Aquatic Species at Risk in the Thames River Watershed, Ontario

B. Cudmore[1], C.A. MacKinnon[2] and S.E. Madzia[2]

[1] Fisheries and Oceans Canada
Great Lakes Laboratory for Fisheries and Aquatic Sciences
867 Lakeshore Rd., P.O. Box 5050
Burlington ON L7R 4A6 CANADA

[2] Upper Thames River Conservation Authority
1425 Clarke Rd.
London ON N5V 5B9 CANADA

December 2004

Prepared for the Thames River Ecosystem Recovery Team

Canadian Manuscript Report of Fisheries and Aquatic Sciences 2707

Canadian Manuscript Report of Fisheries and Aquatic Sciences

Manuscript reports contain scientific and technical information that contributes to existing knowledge but which deals with national or regional problems. Distribution is restricted to institutions or individuals located in particular regions of Canada. However, no restriction is placed on subject matter, and the series reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries and aquatic sciences.

Manuscript reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in *Aquatic Sciences and Fisheries Abstracts* and indexed in the Department's annual index to scientific and technical publications.

Numbers 1-900 in this series were issued as Manuscript Reports (Biological Series) of the Biological Board of Canada, and subsequent to 1937 when the name of the Board was changed by Act of Parliament, as Manuscript Reports (Biological Series) of the Fisheries Research Board of Canada. Numbers 901-1425 were issued as Manuscript Reports of the Fisheries Research Board of Canada. Numbers 1426-1550 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Manuscript Reports. The current series name was changed with report number 1551.

Manuscript reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page. Out-of-stock reports will be supplied for a fee by commercial agents.

Rapport manuscrit canadien des sciences halieutiques et aquatiques

Les rapports manuscrits contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui traitent de problèmes nationaux ou régionaux. La distribution en est limitée aux organismes et aux personnes de régions particulières du Canada. Il n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques du ministére des Pêches et des Océans, e'est-à-dire les sciences halieutiques et aquatiques.

Les rapports manuscrits peuvent être cités comme des publications complèrwa. Le titre exact paraît au-dessus du résumés de chaque rapport. Les rapports manuscrits sont résumés dans la revue *Résumés des sciences aquatiques et halieutiques,*et ils sont classés dans l'index annuel des publications scientifiques et techniques du Ministére.

Les numéros 1 à 900 de cette série ont été publiés à titre de manuscrits (série biologique) de l'Office de biologie du Canada, et aprés le changement de la désignation de cet organisme par décret du Parlement, en 1937, ont été classés comme manuscrits (série biologique) de l'Office des recherches sur les pêcheries du Canada. Les numéros 901 à 1425 ont été publiés à titre de rapports manuscrits de l'Office des recherches sur les pêcheries du Canada. Les numéros 1426 à 1550 sont parus à titre de rapports manuscrits du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 1551.

Les rapports manuscrits sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur don't le nom figure sur la couverture et la page du titre. Les rapports épuisés seront fournis contre rétribution par des agents commerciaux.

Canadian Manuscript Report of
Fisheries and Aquatic Sciences 2707

2004

AQUATIC SPECIES AT RISK IN THE THAMES RIVER WATERSHED, ONTARIO

By

B. Cudmore[1], C.A. MacKinnon[2] and S.E. Madzia[2]

[1] Fisheries and Oceans Canada
Great Lakes Laboratory for Fisheries and Aquatic Sciences
867 Lakeshore Rd., P.O. Box 5050
Burlington ON L7R 4A6 CANADA

[2] Upper Thames River Conservation Authority
1425 Clarke Rd.
London ON N5V 5B9 CANADA

Prepared for the Thames River Ecosystem Recovery Team

Cat. No. Fs 97-4/2707E ISBN 0706-6473

Correct citation for this publication:

Cudmore, B., C.A. MacKinnon and S.E. Madzia. 2004. Aquatic species at risk in the Thames River watershed, Ontario. Can. MS Rpt. Fish. Aquat. Sci. 2707: v + 123 p.

TABLE OF CONTENTS

ABSTRACT v
RÉSUMÉ vii
INTRODUCTION 1
FRESHWATER MUSSELS 3
Knowledge Gaps – Freshwater Mussels 24
Recent and Current Research on Thames River Freshwater Mussel Species at Risk .. 26
AQUATIC REPTILES 27
Knowledge Gaps - Reptiles 46
Recent and Current Research on Thames River Reptile Species at Risk 46
FISHES 47
Knowledge Gaps - Fishes 72
Recent and Current Research on Thames River Fish Species at Risk 73
CONSERVATION PRIORITIES 74
SPECIES AT RISK 74
THREATS 75
CONCLUSIONS 75
LITERATURE CITED 78

LIST OF TABLES

Table 1. Aquatic species at risk in the Thames River watershed…..95

Table 2. Summary of status, extant sites, direct and indirect threats and conservation priority ranks for aquatic species at risk in the Thames River watershed…...118

LIST OF FIGURES

Figure 1. The Thames River watershed in Ontario…93

Figure 2. Subwatershed of the Thames River watersheds…94

Figure 3. Evidence occurrence of the snuffbox in the Thames River watershed…..96

Figure 4. Evidence occurrence of the wavyrayed lampmussel in the Thames River watershed…...97

Figure 5. Evidence occurrence of the round hickorynut in the Thames River watershed…...98

Figure 6. Evidence occurrence of the round pigtoe in the Thames River watershed…...99

Figure 7. Evidence occurrence of the kidneyshell in the Thames River watershed…100

Figure 8. Evidence occurrence of the mudpuppy mussel in the Thames River watershed…………………………………………………………………………….101

Figure 9. Evidence occurrence of the rayed bean in the Thames River watershed…….102

Figure 10. Sightings of the spotted turtle in the Thames River watershed.…………….103

Figure 11. Sightings of the spiny softshell turtle in the Thames River watershed.…….104

Figure 12. Sightings of the stinkpot turtle in the Thames River watershed.…………....105

Figure 13. Sightings of the queen snake in the Thames River watershed.……………..106

Figure 14. Sightings of the northern map turtle in the Thames River watershed.……...107

Figure 15. Sightings of the northern ribbonsnake in the Thames River watershed.…....108

Figure 16. Occurrence of the gravel chub in the Thames River watershed.…………....109

Figure 17. Occurrence of the northern madtom in the Thames River watershed.……...110

Figure 18. Occurrence of the black redhorse in the Thames River watershed.………...111

Figure 19. Occurrence of the northern brook lamprey in the Thames River watershed..112

Figure 20. Occurrence of the greenside darter in the Thames River watershed.……….113

Figure 21. Occurrence of the bigmouth buffalo in the Thames River watershed.……...114

Figure 22. Occurrence of the pugnose minnow in the Thames River watershed.……...115

Figure 23. Occurrence of the river redhorse in the Thames River watershed.………....116

Figure 24. Occurrence of the spotted sucker in the Thames River watershed.……......117

Appendix

Appendix A. Rank definitions for species at risk………………………………………123

ABSTRACT

The Thames River watershed, located in southwestern Ontario, is home to one of the most diverse aquatic faunal assemblages within the Great Lakes basin. It faces numerous stressors on its water quality and physical habitat. As such, there are 25 freshwater species at risk within the watershed, which includes seven freshwater mussels, six reptiles and 12 fishes. In order to protect these species from becoming more at risk of extinction, a watershed recovery team was developed in order to compile recovery approaches to address this problem. It was first necessary to compile information on the species at risk in the watershed. This report includes information on, for each species at risk, distribution, status, biology and threats. Conservation priority rankings were also assigned to each species and knowledge gaps presented. This information will be used in the development of a recovery strategy for the Thames River watershed.

RÉSUMÉ

Le bassin versant de la rivière Thames, situé dans le sud-ouest de l’Ontario, abrite un des assemblages fauniques aquatiques des plus diversifiés au sein du bassin des Grands Lacs. La qualité de son eau et son habitat physique font face à de nombreux agresseurs. Par conséquent, 25 espèces dulcicoles sont en péril au sein du bassin versant, dont sept mulettes, six reptiles et 12 poissons. Dans le but de protéger ces espèces contre le risque encore plus grand d’extinction, on a mis sur pied une équipe de rétablissement du bassin versant afin d’établir des méthodes pour aborder ce problème. Il a d’abord été nécessaire de compiler l’information sur les espèces en péril dans le bassin versant. Le présent rapport comprend, pour chaque espèce en péril, des renseignements sur la répartition, la situation, la biologie et les menaces. On a également attribué des rangs de priorité à chaque espèce et présenté les écarts de savoir. Ces renseignements seront utilisés dans l’élaboration d’une stratégie de rétablissement du bassin versant de la rivière Thames.

INTRODUCTION

The Thames River is the second largest river in southern Ontario and home to one of the most diverse faunal assemblages within the Great Lakes drainage. The majority of its watershed (90%) falls within the Carolinian Life Zone, a region with warmer year-round temperatures supporting unique Canadian ecosystems and high levels of biodiversity (Carolinian Canada 2004). The Thames River is a “gateway” watershed linked directly to the Great Lakes, then to the Atlantic Ocean. It has unique natural heritage features as it was once connected to the headwaters of the Mississippi River and was one of the first rivers to form following the retreat of the Wisconsin Glacier. The upper part of the Thames River watershed still flows through these ancient spillways, while the lower part of the river emerged after thousands of years as part of a glacial lake (Wilcox *et al.* 1998).

The Thames River originates northeast of London, Ontario and flows 273 km through the agricultural heartland of southwestern Ontario to Lake St. Clair which drains into Lake Erie (Figure 1). The river drains 5,285 square kilometers of land which makes it the second largest watershed in southwestern Ontario (Wilcox *et al.*1998). The river consists of three distinct branches (North, Middle and South Thames) that are easily accessible to the half million people that reside within the watershed. The North Thames starts north of Mitchell and flows through St. Marys. The Middle Thames begins southwest of Tavistock and flows through Thamesford where it joins the South Thames. The South Thames starts west of Tavistock and passes through Woodstock. The North and South branches meet in London, at the historic Fork of the Thames. Above the Fork of the Thames, consisting of the three branches, is the Upper Thames. Below the Fork of the Thames, the river (known as the Lower Thames) flows in a southwesterly direction through Chatham and into Lake St. Clair (Wilcox *et al.* 1998) (Figure 2). The Thames River watershed has been subdivided for management purposes by the Upper Thames River Conservation Authority and the Lower Thames Valley Conservation Authority into 47 subwatersheds (Figure 2). Watershed boundaries within the report were created by the Upper Thames River Conservation Authority, agreed upon by the Recovery Team and used in this report, as well as in the Recovery Strategy. They were manually defined on 1:50000 National Topographic Series maps (1994,95) and table digitized to create a digital copy of the data. The boundaries are general in nature because of the dates and scale of the maps they were generated from, and may not necessarily reflect the subwatershed boundaries used for other purposes by the conservation authorities.

There are a number of features of the Thames River that create an array of habitat opportunities for aquatic species. The postglacial landscape, the dynamic physical features (fluctuating water levels, pools and riffles, high nutrient levels due to the long growing season, etc.) and the Carolinian Zone influence all contribute to its biological diversity. The watershed's complex ecosystem contains one of the most diverse communities of aquatic species in Canada and supports one of the highest percentages of species at risk.

