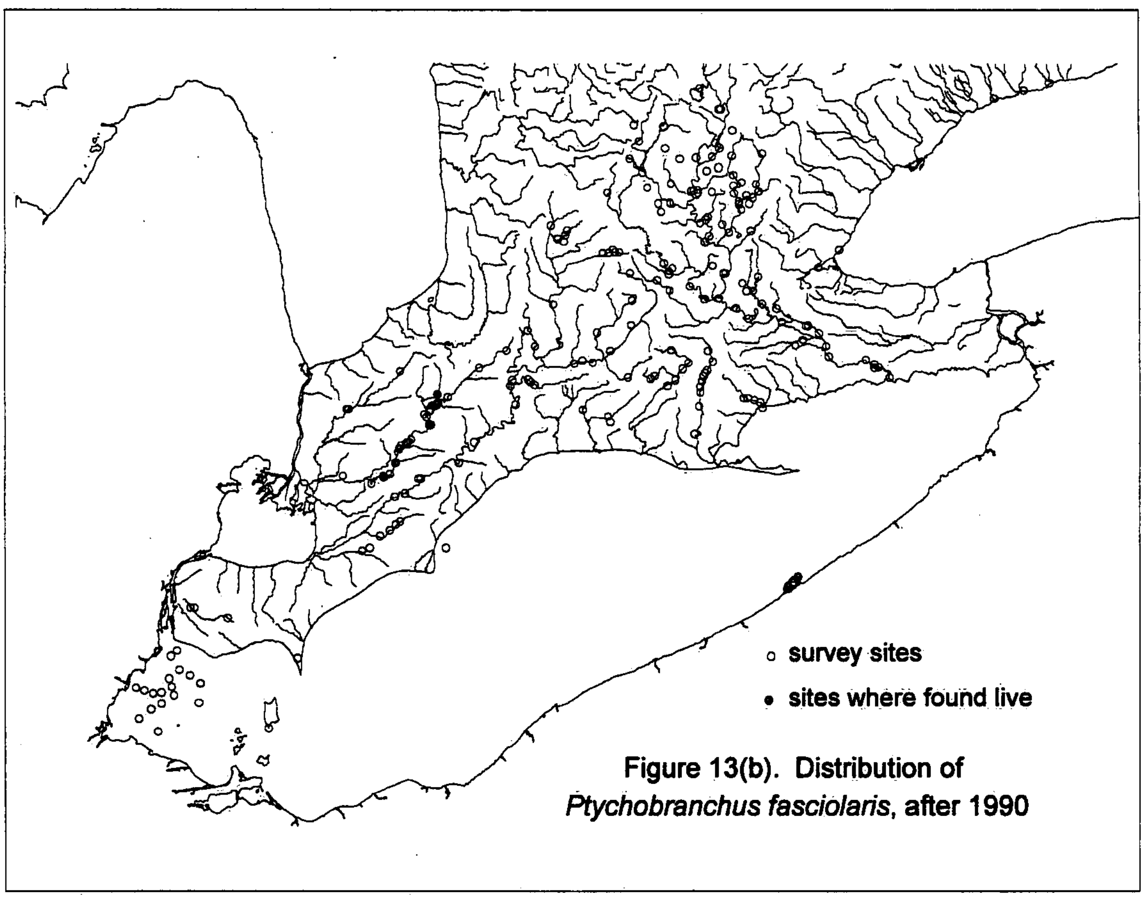


Figure 13(b). Distribution of *Ptychobranchus fasciolaris*, after 1990

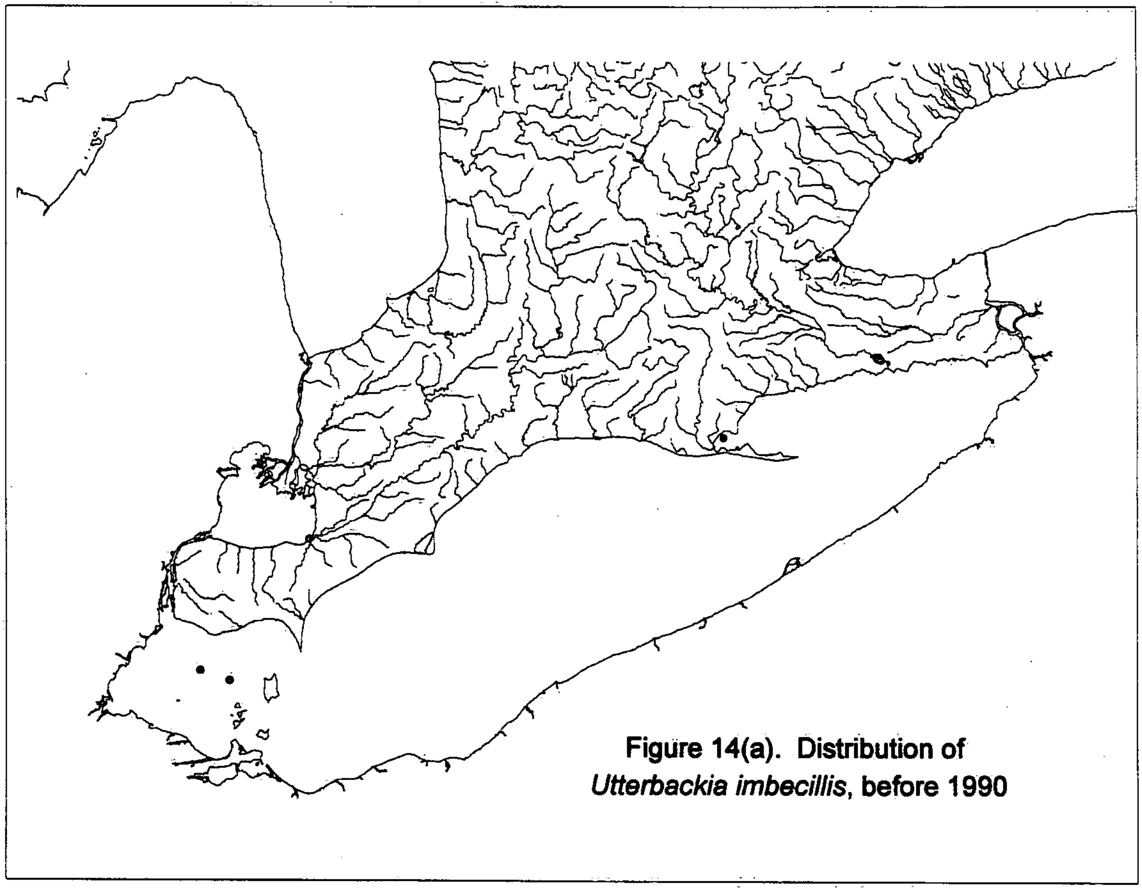


Figure 14(a). Distribution of *Utterbackia imbecillis*, before 1990

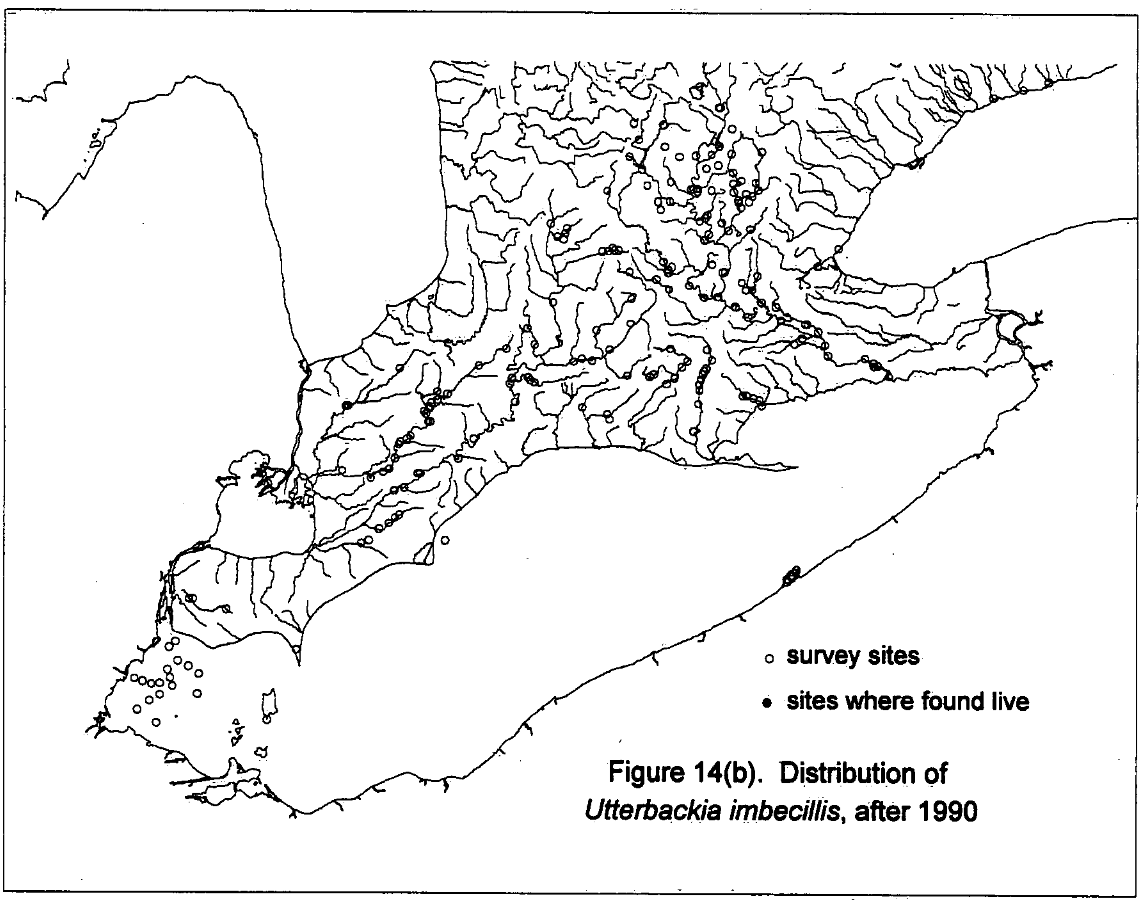


Figure 14(b). Distribution of *Utterbackia imbecillis*, after 1990

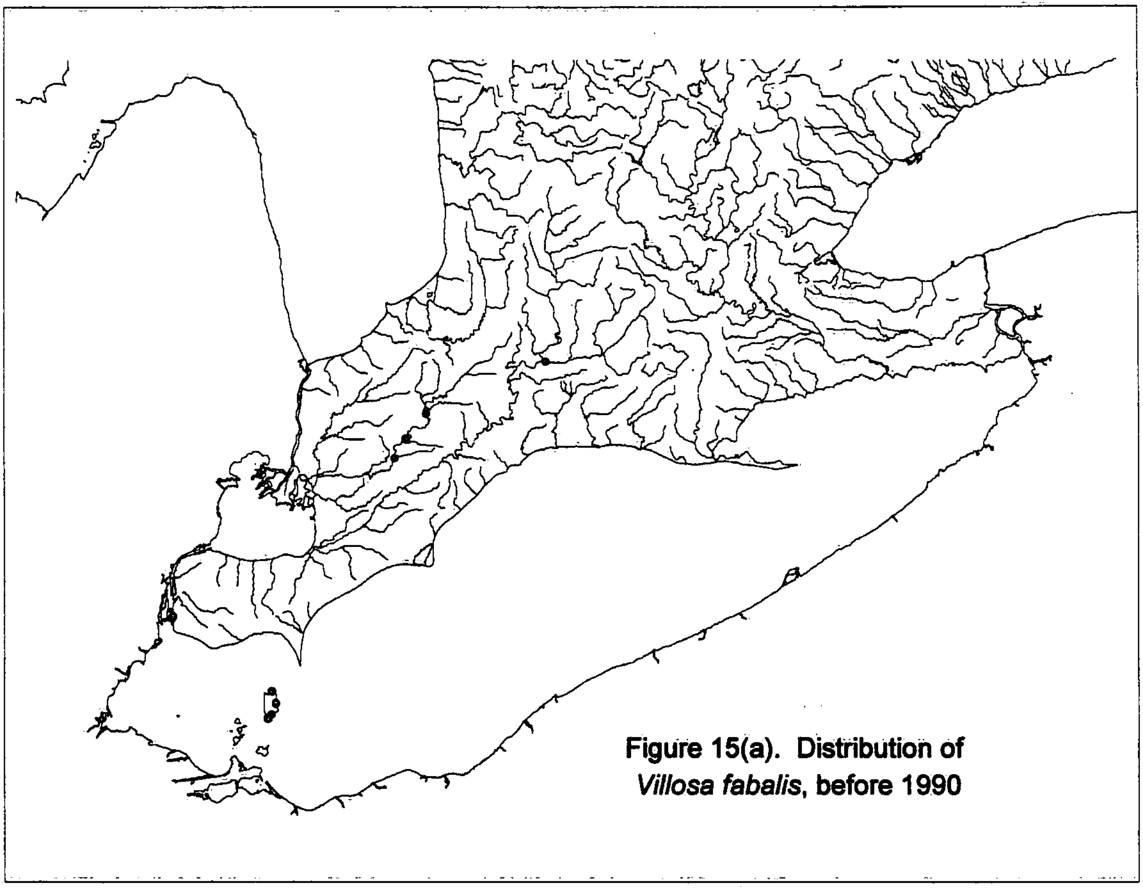


Figure 15(a). Distribution of *Villosa fabalis*, before 1990

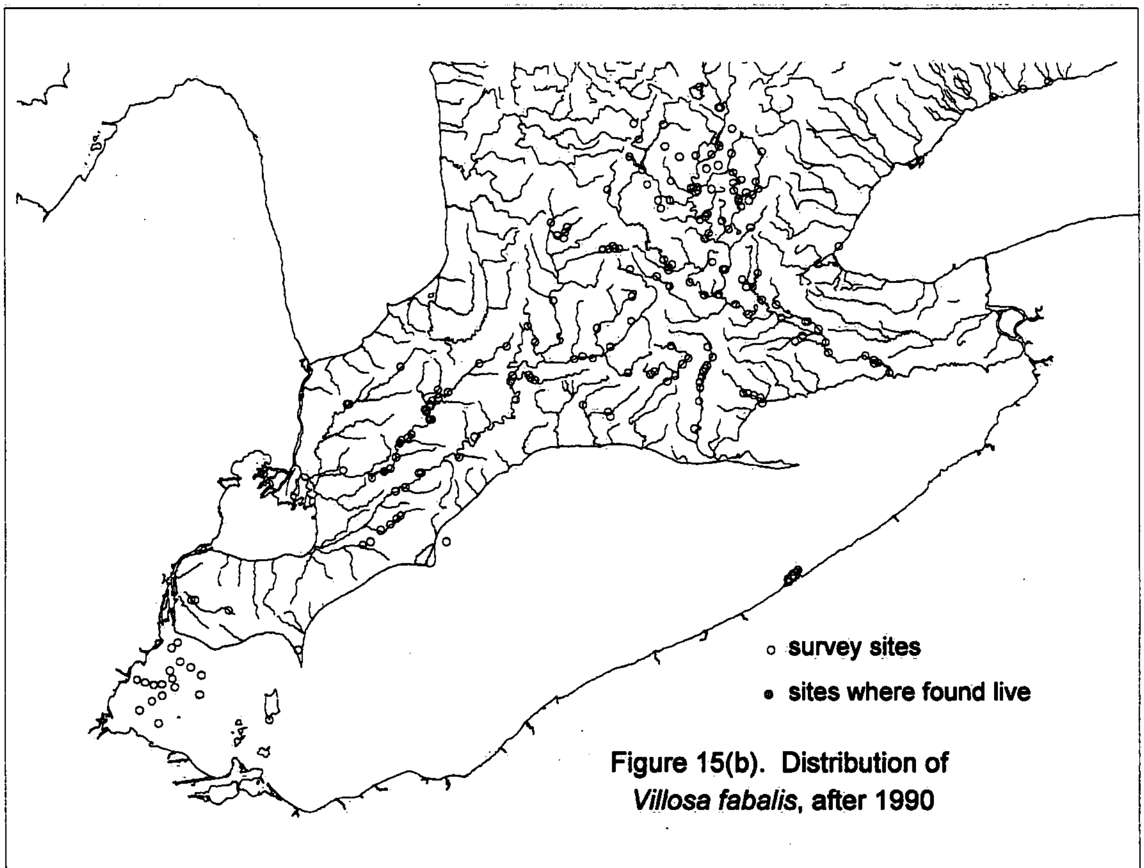


Figure 15(b). Distribution of *Villosa fabalis*, after 1990

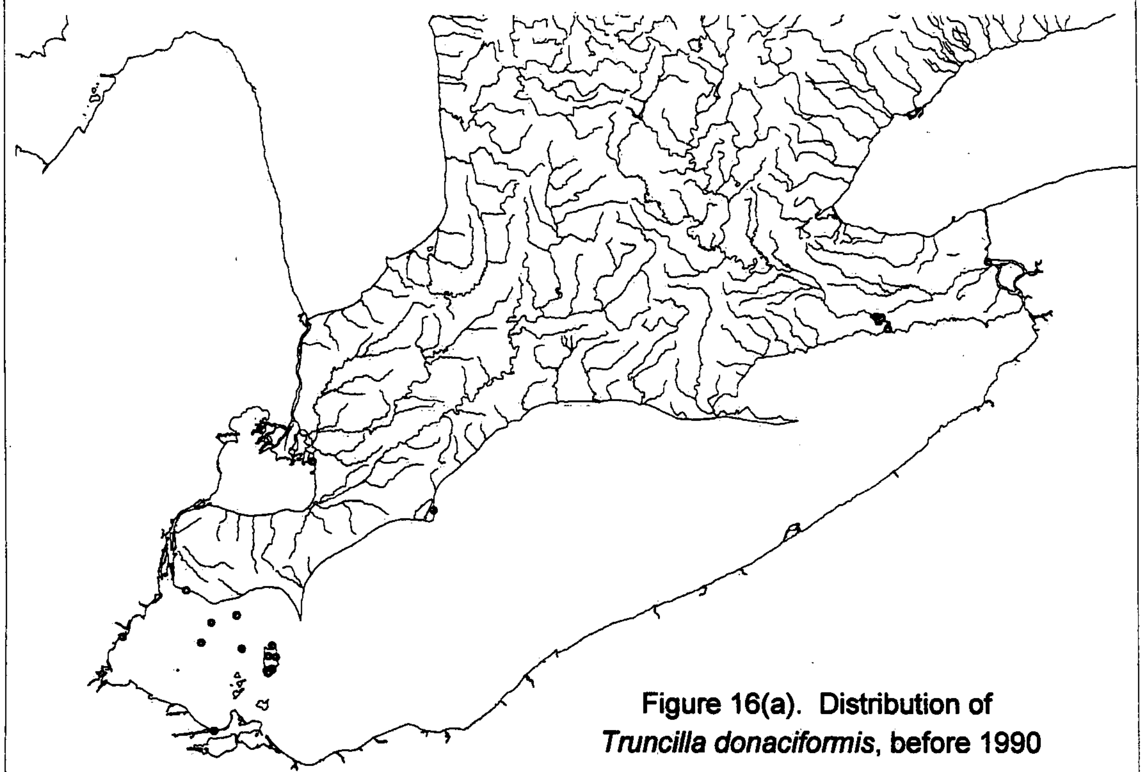


Figure 16(a). Distribution of *Truncilla donaciformis*, before 1990

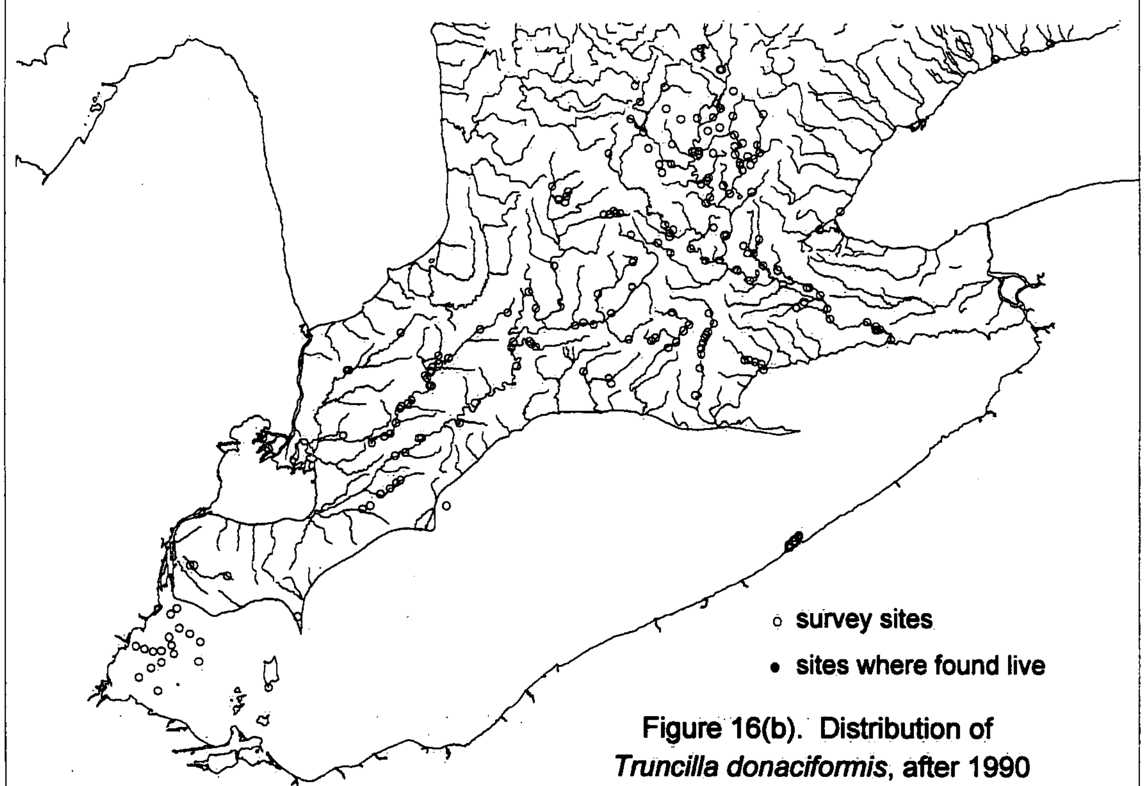