In the Thames River watershed, 25 aquatic species (7 freshwater mussels, 6 reptiles and 12 fishes) have been assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and designated as either Extirpated, Endangered, Threatened or Special Concern (COSEWIC 2004) (see Appendix A for status definitions).

There are valid concerns about the ability of the Thames River to maintain and sustain its diverse aquatic population. The Thames River is situated in a heavily populated and highly developed urban and rural sector of southern Ontario and faces many threats. The Thames and its tributaries have been affected in the past century as a result of this human activity. Concerns include: 1) improper sewage treatment plant discharges; 2) increased phosphorus loadings; 3) forest cover cleared for agricultural or urban development; 4) faulty private septic systems; 5) significant inputs of industrial discharges and non-urban industrial waste; 6) agricultural runoff; 7) bank alterations; 8) introduced species; and 9) over-logging (UTRCA 2001). Therefore, there is a need to improve the current conditions of the Thames River watershed in order to maintain and improve the river's aquatic species diversity. The Thames River thus provides an important role in maintaining key habitats for many declining species, as well as contributing to their decline.

The introduction of non-native species also impacts species at risk in the Thames River. For example, zebra mussels (*Dreissena polymorpha*) were recently (2002) discovered for the first time in the Thames River in one of its reservoirs (Fanshawe Lake). The impact this species can have on altering the aquatic community has been well documented and discussed further in this report.

This report compiles the biology of each aquatic species at risk found within the Thames River watershed in a species specific format. Information on the species distinguishing characteristics and general biology, distribution, and the official global, national (United States and Canada), and subnational (Ontario) ranks, as well as its current status within the Thames River, is given. The habitat used by the species, along with information on reproduction, diet, and the threats and limiting factors within the Thames River watershed, is also presented. Status reports written for COSEWIC were heavily used as these contain the most up-to-date published information on these species. A brief account of recent and current research in the Thames River watershed, and knowledge gaps for each group of aquatic species at risk, is also included. It is important to note that the information provided in this report (especially with respect to distribution and status) are current as of the 2002 field season.

FRESHWATER MUSSELS

Freshwater mussels, those species belonging to the families Margaritiferidae and Unionidae, are among the most endangered organisms in North America, with nearly 75% of species at risk of extinction and, in some cases, whole genera are on the verge of extinction (Williams *et al.* 1993, Morris 2004a). The decline and loss of many species and populations in North America is "almost totally driven by habitat loss and degradation" (Neves 1993).

In 1994, COSEWIC expanded its mandate to include invertebrates, forming a Species Specialist Subcommittee to consider two groups – the lepidopterans and the molluscs. Freshwater mussels appeared on the list of Canadian Species at Risk for the first time in 1999. Approximately 50% of Canadian mussel species are believed to be potentially at risk and in need of formal assessment (Metcalfe-Smith and Cudmore-Vokey 2004). Metcalfe-Smith *et al.* (1998) showed that mussels are declining both in diversity and population numbers in the lower Great Lakes drainage basin, where three-quarters of Canada's freshwater mussel species were historically found. During the past fifty years, this decline has been due to the destruction of their habitat by impacts such as siltation, dredging, channelization, the creation of impoundments, pollution, and the introduction of the zebra mussel (Metcalfe-Smith *et al.* 1997). This is consistent with the factors discussed in Williams *et al.* (1993) and in Richter *et al.* (1997).

The Thames River is home to one of the most diverse populations of mussels in Canada (the Sydenham River is home to more mussel species) (Table 1). Results of a 1997-1998 study conducted in the lower Great Lakes basin indicate that the Thames River has lost 29% of its native mussel species in the latter half of the last century (Metcalfe-Smith *et al.* 1997, Metcalfe-Smith *et al.* 1999, Morris 2004a). In the past, there was an unregulated harvest of mussel species for their shells to make buttons (Anthony and Downing 2001), but this likely had minimal impact on populations and no longer occurs today. Factors currently impacting the freshwater mussel community in the Thames River are siltation, poor water quality (from agricultural and urban sources), habitat alteration, zebra mussels, mammal predation, and loss of host species. A detailed discussion of how these factors impact freshwater mussels is presented below.

Soil and streambank erosion is severe in the Thames River, causing high suspended sediment loads in the lower reaches, thus impacting water quality for mussels (Watson *et al.* 2001b). Siltation of fine sediments adversely affects mussels by clogging gills (reducing respiration rates, feeding efficiency and growth), decreasing their food availability by reducing the amount of available light for photosysnthesis and impacting their host fishes. Heavy deposits of silt bury and smother mussels and siltation can also transport pollutants decreasing the quality of mussel habitat (Metcalfe-Smith *et al.* 2000).

According to Strayer and Fetterman (1999), agriculture is believed to be the main cause of the destruction of mussel habitat across North America. Agriculture accounts for a large percentage of land use in the Thames River basin; therefore, it is likely that impacts (runoff of sediment, nutrients and pesticides, increased water temperatures due to loss of riparian vegetation, destruction of habitat by tractor and livestock crossings) are primarily responsible for the loss of mussel habitat in this river (Zanatta and Metcalfe-Smith 2003a).

There have been many studies showing the decline of mussel populations downstream from major urban centres due to degraded water quality as a result of pollution (heavy metals, pesticides, fertilizers and road salt, ammonia, crude oil, sedimentation) and eutrophication (from Watson *et al.* 2001b). These are all detrimental to mussels, especially during their early life stages. However, the specific effects of these substances, the levels at which they are detrimental, the impacts to each life stage and the exposure routes are still not well understood (Watson *et al.* 2001b, Newton and Cope 2004). Ammonia concentrations in all subwatersheds exceed federal freshwater aquatic life guidelines, and mean copper concentrations exceed the guideline in several subwatersheds (WQB 1989, Watson *et al.* 2001b).

Habitat alteration is one of the greatest threats to freshwater mussels. Dams alter substrate composition, temperature regimes, water chemistry and dissolved oxygen concentrations in downstream areas, cause an accumulation of silt, which smothers mussels, in the impoundments and separate mussels from their fish hosts. Changes in the normal water temperature cycles can alter reproduction, cause loss of glochidia and delay mussel development. Metcalfe-Smith *et al.* (1997) estimated that the creation of dams alone has resulted in a loss of 30-60% of the mussel fauna found in the lower Great Lakes drainage basin, due mainly to the elimination of host fishes.

Zebra mussels are a threat to native freshwater mussels and have destroyed populations in infested areas (Schloesser *et al.* 1996). Zebra mussels are able to attach to most surfaces, including a mussel's shell, where they interfere with vital life sustaining activities such as feeding, respiration, excretion and locomotion (Haag *et al.* 1993, Baker and Hornback 1997). As highly efficient filter-feeders, zebra mussels also compete with native freshwater mussel species for food resources, thereby imposing a limiting factor on native species (Zanatta and Metcalfe-Smith 2003b).

Predation by muskrats (*Ondatra zibethicus*) and raccoons (*Procyon lotor*) may also be a potential threat for some mussel species. Muskrats have been shown to significantly alter the population structure of mussels in both lakes and rivers (from Watson *et al.* 2001b). There is anecdotal information that the recent adoption of conservation tillage in southwestern Ontario has led to an explosion of these mammal populations but the actual effects of conservation tillage on raccoon populations needs verification (Metcalfe-Smith and McGoldrick 2003).

The unique life cycle of the freshwater mussel makes it particularly vulnerable to changes in the environment. Males release sperm into the water which floats downstream to females, who take in the sperm through their siphons. Ova are fertilized and develop until they reach an intermediate larval stage (called glochidia). The glochidia are released, triggered by water temperature changes, into the water column and must then attach as an obligate parasite to a species-specific host where they encyst in the host's tissue to complete their metamorphosis to the juvenile stage. The percentage of glochidia successfully reaching this stage is estimated at 0 .004% to as low as 0.000001% (Watters 1994, Zanatta and Metcalfe-Smith 2003a). After this transformation, the juvenile detaches from the host, falls into the substrate and completes its development into an adult (Watson *et al.* 2001b). Hoggarth (1993) suggested that morphologically depressed glochidia (valve height is equal to or less than valve length) are less likely to make initial contact with a host due to the small valve gape, but are better at holding on once contact has been made. This suggests that species with morphologically depressed glochidia have a lower recruitment rate. Most freshwater mussel species at risk have morphologically depressed glochidia and therefore are at risk of extirpation once breeding adult numbers decline below a critical threshold level. The glochidial and juvenile stages are both vulnerable as the glochidia must successfully attach to an appropriate host in order to complete their metamorphosis to the juvenile stage. Therefore, any factors changing the distribution or abundance of their host fauna impacts mussels. If host fish populations disappear, or decline in abundance to levels below that which can sustain a mussel population, mussel recruitment will no longer occur and the mussel species may become functionally extinct (Bogan 1993). Therefore, freshwater mussels are sensitive to both ecological and environmental disturbances to their environment and to the environment of their host species.

The freshwater mussel communities in the Great Lakes region are exposed to many of the threats and face the limiting factors listed above (Watson *et al.* 2001b). The specific threats impacting each species are further discussed below in each species' summary.

Over 30 freshwater mussel species that have been historically, or are currently, found in the Thames River and of the 11 freshwater mussel species designated as Extinct/Extirpated, Endangered, Threatened or Special Concern by COSEWIC, seven have been designated Endangered (Table 1) and, as such, are facing imminent extirpation from the Thames River watershed. Preservation of these seven mussel species is urgently needed as are efforts to conserve their unique aquatic habitats (Metcalfe-Smith *et al.* 1997). Summaries are presented here for snuffbox (*Epioblasma triquetra*), wavy-rayed lampmussel (*Lampsilis fasciola*), round hickorynut (*Obovaria subrotunda*), round pigtoe (*Pleurobema sintoxia*), kidneyshell (*Ptychobranchus fasciolaris*), mudpuppy mussel (*Simpsonaias ambigua*), and rayed bean (*Villosa fabalis*).

Snuffbox (*Epioblasma triquetra*) – Endangered

Distinguishing Characteristics and General Biology – The following description is from Watson *et al.* (2001b). The snuffbox is a small freshwater mussel with a solid, thick shell and is triangular-shaped in males and somewhat elongated in females. The species has a high and sharply-angled ridge and the beak is swollen and sculptured with three or four faint, double-looped ridges. The outside of the shell is mainly smooth, yellowish to yellowish-green and is marked with numerous dark green rays that are often broken into triangular spots resembling "dripping paint" (Watson *et al.* 2001b). The nacre is white, iridescent posteriorly and has a grey-blue tinge in the beak cavity. Males may reach a length of 70 mm, while females are generally smaller with a maximum length of about 60 mm (Watson *et al.* 2001b). The lifespan of the snuffbox is unknown.

Distribution - The snuffbox was historically known to occur throughout the Ohio-Mississippi River system, in the Great Lakes system in lakes Erie and St. Clair and in tributaries of lakes Erie, St. Clair, Huron and Michigan. The distribution of the snuffbox has been significantly reduced throughout its range and extant populations have become small and geographically isolated (NatureServe 2004).

The snuffbox was first recorded in the Thames River at Chatham in 1894 and again in 1935 near Thamesville. Observations were made in 1970 regarding a healthy population in the Middle Thames River, north of Thamesford (Watson *et al.* 2001b). Intensive research conducted in 1997 and 1998 surveyed 16 sites on the Thames, Middle Thames and North Thames rivers, resulting in three weathered valves found at one historical site near Thamesville in 1997 and one fresh valve found at the same site in 1998 (Metcalfe-Smith *et al.* 1998, 1999, Watson *et al.* 2001b) (Figure 3).

Status – Global and United States: This is the most widespread member of the critically endangered genus *Epioblasma* (NatureServe 2004). Globally and nationally in the United States, the snuffbox is considered Rare to Uncommon (G3 and N3, respectively) (NatureServe 2004). *Canada and Thames River*: The species was designated by COSEWIC as Endangered in 2001 and is currently (June 2004) found on Schedule 1 under SARA (Government of Canada 2004). It has been given a rank of Critically Imperiled in Canada (N1), as well as in Ontario (S1) (NatureServe 2004). It has also been given a General Status rank of At Risk (1) by Canada and by Ontario (Metcalfe-Smith and Cudmore-Vokey 2004). Watson *et al.* (2001b) suggest, based on the results of the 1997 and 1998 surveys, that a small, isolated population may still persist in the lower reaches of the Thames River. However, Metcalfe-Smith *et al.* (1999) feel that it is relatively certain that the snuffbox has been extirpated from this system.

Habitat – The snuffbox is typically found deeply buried in clean, clear, swift-flowing riffle/run areas in small- to medium-sized streams and rivers with coarse, silt-free substrates consisting of combinations of sand, gravel, stone, cobble and boulder (Watson *et al.* 2001b, NatureServe 2004). The snuffbox is usually found entirely buried in the substrate, or with only the posterior slope exposed (Watson *et al.* 2001b). From various studies, Watson *et al.* (2001b) identified the depths at which the snuffbox has been found varied from 5 cm to 2.5 m.

Reproduction – The age at sexual maturity is unknown for Canadian populations. The snuffbox is a long-term brooder with fertilization occurring in the late summer and the release of glochidia occurring the following spring or summer (Watson *et al.* 2001b). Spawning of the snuffbox in the Clinton River, Michigan was described in Sherman (1994) as occurring from mid-July to August at water temperatures of 21-27°C, with the release of glochidia occurring over several weeks from early May to mid-July. The glochidia of the snuffbox are morphologically depressed, making it vulnerable to successful contact with their host species. Logperch (*Percina caprodes*) is a confirmed host for the snuffbox (McNichols and Mackie 2004). Research is ongoing and plans to test other species, such as rainbow darter (*Etheostoma caeruleum*) and blackside darter (*Percina maculata*), are in place (G. Mackie and K. McNichols, pers. comm.).

Diet – The specific food habits of the snuffbox are unknown. Freshwater mussels are, however, filter feeders consuming various materials such as algae, bacteria, plankton, rotifers, diatoms, protozoans, detritus and sand (Watson *et al.* 2001b).

Threats and Limiting Factors in the Thames River – The overall decline in distribution suggests that the snuffbox is not tolerant of poor water quality as the places where it still occurs are usually high quality streams with little disturbance to substrate or riparian zone (NatureServe 2004). The snuffbox is likely very sensitive to sedimentation because of its specialized habitat requirements and burrowing habits as an accumulation of silt on the streambed would reduce flow rates and dissolved oxygen concentrations below the surface (Watson *et al.* 2001b). One of the greatest on-going threats to the continued existence of the snuffbox is deterioration of water quality (TNC 2000). Decreased water quality associated with the high levels of agricultural, industrial and urban activities found in the Thames River is likely a major factor limiting the occurrence of the snuffbox in this system. The historic range of the snuffbox in the Thames River is in an area of intensive agricultural activity and downstream from a major urban centre, therefore exposure to siltation and agricultural, municipal and industrial pollutants may be impacting this species. Since the known historical occurrences of the snuffbox in the Thames River are 100 km or more downstream of the main reservoirs, dams may not be as much a threat to snuffbox in the Thames River (Watson *et al.* 2001b). However, zebra mussels pose a possible threat to the snuffbox if they continue to become established in the watershed. The known host species of the snuffbox (logperch) is abundant and widespread in the Thames River (J. Schwindt, unpub. data).

Wavyrayed lampmussel *(Lampsilis fasciola)* – Endangered

Distinguishing Characteristics and General Biology – The following description is from Metcalfe-Smith *et al.* (2000). The wavyrayed lampmussel is easily distinguished from other freshwater mussels by its yellow or yellowish-green rounded shell with numerous, narrow, wavy, green rays with multiple interruptions. The shape of the shell of males is quadrate-ovate and ovate in females. The shell is heavy, strong and moderately inflated with white or bluish-white nacre. The shell is usually less than 75 mm in length, though longer specimens (89 mm, 91 mm and 100 mm) have been recorded. The species has been shown to live at least 10 years, but rarely more than 20 years (Metcalfe-Smith and McGoldrick 2003).

Distribution – The wavyrayed lampmussel historically occurred throughout the Ohio and Mississippi River drainages, as far south as the Tennessee River system, and in the Great Lakes basin in the tributaries of Lake Michigan, lower Lake Huron, Lake St. Clair and Lake Erie.

Until recently, the wavyrayed lampmussel had only been recorded from the Thames River in 1902, 1931 and 1936. Sampling of 46 sites throughout the Thames River in

1994-1995 found no trace of this species (Morris 1996, Morris and Di Maio 1998). In a 1997-1998 survey of 16 sites on the Thames River, Metcalfe-Smith *et al.* (1998, 1999) found evidence of this species at six sites in the Upper Thames, North Thames and Middle Thames rivers (Figure 4).

Status – Global and United States: The species is Apparently Secure globally (G4) and nationally in the United States (N4) (NatureServe 2004). However, the species is declining throughout much of its North American range (Metcalfe-Smith and McGoldrick 2003). *Canada and Thames River*: The wavyrayed lampmussel was designated as Endangered in 1999 by COSEWIC and is currently (June 2004) listed on Schedule 1 under SARA (Government of Canada 2004). It is ranked in Canada and Ontario as Critically Imperiled (N1 and S1) (NatureServe 2004) and given a General Status of At Risk (1) in Canada and Ontario (Metcalfe-Smith and Cudmore-Vokey 2004). Metcalfe-Smith *et al.* (2000) suggest that the wavyrayed lampmussel still persists in the Thames River ecosystem, but may no longer be successfully reproducing.

Habitat – Wavyrayed lampmussels are mainly found in and around riffle areas of clear, hydrologically stable small- to medium-sized streams and rivers of various sizes at depths of up to 1 m with clean substrates of gravel and sand stabilized with cobble and boulders (Metcalfe-Smith *et al.* 2000).

Reproduction – As a long-term brooder, the wavyrayed lampmussel spawns in August and glochidia are generally released the following July through August (Clarke 1981). Females possess a minnow-shaped lure on the edge of the mantle to attract potential fish hosts to release pursed-shaped glochidia (Strayer and Jirka 1997, Metcalfe-Smith *et al.* 2000). The only known fish hosts for the wavyrayed lampmussel are the smallmouth bass (*Micropterus dolomieu*) and largemouth bass (*M. salmoides*) (Metcalfe-Smith *et al.* 2000), and recent research at the University of Guelph was able to transform juveniles on mottled sculpin (*Cottus bairdi*) (McNichols and Mackie 2004).

Diet – Food preferences are unknown for the wavyrayed lampmussel; however suspended organic particles, such as detritus, bacteria and algae, are likely consumed (Metcalfe-Smith *et al.* 2000, Nedeau *et al.* 2000).

Threats and Limiting Factors in the Thames River – It has been speculated (Metcalfe-Smith *et al.* 2000) that the wavyrayed lampmussel is an excellent indicator species of high quality habitat as it is usually found at sites supporting diverse mussel communities and are sensitive to toxic chemicals. Sedimentation from urban projects is threatening water and habitat quality for the wavyrayed lampmussel (Metcalfe-Smith *et al.* 2000). It has also been speculated (Metcalfe-Smith and McGoldrick 2003) that the wavy-rayed lampmussel may have a vital requirement for clear water during reproduction, as females must rely on good visibility in order to attract a host fish with her lure. The availability of preferred habitat is likely the main factor limiting the occurrence of the species in Ontario and in the Thames River (Metcalfe-Smith and McGoldrick 2003). Clearing of riparian vegetation and livestock access to waterways contributes to the destruction of mussel habitat (Metcalfe-Smith *et al.* 2000). All industrial and 70% of municipal outfalls are in the upper reaches of the Thames where the wavyrayed lampmussel are extant (Metcalfe-Smith *et al.* 2000). High ammonia and copper concentrations are a significant threat to this species, and other freshwater mussels in the Thames River, as the wavy-rayed lampmussel is especially sensitive to copper (Metcalfe-Smith *et al.* 2000). The wavy-rayed lampmussel has been essentially eliminated from the lower Great Lakes and its connecting channels due, in part, to the impacts of the zebra mussel. It can be expected that the recent discovery of the zebra mussel in the upper Thames' Fanshawe Reservoir, may impact the wavy-rayed lampmussels in this system. Neves and Odum (1989) found that muskrats prefer wavy-rayed lampmussels over other species. The known glochidial host species are found in the Thames River; however the macro-habitat of the wavyrayed lampmussel overlaps more with that of the smallmouth bass. Smallmouth bass abundance has decreased significantly in the Grand River, raising concerns about angling pressure on smallmouth bass populations to levels that will no longer sustain wavyrayed lampmussel (Metcalfe-Smith *et al.* 2000). It is unknown how angling pressure or canoe traffic is impacting Thames River populations.

Round hickorynut *(Obovaria subrotunda)* **–** Endangered

Distinguishing Characteristics and General Biology – The following description of this species is from Zanatta and Metcalfe-Smith (2003a). The round hickorynut is circular in shape and has centrally located beaks. Its thick, unsculptured shell is unrayed, smooth and is generally dark brown or olive-brown. The nacre is silvery white, sometimes with a tinge of blue or pink. The round hickorynut is relatively small, usually reaching a maximum length of 60 mm in Canada, with females being distinctly smaller than males. The lifespan of the round hickorynut is unknown.

Distribution – The round hickorynut was historically found throughout the Tennessee and Cumberland river systems and in the Ohio River system from western Pennsylvania and peninsular Michigan west to eastern Illinois, north to Lake Erie, Lake St. Clair and their drainages (Parmalee and Bogan 1998, Zanatta and Metcalfe-Smith 2003a).

The first recorded observation of the round hickorynut in the Thames River was in 1894 when a fresh, whole shell from a live animal was collected from the Chatham area. Another shell was collected in 1930, however the condition of the specimen is unknown (Zanatta and Metcalfe-Smith 2003a). Recent surveys in 1997-1998 found a total of 13 weathered (subfossil) half shells at three sites in the middle reaches of the Thames River (Metcalfe-Smith *et al.* 1998, Zanatta and Metcalfe-Smith 2003a) (Figure 5).