Figure 16(b). Distribution of *Truncilla donaciformis*, after 1990

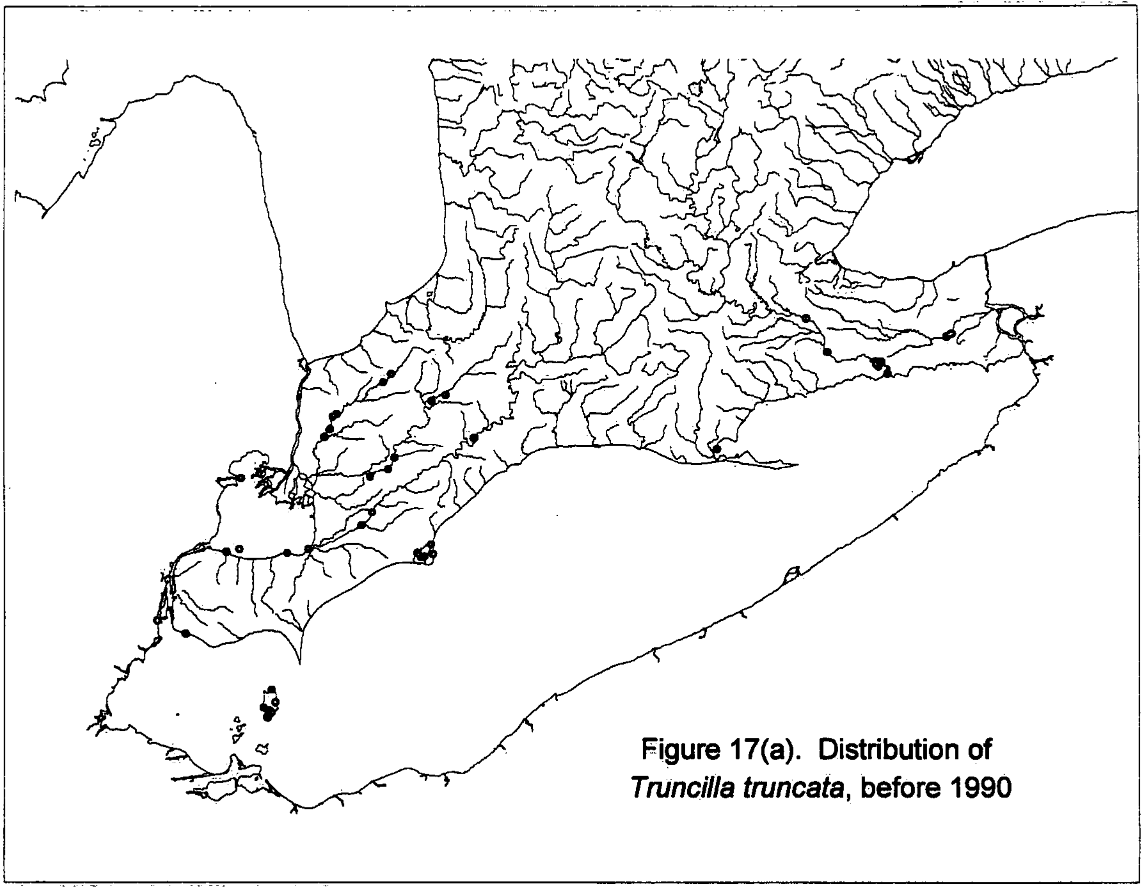


Figure 17(a). Distribution of *Truncilla truncata*, before 1990

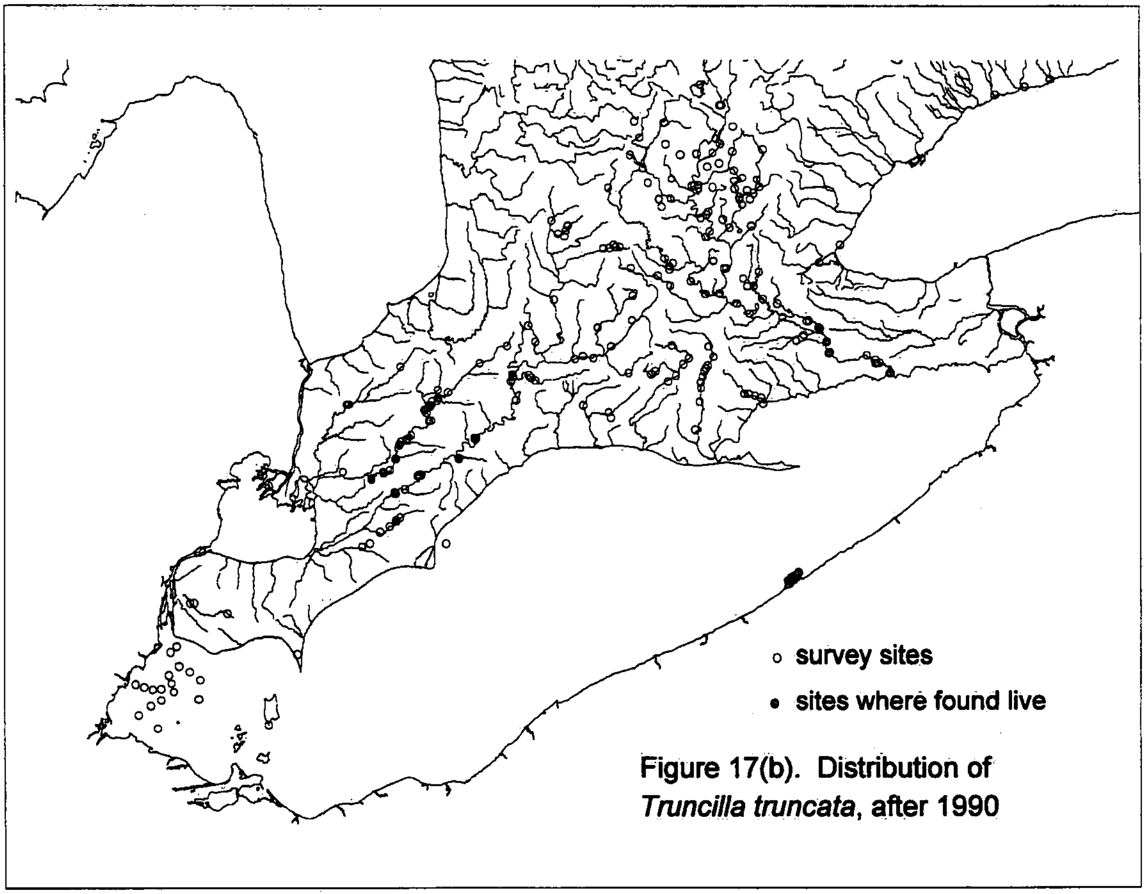


Figure 17(b). Distribution of *Truncilla truncata*, after 1990

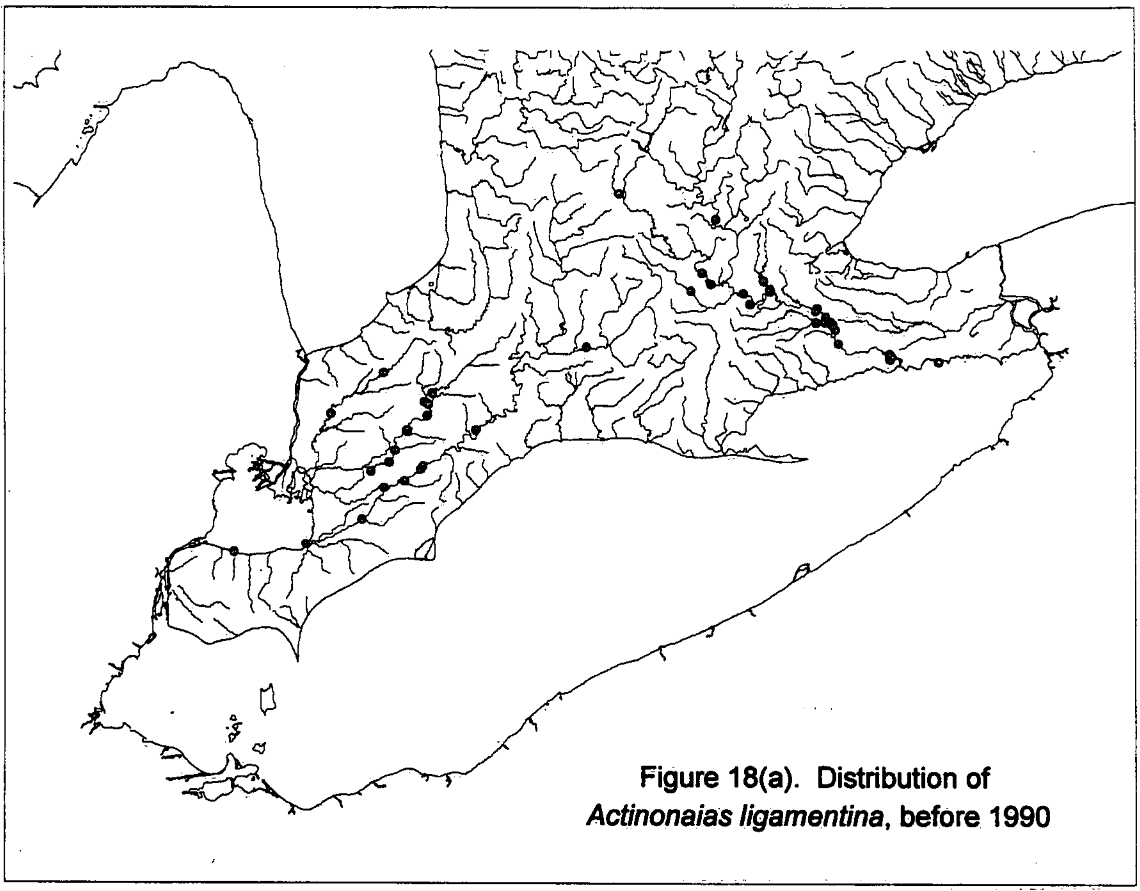


Figure 18(a). Distribution of *Actinonaias ligamentina*, before 1990

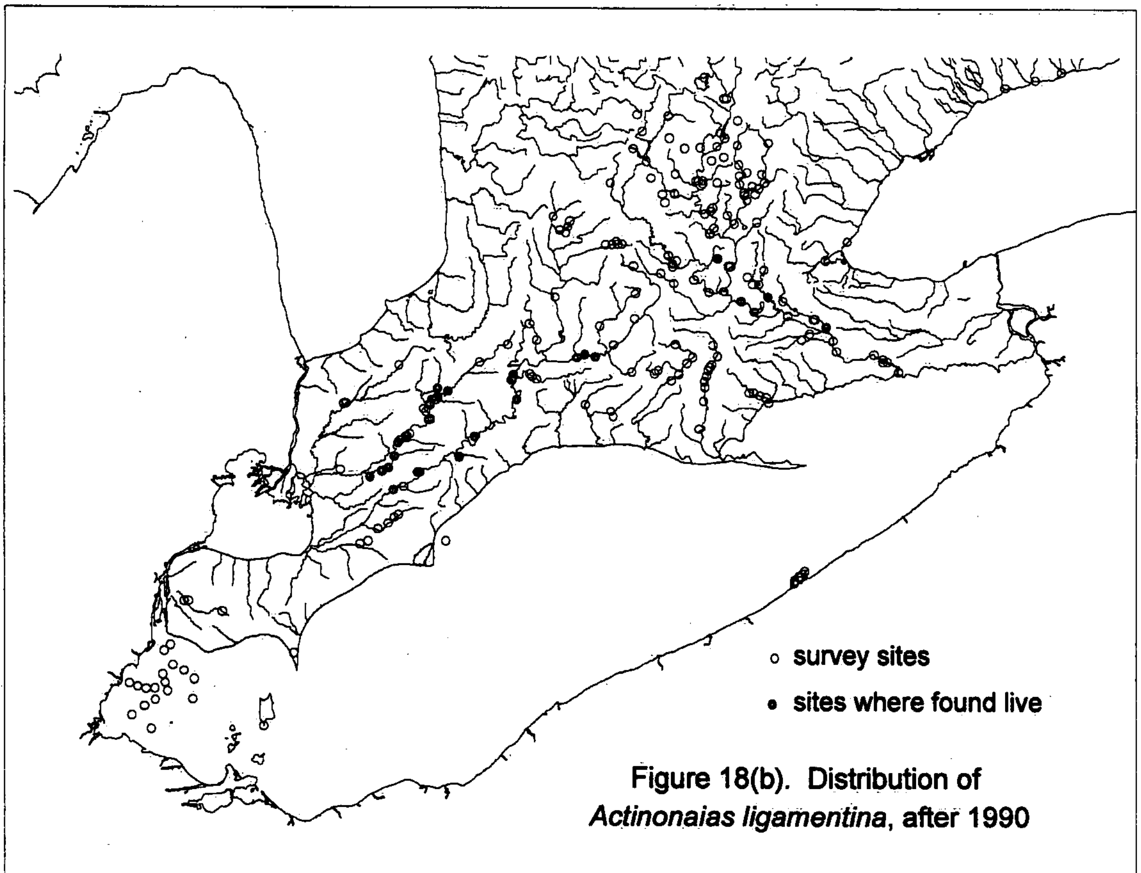


Figure 18(b). Distribution of *Actinonaias ligamentina*, after 1990

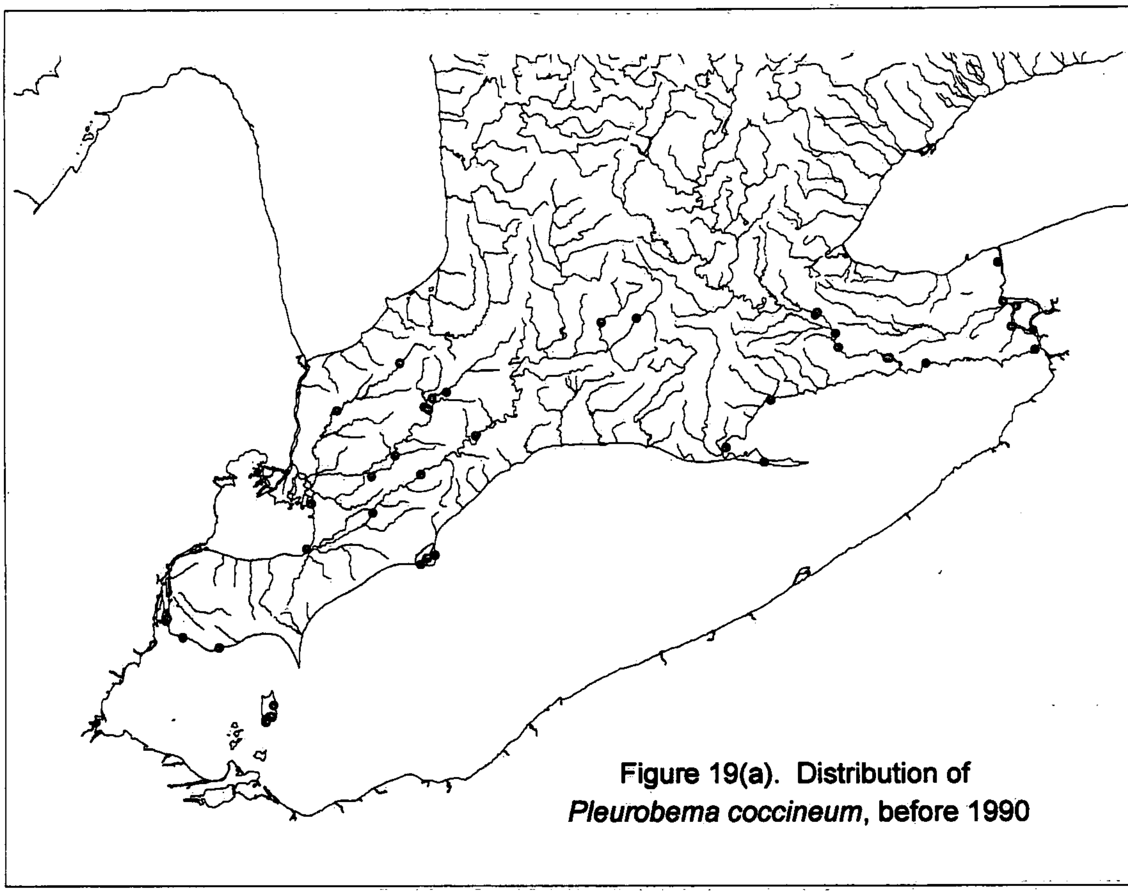


Figure 19(a). Distribution of *Pleurobema coccineum*, before 1990

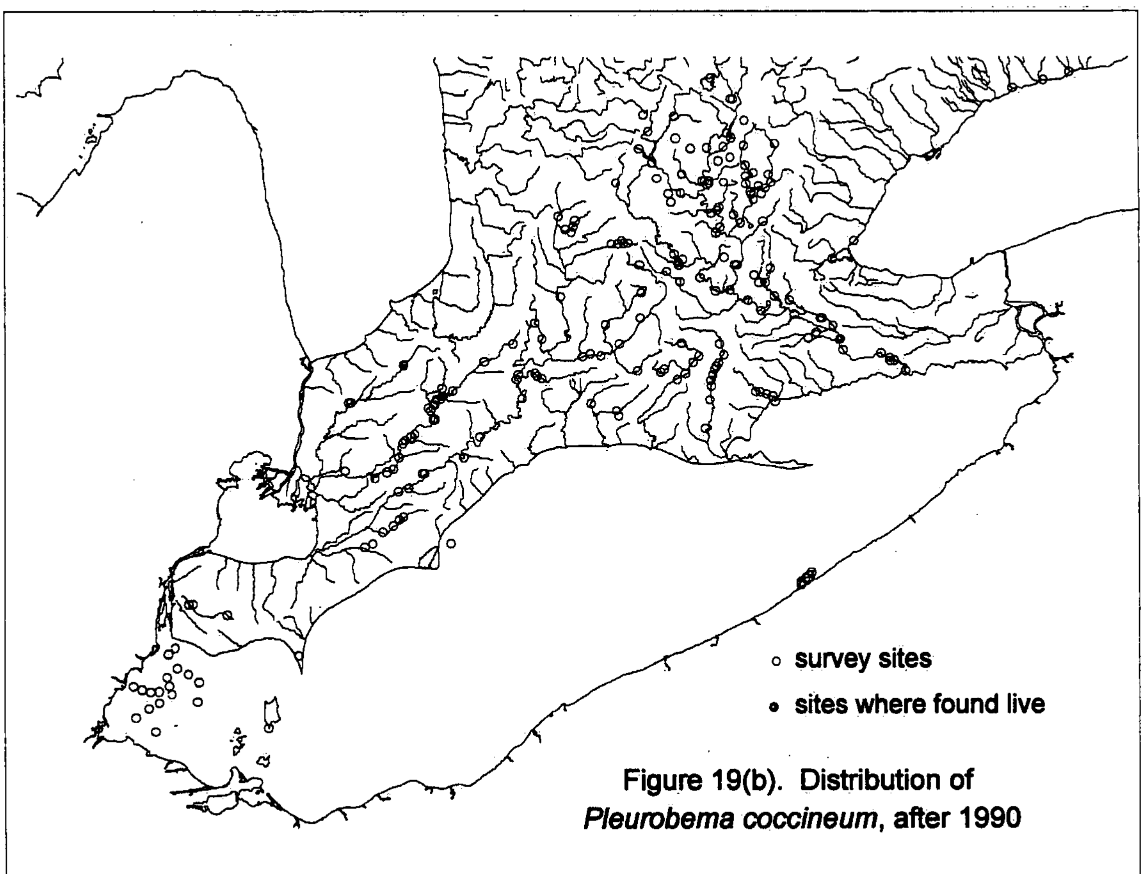