Status – Global and United States: The species is considered Apparently Secure globally (G4) and in the United States (N4) (NatureServe 2004). *Canada and Thames River*: It has been given a status of Endangered by COSEWIC and listing to Schedule 1 is currently (June 2004) pending (Government of Canada 2004). A national and Ontario rank of Critically Imperiled (N1 and S1) has been given to the round hickorynut (NatureServe 2004). Canada and Ontario have also given it a General Status of At Risk (1) (Metcalfe-Smith and Cudmore-Vokey 2004). The finding of only subfossil shells in the Thames River and an exhaustive search of literature and museum collections suggest that the round hickorynut may have been extirpated from this watershed since the turn of the century (Zanatta and Metcalfe-Smith 2003a).

Habitat - The round hickorynut is typically found in medium to large rivers, but has been found in lakes Erie and St. Clair (Clarke 1981, Strayer 1983, Strayer and Jirka 1997, Parmalee and Bogan 1998). The preferred substrates are sand, gravel, or clay/sand or clay/gravel in waters with steady, moderate flows to turbid, low-gradient, hydrologically unstable rivers (Strayer 1983, Gordon and Layzer 1989, Parmalee and Bogan 1998) at depths of up to 2 m (Zanatta and Metcalfe-Smith 2003a). In Lake St. Clair, they were found in shallow (less than 1 m) nearshore areas with firm, sandy substrates (Zanatta *et al.* 2002).

Reproduction – The round hickorynut is a long-term brooder and is estimated to have a gravid period in Canada extending from about September to June (Clarke 1981). The glochidia are ovate in shape without hooks, suggesting they are gill parasites (Zanatta and Metcalfe-Smith 2003a). The host fish for this species is unknown; however, Clark (1977) noticed an association with the eastern sand darter (*Ammocrypta pellucida*) in the Lake Erie drainage.

Diet - Like all freshwater mussels, the round hickorynut is a filter feeder primarily consuming bacteria, algae, particles of organic detritus and some protozoans (Nedeau *et al.* 2000, Zanatta and Metcalfe-Smith 2003a).

Threats and Limiting Factors in the Thames River – Numerous impacts throughout the Thames River watershed have likely contributed to the species decline. Impoundments, channelization, siltation, agricultural runoff, nutrient loading, toxic chemicals, sediment loading from overland runoff and tile drainage and a decline in distribution and abundance of its glochidial hosts are all limiting factors acting solely or in combination leading to the possible elimination of the round hickorynut in the Thames River watershed. Approximately 64% of historical records for the round hickorynut are from waters that are now infested with zebra mussels (Zanatta and Metcalfe-Smith 2003a).

The recent discovery of the zebra mussel in the Thames River may impact any remaining individuals or prevent re-establishment. The eastern sand darter is a Threatened species in Canada (Holm and Mandrak 1996) and is considered uncommon and localized in the Thames River (J. Schwindt, unpub. data, 2003). Predation by muskrats or raccoons may also be a threat to this species.

Round pigtoe *(Pleurobema sintoxia)* - Endangered

Distinguishing Characteristics and General Biology **–** The following description is from Zanatta and Metcalfe-Smith (2003b). The river form of the round pigtoe is compressed, flattened, and usually somewhat rectangular, but can also be oval or elongated. It has a moderately thick shell with a rounded anterior end and a squarely truncated posterior end. The round pigtoe has a smooth shell with a greenish-brown, light brown or reddish-brown periostracum in juveniles, turning chestnut or dark brown in adults. Near the beaks, faint green rays are visible in some shells. The nacre is white or various shades of pink. It is generally considered to be a medium- to large-sized mussel with a maximum length of 100 mm.

The taxonomy of this species is contentious, with some considering the round pigtoe to be part of the Ohio pigtoe (*P. cordatum*) species complex and others considering it to be a unique species. Rigorous genetic, anatomical and conchological studies are required to examine the taxonomic status of this species (Zanatta and Metcalfe-Smith 2003b).

Distribution **–** Historically, the round pigtoe is distributed from New York and Ontario west to South Dakota, Kansas and Oklahoma, and south to Louisiana and Alabama. Large river populations have been largely eliminated in the upper Midwest, but many populations still survive in Mississippi River tributaries (NatureServe 2004).

Between 1934 and 1995, there were six records of round pigtoe throughout the Thames River (both Upper and Lower) (Zanatta and Metcalfe-Smith 2003b). During a 1997-1998 survey of 16 Thames River sites, weathered shells were found at eight sites in an approximately 150 km reach of the river. This, along with the historic collection of the species from widely separated sites, suggests that the round pigtoe was once broadly distributed, although rare, in the Thames River (Zanatta and Metcalfe-Smith 2003b). During this survey, only two live specimens of round pigtoe were found, both from one site in the Middle Thames near Thamesford (Metcalfe-Smith *et al.* 1998, Zanatta and Metcalfe-Smith 2003b). Zanatta and Metcalfe-Smith (2003b) surmised that the round pigtoe is now apparently restricted to a very small (possibly relict) population in the upper reaches of the Middle Thames near Thamesford (Figure 6). Recent work by DFO in 2004, found 21 live specimens in a stretch from just upstream of Thamesford down to near the confluence with the South Thames, as well as near Wellington Road (T. Morris, pers. comm.)

Status – Global and United States: The round pigtoe is considered Apparently Secure globally (G4) and nationally in the United States (N4) (NatureServe 2004). *Canada and Thames River*: In 2004, the round pigtoe was designated by COSEWIC as Endangered, and its placement to Schedule 1 of SARA is currently (June 2004) pending (Government of Canada 2004). Canada and Ontario have given the round pigtoe a rank of Imperiled (N2 and S2, respectively) (NatureServe 2004) as well as a General Status rank of At Risk (1) (Metcalfe-Smith and Cudmore-Vokey 2004). Recent findings suggest the population in the Middle Thames River may be more extant than previously thought (T. Morris, pers. comm.)

Habitat – The round pigtoe is found at depths greater than 3 m in medium to large rivers with a mix of mud, sand, gravel, cobble and boulder substrate (Cummings and Mayer 1992), but is also found in lakes Erie and St. Clair (Zanatta and Metcalfe-Smith 2003b).

Reproduction – The round pigtoe is a short-term brooder with the breeding-season lasting from early May to late July in Wisconsin (Zanatta and Metcalfe-Smith 2003b). The glochidia are subovate and without hooks, suggesting they are gill parasites (Zanatta and Metcalfe-Smith 2003b). Studies from the United States report several glochidial hosts of the round pigtoe (Hove 1995, Zanatta and Metcalfe-Smith 2003b). Of those, the spotfin shiner (*Cyprinella spiloptera*), northern redbelly dace (*Phoxinus eos*), bluntnose minnow

(*Pimephales notatus*) and the bluegill (*Lepomis macrochirus*) occur in Ontario but have not been tested in Canada (K. McNichols, pers. comm.).

Diet – The round pigtoe is a filter feeder consuming various materials such as algae, bacteria, plankton, rotifers, diatoms, protozoans, detritus and sand (Watson *et al.* 2001a).

Threats and Limiting Factors in the Thames River – As with many other freshwater mussels, the round pigtoe is sensitive to pollution, siltation, habitat perturbation, inundation, and loss of glochidial hosts (NatureServe 2004). Municipal and industrial pollution may be responsible for the loss of mussel habitat in the heavily populated Thames River watershed (Zanatta and Metcalfe-Smith 2003b). The recent discovery of zebra mussels in the Thames River is a potential threat to the round pigtoe (Zanatta and Metcalfe-Smith 2003b). All of the above threats occur to varying degrees in the Thames River. Round pigtoes are less likely to be vulnerable to muskrat predation because their heavy shells are difficult to open (Zanatta and Metcalfe-Smith 2003b). Of the three possible glochidial hosts, only the bluegill is uncommon and localized in the watershed (J. Schwindt, unpub. data).

Kidneyshell *(Ptychobranchus fasciolaris)* – Endangered

Distinguishing Characteristics and General Biology – The following description is from Metcalfe-Smith and Zanatta (2003). The kidneyshell is a medium to large freshwater mussel with an elongate, elliptical shell. The periostracum is yellowish-brown, yellowish-green or medium brown with wide, interrupted green rays that appear as squarish spots. The solid, heavy shell is compressed and may have a humped shape in old individuals. The anterior end of the kidneyshell is rounded and the posterior end is bluntly pointed. The hinge teeth are heavy and the beak sculpture is poorly developed, consisting of several fine, indistinct wavy ridges. A good distinguishing feature is the lateral teeth which are almost pendulous distally. The nacre is generally white or bluish-white, but can be pinkish in younger specimens. Recent surveys in Ontario observed the maximum shell length to be up to 124 mm (Metcalfe-Smith and Zanatta 2003). The lifespan of the kidneyshell is unknown.

Distribution – The kidneyshell was historically distributed throughout the Ohio, Tennessee, and Cumberland river systems; Lake Erie, Lake St. Clair and some of their tributaries; the Detroit River, Niagara River and some of its tributaries; and at least one tributary (Ausable River) to lower Lake Huron (Metcalfe-Smith and Zanatta 2003).

Only two historical records exist for the kidneyshell in the Thames River (1894 and 1933), both from the Chatham area (Metcalfe-Smith and Zanatta 2003). In 1996, one fresh shell was found in the Thames River above Chatham during a survey of 30 sites (Morris 1996). Sixteen sites on the Upper Thames River were surveyed in 1997-1998 and a total of two fresh shells and four weathered shells at four sites were found, but no live specimens (Metcalfe-Smith *et al.* 1998, 1999) (Figure 7).

Status – Global and United States: The kidneyshell is considered Apparently Secure/Secure globally (G4G5), as well as nationally in the United States (N4N5) (NatureServe 2004). *Canada and Thames River*: This species was designated as Endangered by COSEWIC in 2003, and listing to Schedule 1 under SARA is currently (June 2004) pending (Government of Canada 2004). It has been given a rank of Critically Imperiled in Canada (N1) and Ontario (S1) (NatureServe 2004) and a General Status rank of At Risk (1) both nationally and in Ontario (Metcalfe-Smith and Cudmore-Vokey 2004). Metcalfe-Smith and Zanatta (2003) estimated that the kidneyshell has been lost from up to 70% of its historical range in Canada. The findings of recent surveys (Morris 1996, Metcalfe-Smith *et al.* 1998, 1999) suggest that the kidneyshell is likely extirpated from the Thames River (Metcalfe-Smith and Zanatta 2003).

Habitat – The kidneyshell is most commonly found in small- to medium-sized rivers, but may also occur occasionally in shallow sections of impoundments with some moving water, large rivers and lakes (Gordon and Layzer 1989, Parmalee and Bogan 1998). The species is usually found in stable substrates of firmly-packed, coarse gravel and sand in moderate to swift flowing riffle areas, buried at depths of less than one metre (Gordon and Layzer 1989, Metcalfe-Smith and Zanatta 2003). It is frequently associated with emergent vegetation beds of water willow (*Justicia americana*) (Metcalfe-Smith and Zanatta 2003).