Figure 19(b). Distribution of *Pleurobema coccineum*, after 1990

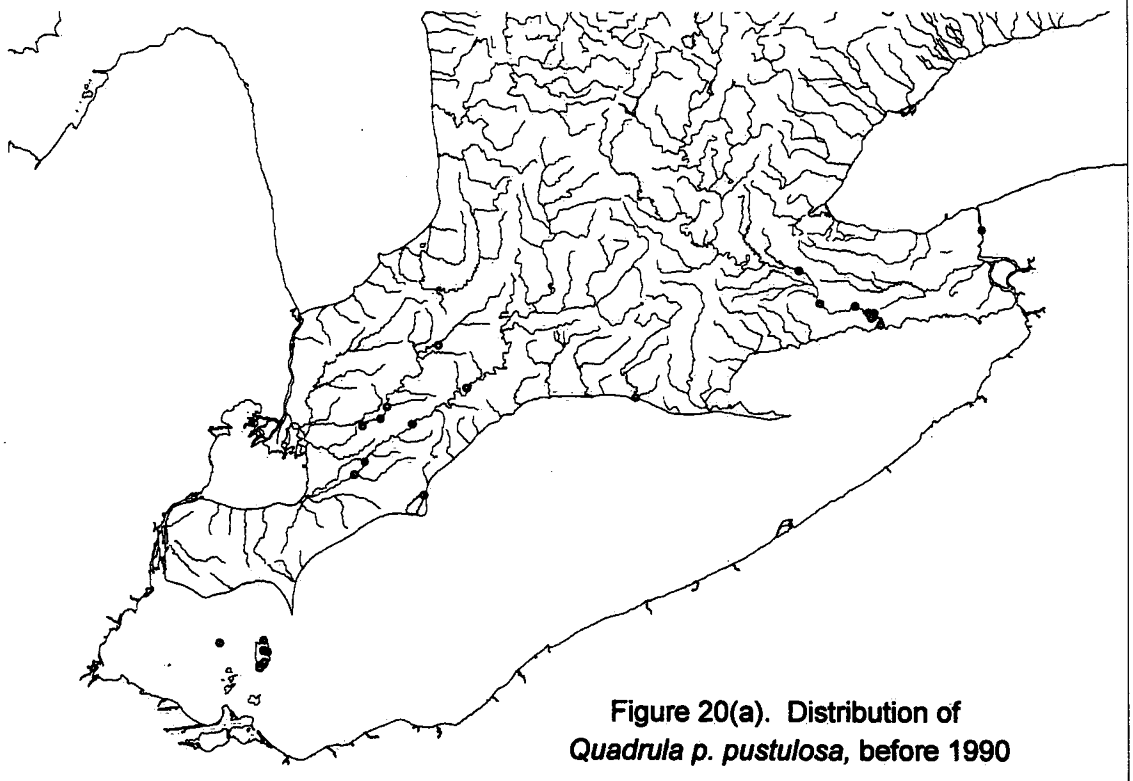


Figure 20(a). Distribution of *Quadrula p. pustulosa*, before 1990

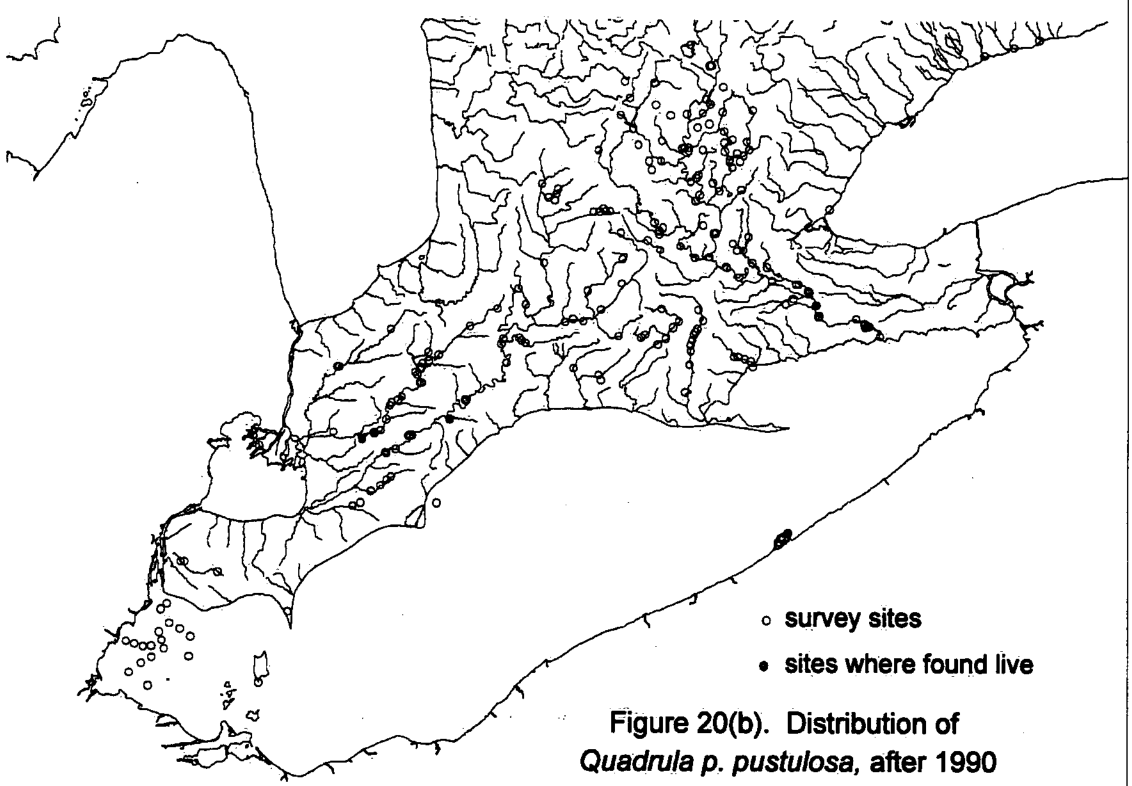


Figure 20(b). Distribution of *Quadrula p. pustulosa*, after 1990

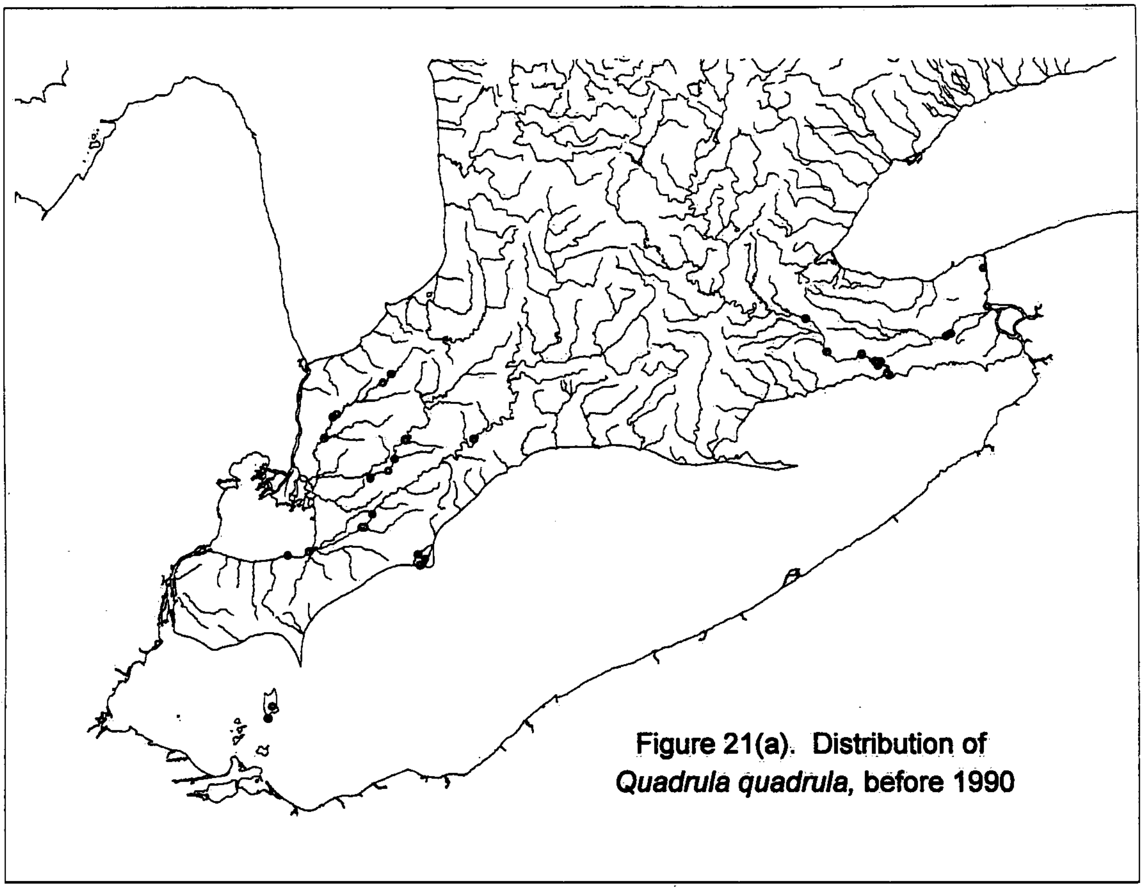


Figure 21(a). Distribution of *Quadrula quadrula*, before 1990

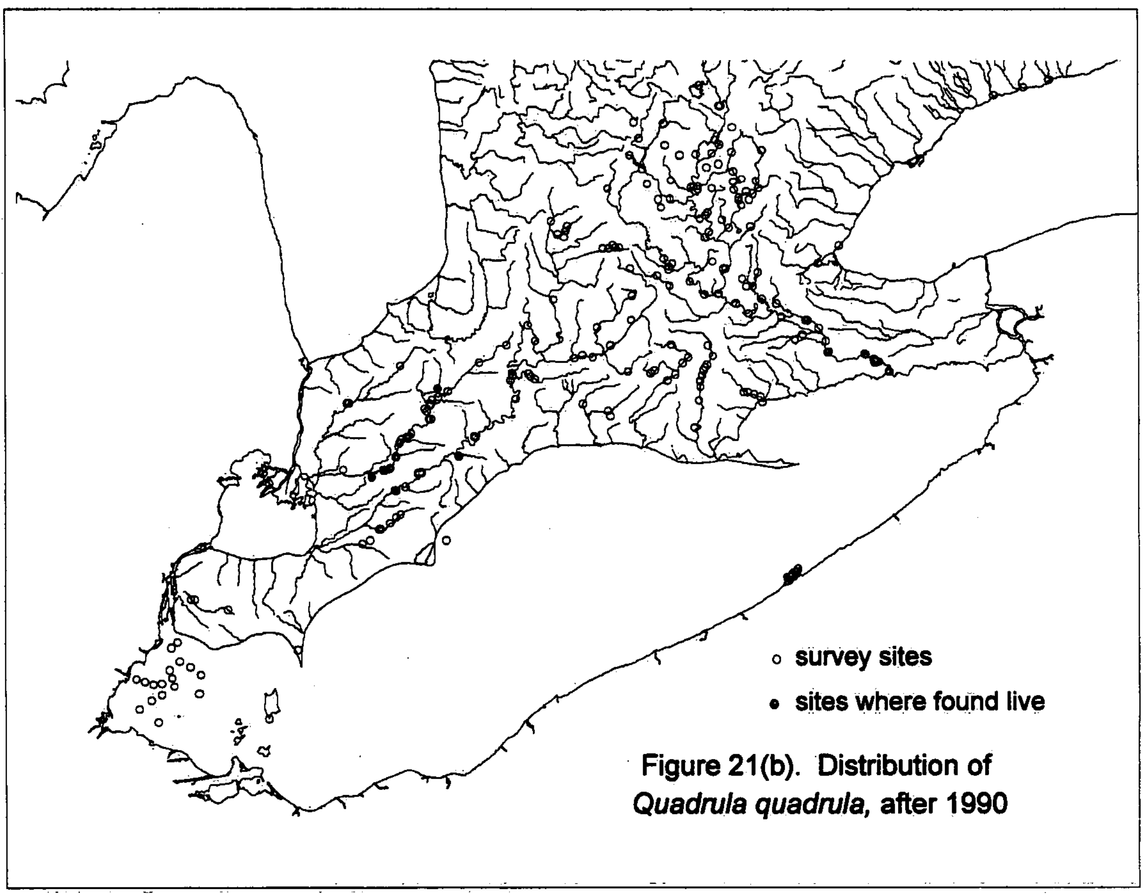


Figure 21(b). Distribution of *Quadrula quadrula*, after 1990

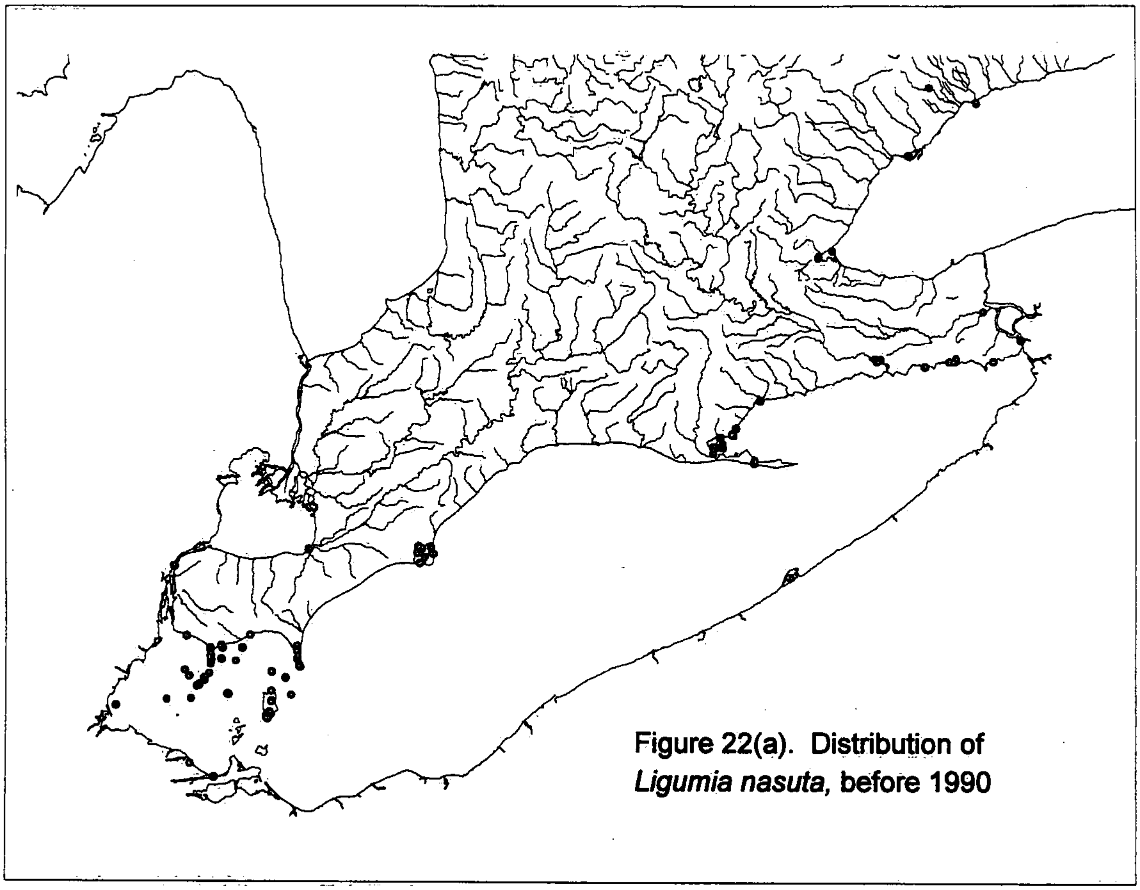


Figure 22(a). Distribution of *Ligumia nasuta*, before 1990

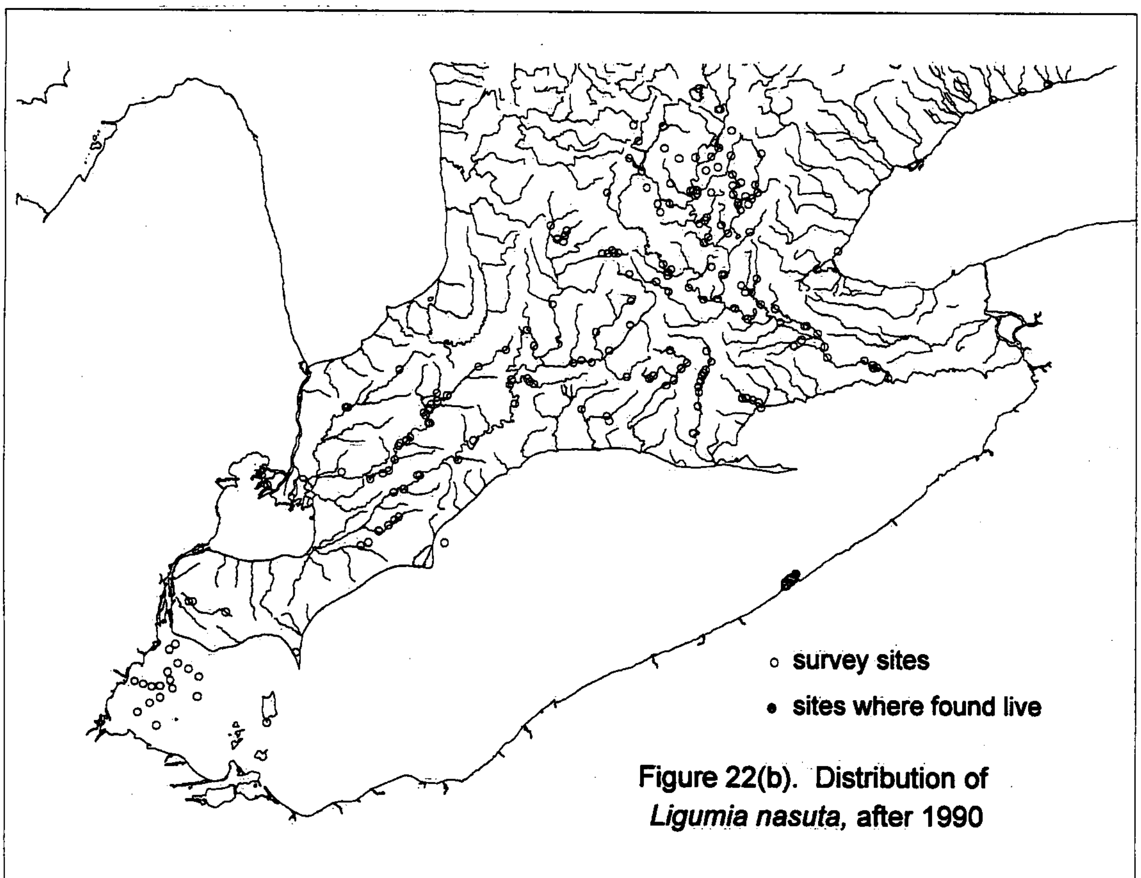


Figure 22(b). Distribution of *Ligumia nasuta*, after 1990

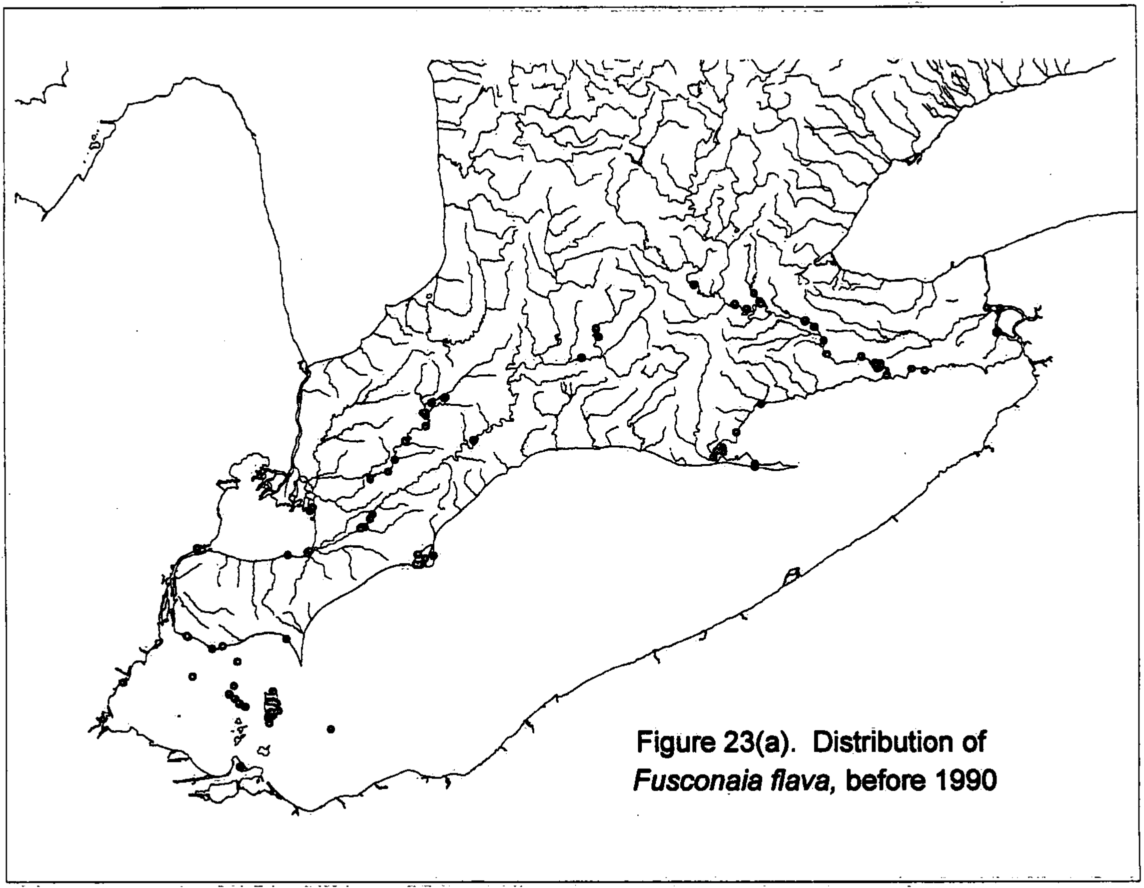


Figure 23(a). Distribution of *Fusconaia flava*, before 1990

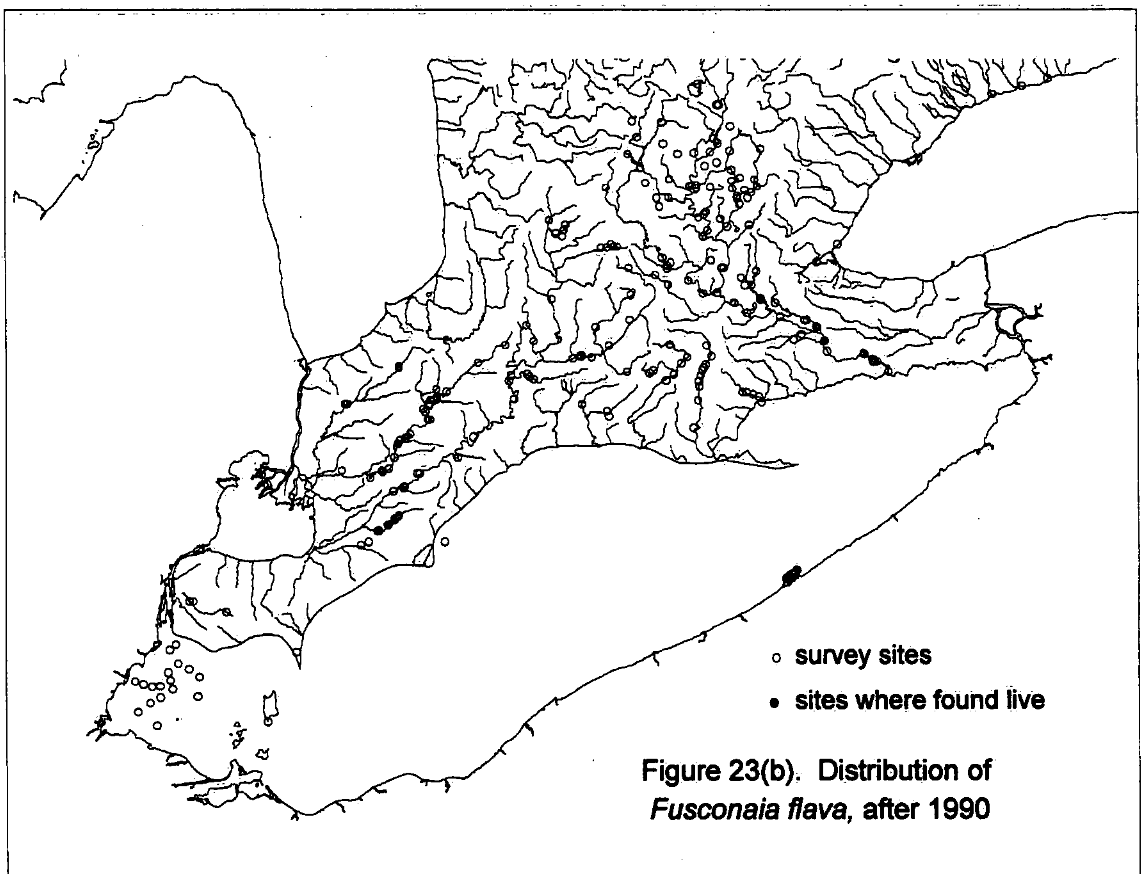


Figure 23(b). Distribution of *Fusconaia flava*, after 1990

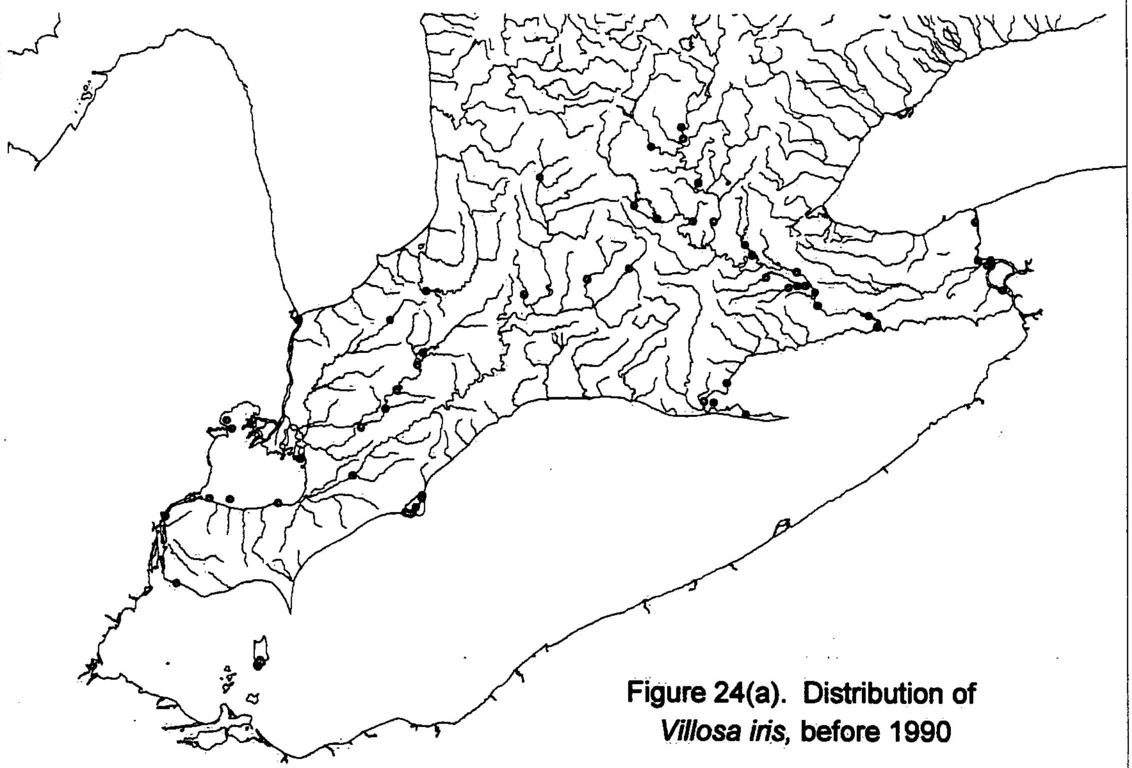


Figure 24(a). Distribution of *Villosa iris*, before 1990

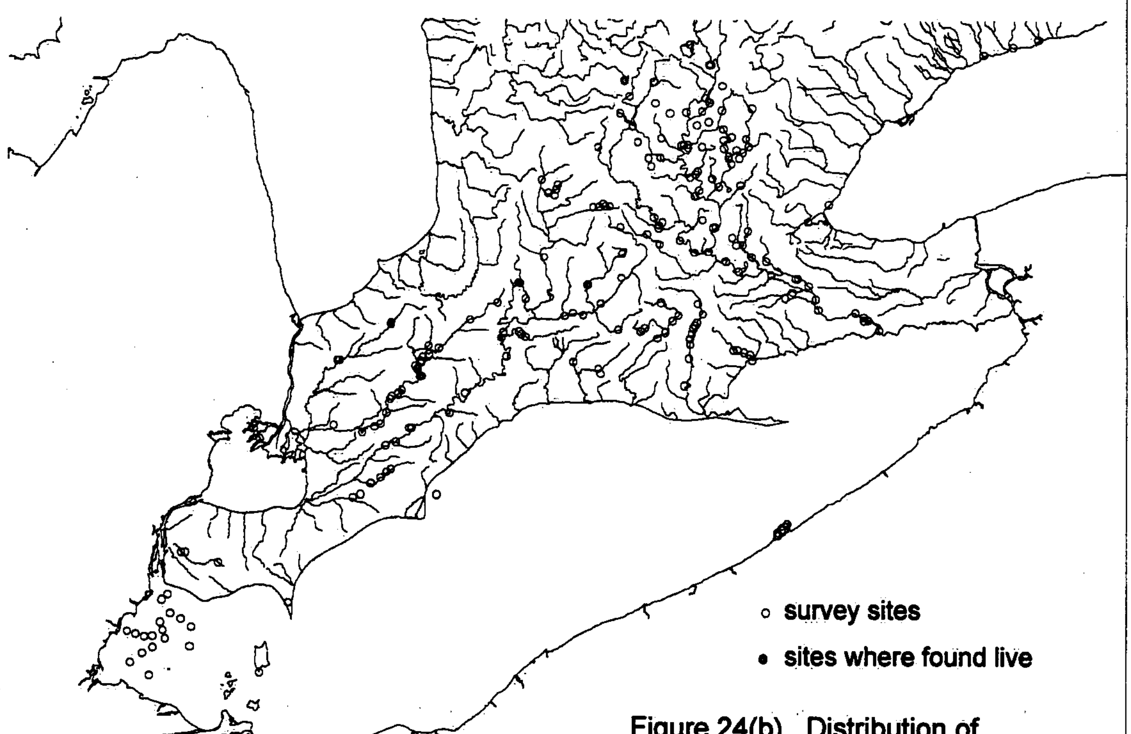


Figure 24(b). Distribution of *Villosa iris*, after 1990

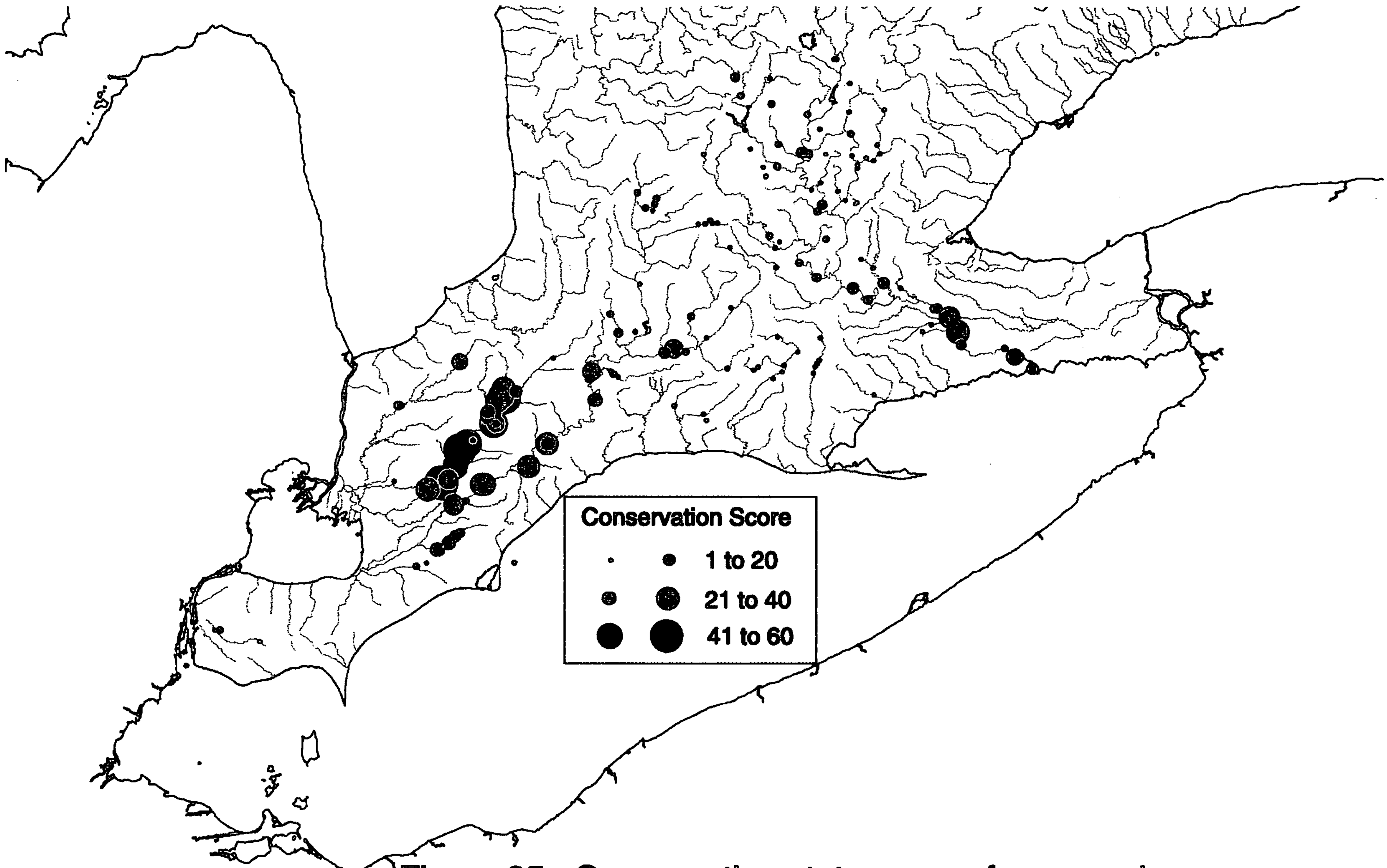


Figure 25. Conservation status score for mussel survey sites based on live animals collected after 1990

Appendix I. Occurrences of target species at historical sites selected for survey in the Grand River.