Reproduction - The species is a long-term brooder, breeding in August and releasing glochidia the following June to August (Clarke 1981). Van der Schalie (1970) reported that this species may occasionally be hermaphroditic, allowing females to switch to self-fertilization to ensure that recruitment continues when population densities are low. The glochidia are small, purse-like and without hooks, suggesting they are gill parasites (Metcalfe-Smith and Zanatta 2003). This species, as with other members of the genus *Ptychobranchus*, produce conglutinates (specialized packets of glochidia bound in a cellular or mucoidal matrix) (Watters 1999). These are expelled in two types that mimic host prey items. One, the major type, closely resembles fish fry (with pigmentation resembling eyes and lateral lines), the other is brightly coloured and mimics insect larvae (such as simuliids or chironomids) (Watters 1999, Metcalfe-Smith and Zanatta 2003). The host becomes infected when it bites the conglutinate, rupturing and releasing the glochidia near the fish's gills (Watters 1999, Metcalfe-Smith and Zanatta 2003). During recent laboratory research through the University of Guelph, juvenile kidneyshells were transformed on fantail darter (*E. flabellare*), johnny darter (*E. nigrum*) and blackside darter (McNichols and Mackie 2004).

Diet – Adult kidneyshells are filter feeders consuming bacteria, algae, particles of organic detritus, and some protozoans (Nedeau *et al.* 2000, Metcalfe-Smith and Zanatta 2003).

Threat and Limiting Factors in the Thames River – Habitat loss, from the exotic zebra mussel, should be considered permanent (Metcalfe-Smith and Zanatta 2003). The recent discovery of the zebra mussel in the Thames River may severely affect the ability of kidneyshell to recolonize the river. Increased predation by muskrats and raccoon, caused by increased population of these species, may also impact any remaining kidneyshells as these predators tend to remove the smaller, younger adults of a population. The removal of this group greatly influences the ability of the population to sustain itself longterm

(Metcalfe-Smith and Zanatta 2003). The identified host darter species of the kidneyshell are common and widespread in the Thames River (J. Schwindt, unpub. data).

Mudpuppy mussel *(Simpsonaias ambigua)* – Endangered

Distinguishing Characteristics and General Biology - The following description is from Watson *et al.* (2001a). The mudpuppy mussel is commonly known as the salamander mussel in the United States (Turgeon *et al.* 1988). Its shell is elongated, oval to elliptical in shape with a yellowish-tan to dark brown, rayless periostracum. It's thin, fragile shell is much thicker at the front end than at the back. The beak is slightly swollen and sculptured with four to five double-looped ridges. The nacre is bluish-white, sometimes with a tinge of salmon colour near the beak cavities, and iridescent on the posterior half of the shell. Specimens collected from Ontario had shell lengths up to 49 mm (Watson *et al.* 2001a). The lifespan of the mudpuppy mussel is unknown.

Distribution – The mudpuppy mussel was historically found throughout the Ohio, Cumberland and Upper Mississippi river systems and the drainages of lakes St. Clair, Huron and Erie (NatureServe 2004).

The mudpuppy mussel was first recorded in the Thames River during a 1998 survey on freshwater mussels in southwestern Ontario (Metcalfe-Smith *et al.* 1999). A single fresh valve was found on the Thames River in the city of London (Watson *et al.* 2001a) (Figure 8).

Status – Global and United States: Globally and in the United States, the mudpuppy mussel is considered a Rare to Uncommon (G3 and N3) species (NatureServe 2004). *Canada and Thames River*: The mudpuppy mussel was designated Endangered by COSEWIC in 2001 and is listed under Schedule 1 in SARA (Government of Canada 2004). It is Critically Imperiled in Canada (N1) and in Ontario (S1) (NatureServe 2004). It has been given a General Status of At Risk (1) both nationally and in Ontario (Metcalfe-Smith and Cudmore-Vokey 2004). The results of the 1998 survey could indicate at least one small, isolated population present in the upper reaches of the river (Watson *et al.* 2001a) (Figure 8).

Habitat - The mudpuppy mussel is found in all types of clear, freshwater habitat, including creeks, streams, rivers and lakes. It is found on a variety of substrates (mud, silt, sand, gravel, cobble or boulder) in areas of swift current (TNC 1999, Watson *et al.* 2001a). Often up to several hundred mudpuppy mussels are found packed tightly together under large, flat stones (Watson *et al.* 2001a).

Reproduction – The mudpuppy mussel has a perennial and iteroparous life cycle (Watson *et al.* 2001a). The age at sexual maturity is not known for the mudpuppy mussel. This species of freshwater mussel is unique in that rather than its glochidial host being a fish species, the only known host is an aquatic salamander, the mudpuppy (*Necturus maculosus*) (Gendron 1999). The reproductive period is believed to begin with fertilization occurring in the late summer and glochidia held over the winter for release the following spring or summer, thereby making the mudpuppy mussel a long-term brooder (Watson *et al.* 2001a). The glochidia are triangular in shape with well-developed hooks and are morphologically depressed (Hoggarth 1993).

Diet – The specific food habits of the mudpuppy mussel are unknown, however, it is assumed they consume algae, plankton, rotifers, diatoms, protozoans, detritus, sand and bacteria filtered from the water (Nedeau *et al.* 2000, Watson *et al.* 2001a).

Threats and Limiting Factors in the Thames River – Many of the threats impacting other freshwater mussels can likely be inferred to the mudpuppy mussel. Siltation, pollution, and impoundments may all be limiting factors in the Thames River. The area of the upper Thames River, where the only evidence of the mudpuppy mussel has been found, is in a section supporting a large urban population with 22 sewage treatment plants and two industries, all of which discharge wastes into the system (Watson *et al.* 2001a). Decline in water and habitat quality from this, as well as from agriculture, erosion and phosphorus and nitrogen loadings, decrease available habitat for the mudpuppy mussel in the Thames

River (Watson *et al.* 2001a). The recently discovered zebra mussel may have an impact on any mudpuppy mussel population in the Thames River. Any factors that change the distribution or abundance of the mudpuppy salmander (including siltation, habitat loss, and environmental contamination) will also have detrimental effects on the mudpuppy mussel (Watson *et al.* 2001a). The mudpuppy mussel is a very poorly understood species of freshwater mussel, and the factors limiting its occurrence in North America are completely unknown (Watson *et al.* 2001a). This species is very difficult to locate in traditional mussel surveys due to its unique habitat. It is also extremely difficult to tell the difference between the two sexes. These two factors make estimating population numbers and structure difficult (Watson *et al.* 2001a).

Rayed bean *(Villosa fabalis)* – Endangered

Distinguishing Characteristics and General Biology – The following description is from West *et al.* (2000). The rayed bean is a very small mussel with an elliptical shape and particularly heavy hinge teeth for its small size. The periostracum is usually light to dark green with crowded, wavy, dark green rays. The species has a narrow beak with about five crowded double-looped ridges (West *et al.* 2000). The nacre is silvery white and iridescent. The maximum length of the rayed bean in Canada is 38 mm (Clarke 1981, West *et al.* 2000).

Distribution – The species was once widely, but discontinuously, distributed throughout the Ohio and Tennessee river systems, western Lake Erie and its tributaries, and in tributaries to the St. Clair River and Lake St. Clair.

One single fresh whole shell was collected in 1934 from the south branch of the Thames River (West *et al.* 2000). From 1997-1998, 16 sites throughout the Thames River watershed were surveyed for freshwater mussels. A total of 41 weathered half valves were found at four sites; however no live specimens or fresh valves were found (Metcalfe-Smith *et al.* 1998, 1999) (Figure 9). During a 2004 mussel survey conducted by DFO, one live specimen was found in the North Thames (T. Morris, pers. comm.).

Status – Global and United States: The rayed bean is considered Critically Imperiled/Imperiled globally (G1G2) and Critically Imperiled nationally in the United States (N1) (NatureServe 2004). *Canada and Thames River*: The rayed bean has been designated Endangered by COSEWIC in 1999 and this status was re-examined and confirmed in 2000 (COSEWIC 2004). It is currently (June 2004) listed under Schedule 1 of SARA (Government of Canada 2004). It is Critically Imperiled in Canada (N1) and in Ontario (S1) (NatureServe 2004). Both Canada and Ontario gave the rayed bean a General Status rank of At Risk (1) (Metcalfe-Smith and Cudmore-Vokey 2004). West *et al.* 2000 felt the rayed bean was extirpated from the Thames River, however the recent discovery of a live specimen in 2004 indicates that at least a small population is existing (T. Morris, pers. comm.).

Habitat –The rayed bean is usually found in small to large streams often in or near riffle areas and in the headwaters and smaller tributaries of river systems and lakes (Cummings and Mayer 1992, TNC 1996, West *et al.* 2000). Live specimens found during surveys in the Sydenham River were found buried in the stable substrates of sand or fine gravel, generally in low flow areas along the margins of the river or edges of small islands (Metcalfe-Smith *et al.* 1998, 1999). The rayed bean is usually found deeply buried in the substrate among the roots of aquatic vegetation (West *et al.* 2000).

Reproduction –The species is a long-term brooder, holding its glochidia over winter for spring release (West *et al.* 2000). The glochidia are subspatulate in shape and are likely gill parasites (West *et al.* 2000). Until recently, the host fishes for this species in Canada were unknown. Recent research through the University of Guelph has identified four potential fish species as glochidial hosts for the rayed bean: mottled sculpin (*Cottus bairdi*), smallmouth bass, greenside darter (*Etheostoma blennioides*) and rainbow darter (Woolnough 2002).

Diet – The rayed bean is a filter feeder likely consuming suspended organic particles such as detritus, bacteria and algae (Nedeau *et al.* 2000, West *et al.* 2000).

Threats and Limiting Factors in the Thames River –Factors likely impacting the rayed bean in the Thames River watershed include siltation due to poor agricultural practices, exposure to agricultural chemicals, highway runoff (Mackie 1996), and high levels of phosphorus, nitrogen, ammonia and copper through agricultural, municipal and industrial discharge in the Thames River basin (West *et al.* 2000). The rayed bean may not be as sensitive to flow rate fluctuations in its habitat as other freshwater mussel species due to their deep burrowing habits, but may instead be more exposed to sediment-associated contaminants (TNC 1987, West *et al.* 2000). The main limiting factor affecting the rayed bean is likely the availability of shallow silt-free, riffle habitat (West *et al.* 2000). Of the four known glochidial hosts found in the Thames River, the mottled sculpin and rainbow darter are rare and localized (J. Schwindt, unpub. data).

Knowledge Gaps – Freshwater Mussels

In order to effectively develop recovery plans to protect and manage freshwater mussel species, it is necessary to complete certain biological research. Life history studies need to be done to identify age and size at sexual maturity, recruitment success, age class structure, reproductive ecology (such as critical threshold level of breeding adult numbers), critical habitat, limiting factors, meta-population dynamics and population viability (NatureServe 2004). Habitat unknowns include identification of critical habitats and amount of habitat required and available for the long-term survival of many species (especially kidneyshell) (Metcalfe-Smith and Zanatta 2003). Habitat use also needs to be quantified for all life stages, particularly for the highly vulnerable juvenile stage (Morris 2004a). The life cycle of the freshwater mussel and their dependence on host species for completion of that life cycle makes it imperative that the host species for the freshwater mussels in the Thames River watershed be identified. For species with limited number of host species, knowledge of the distribution and abundance of the host is imperative as it is directly linked to the survival of the mussel species. Species for which functional hosts are unknown or uncertain, laboratory testing and field confirmation must take place (Zanatta and Metcalfe-Smith 2003b). There is also a need to know if host species are functionally available to mussels, meaning the distributions must overlap during the time when mature glochidia are released (Morris 2004a). Laboratory testing and field confirmation must take place in order to determine functional availability (K. McNichols, pers. comm.).