SRANK	Species	Historical Site identification number																
		GR-A	GR-B	GR-C	GR-D	GR-E	GR-F	GR-G	GR-H	GR-I	GR-J	GR-K	GR-L	GR-M	GR-N	GR-O	GR-P	GR-Q
SH	*Epioblasma t. rangiana*																	
SH	*Epioblasma triquetra*	X		X														
SH	*Obliquaria reflexa*	X	X	X						X								
SH	*Obovaria olivaria*		X															
SH	*Simpsonaias ambigua*																	
SH	*Toxolasma parvus*	X	X	X	X	X												
S1	*Cyclonaias tuberculata*		X															
S1	*Lampsilis fasciola*										X	X	X	X		X	X	
S1	*Obovaria subrotunda*		X	X														
S1	*Ptychobranchus fasciolaris*	X	X				X		X									
S1	*Utterbackia imbecillis*		X	X	X													
S1	*Villosa fabalis*																	
S1/S2	*Truncilla donaciformis*	X	X	X														
S1/S2	*Truncilla truncata*	X	X	X					X	X								
S2	*Actinonaias ligamentina*		X	X			X	X	X	X				X		X		X
S2	*Pleurobema coccineum*		X				X		X	X								
S2	*Quadrula p. pustulosa*	X	X	X	X				X	X								
S2	*Quadrula quadrula*	X	X	X	X				X	X								
S3	*Ligumia nasuta*		X	X											X			

Appendix II. Occurrences of target species at historical sites selected for survey in the Thames River.

SRANK	Species	Historical Site identification number								
		TR-A	TR-B	TR-C	TR-D	TR-E	TR-F	TR-G	TR-H	TR-I
SH	*Epioblasma t. rangiana*									
SH	*Epioblasma triquetra*	X		X						
SH	*Obliquaria reflexa*		X							
SH	*Obovaria olivaria*		X							
SH	*Simpsonaias ambigua*									
SH	*Toxolasma parvus*									X
S1	*Cyclonaias tuberculata*			X	X		X			
S1	*Lampsilis fasciola*	X								
S1	*Obovaria subrotunda*	X								
S1	*Ptychobranchus fasciolaris*	X								
S1	*Utterbackia imbecillis*									
S1	*Villosa fabalis*					X				
S1/S2	*Truncilla donaciformis*									
S1/S2	*Truncilla truncata*	X	X		X					
S2	*Actinonaias ligamentina*	X		X	X		X			
S2	*Pleurobema coccineum*		X	X	X			X	X	
S2	*Quadrula p. pustulosa*	X	X	X	X					
S2	*Quadrula quadrula*	X	X		X					X
S3	*Ligumia nasuta*									

Appendix III. Occurrences of target species at historical sites selected for survey in the Sydenham River.