Despite the richness of the Thames River mussel assemblage, the river has been relatively under-sampled with very limited information available regarding historical or current species populations and distributions. For example, in the recovery strategy for the wavy-rayed lampmussel, the upper reaches of the Thames River watershed and its tributaries were identified as an area where surveys need to occur for this species in order to determine the extent, abundance and population demographics of the species (Morris 2004b). Abundance and distribution of the Thames River mussel species needs to be monitored in order to ascertain how species abundances change over time. This would allow assessment of land-use changes, conservation practices, and physical/chemical parameters that correlate with, and are possibly responsible for, any biological or ecological changes (NatureServe 2004).

The cause of decline for the mussel species also needs to be better studied, especially identification of threats to specific life stages (Morris 2004a,b) in order to develop recovery strategies that will best target threats. The poor water quality found in the Thames River, as a result of agricultural, industrial and urban impacts, needs to be studied in order to determine the likelihood of recovering these endangered freshwater mussel species in the Thames River watershed (Watson *et al.* 2001b). Point and non-point pollution sources is perhaps the greatest on-going threat to most freshwater mussels. Destruction of habitat through stream channelization and maintenance and construction of dams is occurring in some areas. Impoundments reduce currents that are necessary for basic physiological activities such as feeding and a settling out of suspended solids – both of which are detrimental to mussels (NatureServe 2004). Longterm viability of freshwater mussel populations with respect to the recent invasion of zebra mussels also needs to be further studied, along with determining if St. Clair refuge sites are permanent or vulnerable to zebra mussels (Morris 2004a,b). These factors render habitat unsuitable and lead to isolation of populations, thereby increasing their vulnerability to extirpation (NatureServe 2004).

Conservation genetics of freshwater mussels is poorly understood which limits our understanding of the potential of relocation/reintroductions and the technical feasibility of artificial propagation (Morris 2004a).

Recent and Current Research on Thames River Freshwater Mussel Species at Risk

A freshwater mussel survey conducted in 1997-1999 sampled 16 sites on the Thames, Middle Thames and North Thames Rivers to assess the status of rare species of freshwater mussels. A timed-searched method was used, which is one of the most effective methods for detecting rare species (Strayer and Jirka 1997), combined with an intensive sampling effort of 4.5 person-hours per site. Sites that were known to support rare mussel species and/or diverse mussel communities in the past were targeted. For further information, see Metcalfe-Smith *et al.* (1998, 1999).

During the summer of 2004, DFO and Thames River conservation authorities (Upper Thames River Conservation Authority and Lower Thames Valley Conservation Authority) staff conducted surveys to assess the status of endangered mussel species in the Thames River (T. Morris, pers. comm.). The goal is to provide a complete assessment of the mussel fauna throughout the upper basin providing information about the distribution, abundance, demographics and habitat preferences of all mussel species at risk. Additional stations located in four large reservoirs (Fanshawe, Springbank, Wildwood and Pittock) will monitor for the establishment of zebra mussels - a serious threat to mussel species at risk. These sites will be examined for signs of veligers and for the establishment of juveniles and adults (T. Morris, pers. comm.). Information derived from these surveys that may update the distribution, abundance and status of the freshwater mussels will be compiled and presented in the Thames River Ecosystem Recovery Strategy.

Species-specific recovery strategies for the wavy-rayed lampmussel, round hickorynut and kidneyshell are currently being drafted by the Freshwater Mussel Recovery Team to prevent the imminent extirpation of these species in Canada (Morris 2004a,b).

AQUATIC REPTILES

Both aquatic turtle and snake species are vulnerable to becoming at risk due to several factors with respect to their life history and anthropogenic impacts. A general description is provided here, with more species specific threats and limiting factors provided in the species summaries below.

Turtles are generally long-lived, have a late age to maturity and produce relatively few offspring. This renders this group vulnerable to decline as any increase in adult mortality could have a severe impact on the population (Congdon *et al.* 1993). Turtle nests are frequently predated by raccoons (*Procyon lotor*), coyotes (*Canis latrans*), foxes (*Vulpes vulpes*) or flesh fly maggots (Family Sarcophagidae). An increase in raccoon populations in and around highly populated areas such as London, as well as mink along the Thames River, may increase the predation rate on adults and nests. A high level of nest predation combined with alteration or loss of sensitive turtle nesting habitat results in very low nest success in the watershed.

Snakes are especially vulnerable to decline due to their extreme habitat and food specializations. The primary threats for both adult turtles and snakes in the Thames River include shoreline habitat destruction or stream alteration, human interference and road mortality. Reptile habitat is lost or altered by wetland drainage, changes to shoreline habitat (gabion structures), artificial water levels (habitat loss and drowning of eggs), dams (physical barriers to habitat and isolation of populations) and the introduction of non-native plant species. Recreational activities, such as fishing, trapping and motor boating, impact aquatic reptile populations by causing disturbance, injury or death. Also, as aquatic reptiles spend much of their time in water and have permeable skin, these species are vulnerable to accumulating environmental contaminants. Many of Ontario’s reptiles are cryptic, wary or elusive and therefore accurate population estimates and trends are difficult to assess.

Of the 26 turtle and snake species listed by COSEWIC as Extinct/Extirpated, Endangered, Threatened or Special Concern, six are considered partially or mainly aquatic and occur in the Thames River watershed (Table 1). These six species are: spotted turtle (*Clemmys guttata*), spiny softshell (*Apalone spinifera*), stinkpot (*Sternotherus odoratus*), queen snake (*Regina septemvitatta*), northern map turtle (*Graptemys geographica*) and eastern ribbonsnake (*Thamnophis sauritis*).

Spotted Turtle (*Clemmys guttata*) - Endangered

Distinguishing Characteristics and General Biology – The following description is from Litzgus (2004). The spotted turtle is a small, aquatic turtle with small, yellow-orange spots on a black carapace. Its plastron is black and orange and the black head and limbs have yellow spots. The tail sometimes has yellow stripes. Large yellow-orange patches are found on each side of the head. The carapace length usually reaches no more than 13 cm.

Canadian populations emerge from hibernation in late March and throughout April (Litzgus and Brooks 2000). The lifespan of spotted turtles is unknown, although a captive individual lived for 42 years (Litzgus 2004).

Distribution – The spotted turtle is endemic to eastern North America. It occurs from Quebec and Maine southward to Georgia and northern Florida and westward in southern Ontario, New York, Pennsylvania, Michigan, Ohio, Indiana, Illinois, and Wisconsin. In Canada, the spotted turtle is found mainly in southern Ontario and southern Quebec. These populations are not contiguous (Litzgus 2004).

Historical records for the Thames River are located in the Lower Thames, North of Thamesville and the London area (Figure 10).

Status – Global and United States: The spotted turtle is considered Secure globally (G5) and in the United States (N5) (NatureServe 2004). *Canada and Thames River*: COSEWIC first designated the spotted turtle as Special Concern in Canada in 1991 but was uplisted to Endangered in 2004 (COSEWIC 2004). It is currently (June 2004) listed under Schedule 3 of SARA; however, as a result of the COSEWIC uplisting, the process for its placement on Schedule 1 has been initiated (Government of Canada 2004). The spotted turtle has a rank of Rare to Uncommon in Canada (N3) and in Ontario (S3) (NatureServe 2004). It has been given a General Status rank of Sensitive (3) in Canada and in Ontario (CESCC 2001). It is considered Vulnerable in Ontario by the Ontario Ministry of Natural Resources (OMNR) (NHIC 2004).

Search efforts were conducted in 2002 on the upper Thames River watershed. A total of 132 person hours were dedicated to searching six sites where spotted turtles were formerly recorded and three additional sites that contained potentially suitable habitat; no spotted turtles were found at any of the sites (S. Gillingwater, pers. comm.).

Habitat - Spotted turtles prefer quiet, small bodies of water; usually avoiding swift-flowing streams (Oldham 1990). Habitats may include ponds, ditches, streams and wetlands (Litzgus 2004). Spotted turtles have a preference for soft, muddy substrate and some aquatic vegetation (Litzgus 2004). In the Georgian Bay region nesting habitat generally consists of soil-filled rock crevices exposed to full sunlight (Litzgus and Brooks 2000, Litzgus 2004). In southwestern Ontario, spotted turtles have been known to nest along dykes, on top of muskrat lodges and at the base of grass tussocks (Litzgus 2004). Hibernacula can be found in sphagnum swamps, under moss and tree root hummocks, in rock coverns near swamps (Litzgus *et al.* 1999) or in soft bottom lake/marsh habitats usually in association with hummocks and tussocks (S. Gillingwater, pers. comm.). Fidelity to hibernacula and mating aggregation sites occurs and hibernation is communal (Litzguz and Brooks 2000).

Reproduction – Sexual maturity in Ontario populations is reached at 11-15 years of age (Litzgus and Brooks 2000). In Ontario, underwater aggregate mating often occurs in April/May (Ernst 1967). Nesting occurs from mid- to late-June in Ontario (Litzgus and

Brooks 2000). Average clutch size is four eggs, and is positively correlated with female body size (Ernst 1975). Eggs likely hatch in September and it is possible that hatchlings may overwinter in the nest and emerge the following spring (Oldham 1990). Most females do not oviposit every year, and three years can go by between egg laying (Litzgus 2004).

Diet – Spotted turtles are omnivorous and actively forage in shallow water for aquatic insect larvae, small crustaceans and snails, algae, carrion, earthworms, tadpoles and aquatic plant stems (Ernst 1976).

Threats and Limiting Factors in the Thames River – The use of communal hibernation and mating aggregation sites make spotted turtles susceptible to extirpation from habitat destruction (Litzgus 2004). Wetland drainage and habitat alteration (including fragmentation) may have significantly reduced suitable habitats for the spotted turtle in the Thames River watershed. Roadways and other developments increase adult mortality and isolate populations. This species is particularly vulnerable to predation by mammals, especially raccoons, after hibernation due to extreme lethargy of the turtles (Litzgus *et al.* 2004). An increase in recreational use of natural areas may disrupt sensitive habitat (S. Gillingwater, pers. comm.). In southwestern Ontario, particularly around Lake St. Clair, the invasive reed plant (*Phragmites*) is destroying spotted turtle habitat (Litzgus 2004). Collection for the pet trade may have posed a threat to spotted turtles if/when they were more common in the watershed. Spotted turtles have a very low reproductive output and population viability is highly dependent upon adult survivorship (Litzgus 2004). The population is therefore more susceptible to decline or extirpations if reproducing adults are lost from the population at an unnatural rate (Congdon *et al.* 1993)

Spiny Softshell (*Apalone spinifera*) – Threatened

Distinguishing Characteristics and General Biology - The following description is from Fletcher (2002). The spiny softshell turtle's carapace is flat, leathery and keel-less and is olive to tan in colour. Juveniles and adult males have a pattern of spots (ocelli) and lines, whereas the carapaces of females have a more mottled pattern. Head and limbs are olive to gray, with dark spots and yellowish-green stripes. The distinctive, tubular snout is truncated with large nostrils. The webbing on its feet extends up the shank of the hind limbs. Females can reach a shell length of 54 cm, which is, on average, 1.6 times larger than males (Conant and Collins 1991).

Distribution – The spiny softshell is one of seven subspecies of spiny softshell turtles (*Apalone spinifera* sp.) which ranges from New York to Wisconsin, south to the Tennessee and Mississippi Rivers and north to southern Ontario and Quebec. It is only one of six subspecies of *Apalone spinifera* whose range extends north into Canada (Fletcher 2002). In Canada, the population of spiny softshells can be subdivided into two isolated subpopulations. The first subpopulation is located on the Ottawa and St. Lawrence rivers and the Richelieu River-Lake Champlain system. The second, and larger, subpopulation occurs in Lake St. Clair, Lake Erie (including its major tributaries), and possibly western Lake Ontario and southern Lake Huron (Fletcher 2002).

Spiny softshell occurrences in Ontario have since decreased significantly however, it is impossible to determine the extent to which the population has declined because there are no historic estimates of population density (Fletcher 2002). A recent study conducted from 2002 to 2004 recorded a total of 82 individual spiny softshells in the Middle Thames watershed and 190 nests (S. Gillingwater, unpub. data) (Figure 11).

Status – Global and United States: The spiny softshell is globally and nationally Secure (G5 and N5) (NatureServe 2004). *Canada and Thames River*: The spiny softshell was designated Threatened in Canada by COSEWIC in 1991 and in 2002, this status was re-examined and confirmed by COSEWIC (COSEWIC 2004). It is currently (June 2004) listed under Schedule 2 of SARA (Government of Canada 2004). It is ranked as Imperiled in Canada (N2) and Rare to Uncommon in Ontario (S3) (NatureServe 2004). The General Status of spiny softshell in Canada and in Ontario is At Risk (1) (CESCC 2001). The OMNR designated the spiny softshell turtle as Threatened provincially in 1996 (NHIC 2004). An historic observation from the Chatham area of the Thames River stated that "hundreds of soft-shelled river turtles were scooped off floating logs to make supper that everyone enjoyed" (Gray 1956 as cited from Fletcher 2002). However, during 1997 survey work in this same area, fewer than 10 individuals were located (Fletcher 2002), suggesting the population is in severe decline in the Thames River watershed.

Habitat – Spiny softshells inhabit soft-bottomed bodies of water. Fletcher *et al.* (1995) noted that softshell sightings along the Thames River were at or just downstream of river bends, suggesting that these points along the river are important habitat areas for this species. Spiny softshell turtles require different habitat features for different aspects of their lives. The following habitat descriptions are from Fletcher (2002). Nesting habitat consists of areas with substrates of sand or fine gravel and abundant sunlight. These areas in the Thames River tend to be found downstream of eroding sandy slopes where sand has been deposited on the inside of a meander or where islands have formed. If sand is not available, as it is along some parts of the Thames, females have been observed to nest on top of sun-baked clay banks or in gravel areas. Shallow underwater muddy or sandy areas provide nursery and juvenile habitat, as well as predator avoidance and thermoregulation habitat for all life stages. River banks where vegetation does not block sunlight, logs, rocks, and some artificial structures (e.g. cement spillways) are used as basking areas. Deep pools (more than 1 m) that do not freeze completely provide winter hibernation sites and summer thermoregulation habitat for spiny softshells. Adequate foraging areas appear to be located in riffles, adjoining creeks, shallow inlets, shallow muddy/sandy substrates and areas of vegetative debris and aquatic plants. Not only is the presence of each of these habitat features necessary for the maintenance of these populations, unobstructed access corridors to and between these areas is also necessary (Fletcher 2002).

Reproduction - Female spiny softshells reach sexual maturity at approximately 12 years of age (18-20 cm plastron length) and males do so at 9-10 cm plastron length (Fletcher *et al.* 1999). Mating occurs in April or May in Ontario with usually one clutch per year laid from mid-June to mid-July containing an average of 20 eggs (range of 6-43 eggs) (Obbard 1991, Fletcher 1997, Fletcher *et al.* 1999, Fletcher 2002, S. Gillingwater, unpub. data). Double clutching can occur during long warm summers (Fletcher 2002). The eggs of the spiny softshell are 24-32 mm in diameter and are unique in that they are hardshelled, allowing nesting in drier areas than other turtle species in Canada (Fletcher *et al.* 1999, Fletcher 2002). Hatching occurs in fall, and hatchlings (30-40 mm in length) have a 1:1 sex ratio (NatureServe 2004, Fletcher *et al.* 1999, Fletcher 2002). With a limited number of suitable nest sites, several females will lay their clutch in the same nesting area.

Diet – Spiny softshells are benthic feeders and scavengers that feed primarily on crayfishes (Fletcher 2002), but will also consume carrion, aquatic insects, earthworms, fishes, tadpoles and frogs (NatureServe 2004).

Threats and Limiting Factors in the Thames River – Historically, habitat loss was the most significant cause of decline in spiny softshells in Ontario. Currently, habitat alteration/degradation is considered the biggest threat to this species which is facing over 50% habitat loss or alteration along the Thames River (Fletcher 2002). Bank stabilization structures, such as gabion baskets, can restrict access to basking and nesting habitats. The control of early spring flooding on the Thames River reduces the amount of scouring in sandy areas which results in an increase in vegetative growth, thus rendering the habitat unsuitable for nesting. Dams represent a significant limiting factor affecting habitat, quality and availability of nesting sites. Dams also act as physical barriers limiting migration. Since the key habitat features are not always in close proximity, it is essential that the natural connectivity of these areas is maintained. Eggs collected from 1997-1999 were analyzed for contaminant levels to determine if this is the reason for the high numbers of infertile eggs found (De Solla *et al.* 2003). The conclusions of the study suggested that reproductive success in the Thames River was not compromised due to organochlorines (De Solla *et al.* 2003); however, as a long-lived, carnivore with a well-developed ability to respire directly through their skin while underwater, the spiny softshell is likely at risk of accumulating environmental contaminants, especially living in urbanized, industrialized and polluted areas (Fletcher *et al.* 1999). Various recreational activities pose potential threats to softshell turtles and their habitat. Spiny softshell turtles have been caught on fishing lines in the Thames River, and human activity often occurs near sensitive nesting areas, decreasing nesting success as the turtles are easily disturbed during nesting (S. Gillingwater, pers. comm.). Incidental capture of adults occurs during trapping of other aquatic species, including other turtle species. Predation by mammals or flesh fly maggots seems to be the largest source of mortality from oviposition to just after hatching (De Solla *et al.* 2003) and survivorship from hatchling to adult is very low (Oldham *et al.* 1996, De Solla *et al.* 2003, S. Gillingwater unpub. data). Of the 190 nests located in the Middle Thames watershed in 2002, 149 were predated by mammalian predators. The 41 remaining nests, which were caged to protect against predation, became inundated with water during a mid-summer flood, and very few eggs hatched despite considerable efforts to remove the eggs and artificially incubate them (S. Gillingwater, unpub. data). It is likely that nesting success would have been close to zero in the absence of human intervention. It is unknown whether the high number of nests located accurately represents the number of gravid females in the area, or is alternatively representative of long distance female migration to suitable nesting sites, double-clutching, or splitting clutches between two or more separate nests (S. Gillingwater, pers. comm.). The spiny softshells are prey generalists with a preference for crayfish, which may be a limiting factor contributing to their decline. This species relies heavily on crayfish, which are also in decline in southwestern Ontario, and will be part of the Wild Species 2005 update which will designate General Status ranks to these to groups (L. Twolan, pers. comm.). A skewed age distribution found within the Sydenham River population (Fletcher and Gillingwater 1994) may also be applicable to the Thames River population. During 6 years of work in Ontario, few observations of softshell turtles under the age of 5 or of young adults were made (Fletcher 1999). With a long-lived population of older adults and few juveniles, the population is vulnerable to collapse (Fletcher 2002).

Stinkpot (*Sternotherus odoratus*) – Threatened

Distinguishing Characteristics and General Biology – The following description is from Edmonds (2002). The stinkpot (formerly known as the common musk turtle) is a small aquatic turtle with an arched, brown-black carapace and a yellowish hinged plastron. It has grey to black skin and many individuals have two prominent light stripes on the side of the head. The species was named for the musky odor it exudes from glands on the underside of the carapacial margins when disturbed. It rarely exceeds 13 cm in carapace length. Wild stinkpots captured in the United States were over 25 years of age (Edmonds 1998).

Distribution – The stinkpot ranges from Florida north to southern Ontario and Quebec, and west to Wisconsin and central Texas. In Ontario, most sightings occur along the southern edge of the Canadian Shield in addition to the edges of lakes Huron, Erie and Ontario and extend north into Quebec, just north of the Ottawa River. It is the only species of the Family Kinosternidae to range into Canada (Edmonds 2002).

Only three records exist in the Ontario Herpetofaunal Atlas for the stinkpot in the Thames River watershed (Figure 12). Two records were located in Essex-Kent County, and one in the southern portion of Middlesex County, all three of which were recorded previous to 1984 (Oldham and Weller 2000).

Status – Global and United States: The stinkpot is widespread and considered Secure globally (G5) and in the United States (N5) (NatureServe 2004). *Canada and Thames River*: In 2002, COSEWIC designated the stinkpot as a Threatened species, but is not currently (June 2004) listed under SARA (Government of Canada). It has been ranked as Apparently Secure in Canada (N4) and in Ontario (S4) (NatureServe 2004, NHIC 2004). It has been given a General Status rank of Secure (4) in Canada and Ontario (CESCC 2001). As no stinkpot have been recorded from the Thames River watershed since 1984, it is likely that stinkpot have been extirpated from the Thames River watershed.

Habitat – The stinkpot prefers shallow water (less than two metres) with a slow current (Cook 1984, Edmonds 1998). In Canada, stinkpot turtles have been found in streams, rivers, ponds, marshes and lakes (Edmonds 1998). They tend to be associated with vegetated areas dominated by *Chara* and *Myriophyllum* (Edmonds 1998). Nesting habitat varies considerably, but is generally exposed shallow gravel or soil-filled crevices close to the shoreline, or in sand (Lindsay 1965, L. Foerster, pers. comm.). In Ontario, nesting habitat must have enough direct sunlight to maintain sufficiently high incubation temperatures for embryonic development (Bobyn and Brooks 1994, Edmonds 1998).

Soft substrate (about 30 cm deep) is required for stinkpot turtles to bury themselves for hibernation, when water temperatures drop below 10°C (Ernst *et al.* 1994a).

Reproduction – Male stinkpot reach maturity at 5-6 years and females at 8-9 years of age (Edmonds 1998). They mate in the spring and fall while they are congregated at hibernation sites (McPherson and Marion 1981, Mendonca 1987). Females can store viable sperm from a fall mating through the winter (Gist and Jones 1989). Females in Ontario populations lay one or fewer clutches of 2-7 eggs per year between June and July (Edmonds 1998). There is not enough information on Ontario populations to estimate nesting success, hatchling survival or recruitment rates.

Diet – Stinkpot are omnivorous and feed primarily on molluscs and aquatic insects but will also consume crayfishes, fish eggs, minnows, tadpoles, carrion, algae and parts of vascular plants (Edmonds 1998).