SRANK	Species		Priority Site identification number					
			SR-A	SR-B	SR-C	SR-D	SR-E	SR-F
SH	*Epioblasma t.*	*rangiana*	X	X		X		
SH	*Epioblasma*	*triquetra*	X	X				
SH	*Obliquaria*	*reflexa*						
SH	*Obovaria*	*olivaria*						
SH	*Simpsonaias*	*ambigua*	X					
SH	*Toxolasma*	*parvus*						
S1	*Cyclonaias*	*tuberculata*	X	X	X	X		
S1	*Lampsilis*	*fasciola*	X			X		
S1	*Obovaria*	*subrotunda*	X		X	X	X	
S1	*Ptychobranchus*	*fasciolaris*	X	X	X	X		
S1	*Utterbackia*	*imbecillis*						
S1	*Villosa*	*fabalis*	X	X		X		
S1/S2	*Truncilla*	*donaciformis*						
S1/S2	*Truncilla*	*truncata*	X					
S2	*Actinonaias*	*ligamentina*	X	X	X	X		
S2	*Pleurobema*	*coccineum*	X			X	X	X
S2	*Quadrula p.*	*pustulosa*	X					
S2	*Quadrula.*	*Quadrula*	X	X				
S3	*Ligumia*	*nasuta*						

Appendix IV.

SITE	length of reach searched (m)	max. depth of reach (m)	max. depth searched (m)	avg. depth searched (m)	min. width of reach (m)	max. width of reach (m)	avg. width of reach (m)	water clarity* (m)	water velocity (m/s)	water temp. (C)	air temp. (C)
GR-97-1	120	1.2	0.5	0.3	48.8	48.8	48.8	0.35		22	24
GR-97-2	228.6	~1.2	0.8	0.4	91.4			0.6	0.1859	21	21
GR-97-3	131.1	0.5	0.35	0.35	67.1	115.8	7		0.3669	24	23
GR-97-4	213.4	1	0.5	0.2	61	68.6	68.6	0.2	0.4235	24.5	24
GR-97-5	750	0.73	0.5	0.37	16	24		0.3	0.4348	23	26
GR-97-6	134.1	0.37	0.25		121.9	121.9		0.3	0.3896	27	30
GR-97-7	60	>2	0.6	0.3	~1000			0.1	0	26	25
GR-97-8	152.4	1.2	0.5	0.25	17.5	30.5	29	0.45	0.6837	21	22
GR-97-9	243.8		1	0.35	51.8	64		0.8	0.4122	23	21
GR-97-10	182.9	>1	1	0.2	167.6	167.6	167.6	0.2	0	23	21
GR-97-11	94.5		1.3	0.8			152.4	0.2	0	26	23
GR-97-12	182.9	1.5	1	0.7		91.4		1	0.4122	21	23
GR-97-13	106.7	1.2	1	0.6		47.2	47.2	1.5	0.3896	22.5	24
GR-97-14	243.8	1.2	0.4	0.2	8	20		0.3	0.1407	21	25
GR-97-15	470.9	0.8	0.8	0.25	2	12	5	>.8	0	21	21
GR-97-16	~100		4	3			91.4	0.2		18	17
GR-97-17	~50	5	5	3	25	25	25	0.2	0	19	22
TR-97-1	167.6	1	0.6	0.4	9	15.5		0.5	0.3104	20	19
TR-97-2	76.2	0.7	0.6	0.4	28.5	28.5	28.5	0.65	0.4122	20	17
TR-97-3	103.6	0.65	0.4	0.2	35	35	35	0.65	0.5253	17.5	20
TR-97-4	152.4	0.9	0.5	0.3		106.7		0.5	0.6045	21	22
TR-97-5	115.8	>1.2	0.6	0.5	30.5	30.5	30.5	0.4	0.3669	21	18
TR-97-6	82.3		0.4	0.35	33.5	33.5	33.5	0.1	0.2764	24	22
TR-97-7	274.3	0.55	0.55	0.45	45.7	45.7	45.7	0.07	0.7063	21	20
TR-97-8	68.6	>1	0.6	0.5	35	39.6	36.6	0.1	0.9326	22	21
TR-97-9	73.2	1	0.5	0.4			48.8	0.08	0.7063	20	22
TR-97-10	100	>1	0.75	0.4	42.7	53.3	45.7	0.08	0.6271	17	20
TR-97-11	411.5	1	0.8	0.6	24.4	45.7	38.1	0.9	0.3104	12	16
SR-97-1	182.9	0.8	0.5	0.4	30.5	30.5	30.5	0.25	0.2199	21	20
SR-97-2	256	0.6	0.4	0.3	18.3	27.4	22.9	0.2	0.4574	18	18
SR-97-3	121.9	0.5	0.5	0.4			19.8	0.2	0.3104	19	17
SR-97-4	152.4	1.2	0.4	0.3	13.5	21		0.15	0.6158	20	17
SR-97-5	213.4	0.6	0.5	0.3	12.2	18.3	16.8	0.2	0.4122	20	17
SR-97-6	146.3	0.5	0.4	0.3	12.2	32	18.3	0.13	0.3443	18	15
SR-97-7	207.3	0.5	0.4	0.3	27.4	61		0.15	0.4687	19	15
SR-97-8	91.4	>1	0.6	0.4	0.1	~15	12	0.6	0.4914	11.5	21
SR-97-9	304.8	0.5	0.3	0.25	5	10	6	0.2	0	15	16

**see text for definitions of these terms.*

bank stability*	stream shading*	adjacent terrain*	Cond. of substrate* *silt*	*algae*	Stream Morphology (%)* *riffle*	*pool*	*run*	*flat*	Substrate (%)* *bedrock*	*boulder*	*rubble*	*gravel*	*sand*	*silt*	*clay*	*muck*	*marl*	*detritus*	Aquatic Vegetation (%)* *submerged*	*emergent*
1,3	3	1,4	1	1	10			90				70	25	5					0	0
2	3	9	1	2	20			80		5	20	70	5						40	0
2	2	4	1	1	100						60	20	20						10	
2	2	7	1		50			50			70	25	5						0	0
3	3	1,3	2	1	70			30			30	60	10						0	0
2	3	1,5																	0	0
2	3	9	2	1				100					40	10	10	40			30	0
2	3	4	2	1	50		50				20	50	30						0	0
2	3	4	3	2			50	50			20	50	30						0	0
2	3		3	1				100												
2	3	1	3	1				100					60		10	30			0	0
2	3	3,9	2	2	10		90			5	20	45	30						15	
2	3	3,9	1	1	10		90				10	60	40						0	5
2	2	1,5	1	1	50	5	35	10			40	40	20						0	0
2	2	2	2	3	5	20		75			40	25	30	5					5	25
1	3			2				100				5	40	30	20			5	0	0
2	3	5,9	3	1				100			20	20		60					0	0
3	2	15	2	1	15	20	65				25	25	35	15					0	0
2	3	9	1	1	70		30				40	30	30						0	0
2	3	9	1	1	100						50	30	20						5	0
2	3	1,5	2	2	50		30	20			20	60	10	10					10	0
4	3	1	2		40		60			20	50	20	10						0	0
4	3	1	2	1	50		50				20	80							0	0
4	2	1,9	1	1	100						15	70	15						0	0
4	2	1	1	1	100					20	50	10	20						0	0
4	3	1,9	2	1	70		30				20	30	50						0	0
3	3	1	1	1	50		30	20			10	60	30						0	0
2	3	9	2	2	50		10	40		5	60	15	10	10					5	0
2	3	1	2	1	20		60	20			10	30	50	10					0	0
2	2	1	2	1	60		40		15	5	50	10	10	10					0	0
3	2	1	2	1	60		40			10	50	20	15	5					0	0
3	2	1	1	1	75		25		10	15	10	35	30						0	0
2	2		2	1	70		3		5	5	30	20	30	10					0	0
3	2	1	1		60		20	20	50		10	40							0	
3	3	1	1	1	50		10	40	70			20	5			5			0	0
3	1	4	2	1	40		20	40				40	20	35	5				0	0
2	2	1	2	1	30	10		60			30	20	10	30	10				0	0

Appendix V. **Comparisons of mussel diversity and abundance observed during the present survey, with the results of other contemporary surveys (>1990) conducted at the same sites. Presence of fresh (F) or weathered (W) shells also indicated.**

	TR-97-6 Present survey	m23 Morris, T.J. 1995	GR-97-13 Present survey	MAC35 Mackie, G.L. 1995	GR-97-2 Present survey	MAC56 Mackie, G 1995	GR-97-4 Present survey	MAC49 Mackie, G.L. 1995	GR-97-10 Present survey	MAC50 Mackie, G. 1995	SR-97-3 Present survey	c60 Clarke, A.H. 1991	SR-97-6 Present survey	c69 Clarke, A.H. 1991	c66 Clarke, A.H. 1991
Actinonaias ligamentina	64						F		F		5	3	28	1	18
Alasmidonta marginata	4	1	6		F		F		F		5	5	4	5	
Alasmidonta undulata															
Alasmidonta viridis			W		W			1							
Amblema p. plicata	6	3					F		F		16	12	25	1	10
Anodontoides ferussacianus			1												
Cyclonaias tuberculata	9										3	2	167		2
Elliptio complanata															
Elliptio dilatata	W		5	5	F		W				3		5		
Epioblasma torulosa rangiana											2		2		
Epioblasma triquetra															
Fusconaia flava							F		F		F		12		
Lampsilis fasciola			1	F	W		W				F				
Lampsilis ovata	W				W		2				1		F		
Lampsilis r. radiata		1													
Lampsilis siliquoidea			5	8	W		F								
Lasmigona c. complanata	2	F											2	12	2
Lasmigona compressa				9						F					
Lasmigona costata	8	1	122	2	F		4		F		23	23	42		6
Leptodea fragilis	6	24					4	1	2		8	3	9	1	10
Ligumia nasuta															
Ligumia recta	W						4		F		7	1	1		
Obliquaria reflexa									F						
Obovaria olivaria															
Obovaria subrotunda	W	F												1	F
Pleurobema coccineum	W						F		F		F				
Potamilus alatus	5	4					2		F		1		3	8	20
Ptychobranchus fasciolaris	W						W				1	3	4		
Pyganodon cataracta															
Pyganodon grandis		4	9	12	W		F		F		1		1	1	
Quadrula p. pustulosa	25						F		3				1		1
Quadrula quadrula	44							1	1				21	3	1
Simpsonaias ambigua											F		F		
Strophitus undulatus			139	2	F		F	1			1				
Toxolasma parvus															
Truncilla donaciformis															
Truncilla truncata	18	3					F		6		F		14		2
Utterbackia imbecillis											F				
Villosa fabalis											F		2		
Villosa iris			F				W				2		F		

NATIONAL WATER RESEARCH INSTITUTE
P.O. BOX 5050, BURLINGTON, ONTARIO L7R 4A6

Environment Canada Environnement Canada

Canada

INSTITUT NATIONAL DE RECHERCHE SUR LES EAUX
C.P. 5050, BURLINGTON (ONTARIO) L7R 4A6

Think Recycling!

Pensez à recycler !