Threats and Limiting Factors in the Thames River – Wetland drainage and other habitat alteration activities along shorelines and pollution may have contributed to a reduction in suitable habitat for stinkpot within the Thames River watershed. Due to the location of nests close to shorelines, high water levels can drown the eggs (Edmonds 1998). Roads and other barriers isolate populations and may prevent any natural repatriation to the area, especially as stinkpot find mobility on land difficult (Edmonds 1998). Stinkpot turtles are often caught on fishing hooks and can be injured or killed (Mahmoud 1968). Injury and death can occur from motorboat traffic as stinkpots bask at the surface of the water (Edmonds 1998). Out of water, stinkpots are highly susceptible to desiccation (Edmonds 1998). Stinkpot populations have high hatchling and juvenile mortality rates, as a result even slight increases (1-2% annually) in these rates could lead to the decline or eventual extirpation of a population (Edmonds 1998).

Queen Snake (*Regina septemvitatta*) – Threatened

Distinguishing Characteristics and General Biology - The following description is from Smith (1999). The queen snake is a slender, highly aquatic snake with a relatively small head. The queen snake has keeled scales with the number of scale rows usually 19 at mid-body, decreasing to 17 posteriorly. The anal plate is divided. The irises of the eyes are dark brown with brassy flecks and the tongue is dark reddish-brown. Dorsally, the species is brownish-olive, olive-brown or grayish-olive (even chocolate brown or chestnut) in coloration, with seven longitudinal stripes running along the body. One longitudinal stripe is sometimes apparent (less so in adults) down its midline, two other stripes run along the fifth and sixth scale rows, the remaining four stripes run along the pale yellow underside (two laterally and two medially). No other snake in Ontario has a striped underside. The average total body length ranges from 38-61 cm and females reach a larger maximum size than males (Branson and Baker 1974). The recorded maximum life span of a queen snake is 11 years (Snider and Bowler 1992).

The seasonal active period for the queen snake in Ontario is from early May to mid-October (Smith 1999) but isolated sightings have been noted as early as mid April (T. Piraino pers.comm.). Late fall aggregations are believed to occur prior to communal hibernation, but reports of this occurring in Ontario are uncommon (Smith 1999).

Distribution – The queen snake ranges from east of the Mississippi River to Ontario and south to Florida (NatureServe 2004). In Canada, the queen snake is restricted to southwestern Ontario, west of the Niagara Escarpment and south of Georgian Bay (Smith 1999).

The queen snake was first reported in the Thames River watershed in 1882 (Campbell and Perrin 1979). Campbell and Perrin (1979) conducted a study in 1979 identifying 16 queen snakes from the Middle Thames watershed. Seven specimens were observed from two locations in the North Branch of the Thames in 1990 (Gartshore and Carson 1990). Observations from the Upper Thames River Conservation Authority from 1995-1997 included 37 live specimens and one dead specimen, mostly in the London area. Current distribution within the Thames River, based on species sightings, can be divided into two distinct areas; the southern portion of the Upper Thames and the southern portion of the Lower Thames (Figure 13).

Status – Global and United States: The queen snake is considered Secure globally (G5) and nationally (N5) in the United States (NatureServe 2004). *Canada and Thames River*: This species was designated as Threatened by COSEWIC in 1999, and this status was re-examined and re-confirmed in 2000 (COSEWIC 2004). The queen snake is listed under Schedule 1 of SARA (Government of Canada 2004). It has been given a rank of Imperiled in Canada (N2) and in Ontario (S2) (NatureServe 2004) and a General Status rank of At Risk (1) both nationally and in Ontario (CESCC 2001). The OMNR designated the queen snake as provincially Threatened (NHIC 2004).

The most recent and rigorous search effort for the queen snake along the Thames River occurred in 2002 where 21,649 rocks were overturned and over 140 person hours were dedicated to searching for queen snakes (S. Gillingwater, pers. comm.). Despite the considerable search effort, only nine individuals were found, all at the same location as previous sightings on the North Branch of the Thames River. Queen snakes were absent from one location where they had been observed in 1997.

Habitat – The queen snake is highly specialized with respect to habitat requirements and is rarely found further than three metres from water (Smith 1999). In a study of queen snake populations in Ohio, three conditions were noted to be necessary to support them: i) a permanent area of water, flowing or still, with temperatures remaining at or above 18.3°C throughout the active season; ii) abundant cover (flat rocks especially either submerged and/or on banks); and iii) an abundance of crayfishes (Wood 1949). In Ontario, the queen snake may also be associated with stony substrates and vegetation such as Joe-pye weeds (*Eupatorium maculatum* and *E. purpureum*), bulrushes (*Scirpus* spp.), golden rods (*Solidago* spp.) and willow (*Salix* spp.) and cottonwood (*Populus deltoids*) trees (Campbell and Perrin 1979, Smith 1999). There is little information on hibernacula in Ontario, however abutments of old bridges, bedrock outcrops and possibly crayfish burrows may provide suitable hibernation sites within the Thames River watershed (Campbell and Perrin 1979, Smith 1999). The only documented hibernation site was found on the Thames River and described as being near the top of a south facing clay bank with seeping water (S. Gillingwater pers. comm..)

Reproduction – Male queen snakes reach maturity during their second year whereas females normally do not reproduce until their third year (Branson and Baker 1974, Smith 1999). Mating likely takes place both in the spring and fall (Branson and Baker 1974). In Ontario, the queen snake gives birth to 10-15 live young between July and early September under stones near water (Campbell 1977, Froom 1981, Smith 1999). Litter size is positively correlated with the body length of the female (Campbell 1977). There is little information on the reproductive success of queen snakes (Smith 1999).

Diet – The queen snake is a highly specialized carnivore feeding almost entirely on freshly molted crayfishes. Various studies conducted in the United States indicated that crayfishes accounted for more than 98% of their diet (Raney and Roecker 1947, Branson and Baker 1974). The gut contents of two snakes from the Thames River were examined and only crayfishes were found (Judd 1955). Other studies reported alternate prey items (small fishes, snails, dragonfly naiads and a toad), but comprised a very small percentage of the stomach contents (Raney and Roecker 1947, Wood 1949, Adler and Tilley 1960). Although Conant (1960) concluded, based on distribution patterns, that crayfishes from the genus *Cambarus* (with the exception of the burrowing *Diogenes* section of the genus) comprised the majority of the queen snake diet in the United States, this crayfish genus is not widely distributed in the northern portion of the queen snake's North American range (Smith 1999). Crocker and Barr (1968), Judd (1968) and Campbell and Perrin (1979) all found that the northern clearwater crayfish (*Orconectes propinquus*) was the most commonly collected crayfish species at queen snake localities in Ontario. Due to their preference for crayfishes, queen snakes forage along the bottom of waterbodies among stones and detritus and feed most heavily during early morning and late afternoon (Raney and Roecker 1947).

Threats and Limiting Factors in the Thames River –Potential threats exist where areas of human activity coincide with queen snake localities (S. Gillingwater, pers. comm.). Dams in the Thames River watershed, may pose a threat to queen snake populations by stream flow alteration which lead to unfavourable habitat conditions (Campbell 1977).

Other habitat alterations along the Thames, such as gabions and storm drains, eliminate cover sources for queen snakes (Smith 1999). In the Lower Thames, towards the mouth at Lake St. Clair (Kent County), agricultural and drainage developments have altered creeks and marshes to the extent that queen snakes are no longer found in this area (Campbell and Perrin 1979). Queen snakes may also be vulnerable to mercury toxicity and to other pollutants because of their highly permeable skin (Stokes and Dunson 1982).

Extreme habitat and food specialization render the queen snake particularly sensitive to disturbances (Smith 1999). Queen snakes are vulnerable to local extinctions because of the extreme habitat specialization which tends to create high concentrations of individuals with large gaps of unfavourable habitat between populations (Smith 1999). Any threat to crayfish populations would be a considerable limiting factor for queen snakes. Crayfish abundance, especially for the northern clearwater crayfish, is unknown for the Thames River, though this species, along with other Canadian crayfishes, is currently under review for General Status ranking assignment (L. Twolan, pers. comm.). Factors impacting Canadian crayfish populations are pollution, siltation and competition with the non-native rusty crayfish (*Orconectes rusticus*) (Johnson 1989, Hamr 1998). Listed predators of queen snakes include crayfishes, mink (*Mustela vison*), osprey (*Pandion haliaetus*), herons (*Ardea herodias*) and mudpuppies (*Necturus maculosus*) (Smith 1999), which are all found in the Thames River watershed.

Northern Map Turtle (*Graptemys geographica*) – Special Concern

Distinguishing Characteristics and General Biology: The following description is from Roche (2002). The northern map turtle is an aquatic turtle with an oval, elongated carapace which is olive to brownish in colour with a reticulated pattern of light yellow lines that fade with age (the lines resemble map contour lines, hence its common name). The plastron is light yellow to cream, usually unmarked, but sometimes with a concentric ring pattern on the bridges. The head, neck and limbs are a dark olive green and have longitudinal greenish-yellow stripes. A triangular-shaped spot is located behind each eye and is separated from the orbit by two or three stripes. Females are larger than males with a carapace length exceeding 25 cm (males on average have a carapace length of 14 cm).

This species is almost exclusively aquatic leaving the water only to bask and lay eggs and is an extremely wary turtle that will dive into the water at the slightest disturbance (Roche 2002). Hibernation is communal and the turtles remain active during the hibernation period (five months in Canada) (Roche 2002).

Distribution – The northern map turtle ranges throughout the eastern United States and north to southern Ontario and southwestern Quebec (Roche 2002).

The Natural Heritage Information Centre has numerous records of northern map turtles in the Thames River watershed (Figure 14). Most records are recent (post-1983), and are mainly located between London and Lake St. Clair, though one record exists for Perth County (Oldham and Weller 2000). There have not been any studies focusing on northern map turtles in the Thames River, however many opportunistic observations exist. In 1997, four northern map turtle sightings were recorded from the Thames by the Upper Thames River Conservation Authority. In 2002, 64 incidental observations of northern map turtles were observed in the Middle Thames watershed, representing at least 26 different individuals (T. Piraino, pers. comm.).

Status – Global and United States: This species is considered Secure globally (G5) and nationally (N5) (NatureServe 2004). *Canada and Thames River*: The northern map turtle was designated as a species of Special Concern by COSEWIC in 2002; however it is not currently (June 2004) listed under SARA (Government of Canada 2004). It is considered Apparently Secure in Canada (N4) and Rare to Uncommon (S3) in Ontario (NatureServe 2004, NHIC 2004). The northern map turtle was given a General Status rank of Secure (4) in Canada and Ontario (CESCC 2001).

The northern map turtle is believed to be fairly common throughout the watershed, with the majority of sightings occurring from London to Lake St. Clair (S. Gillingwater, pers. comm.).

Habitat – The northern map turtle inhabits rivers and lakes, preferably with a slow current, muddy bottom and abundant aquatic vegetation (Behler and King 1979, DeGraaf and Rudis 1983). Basking sites, preferably offshore, must have ample sun exposure, an unobstructed view and be in relatively undisturbed areas (Froom 1971, Cook 1981). If offshore sites are unavailable due to high water levels (such as can occur in spring), northern map turtles will bask along the shore (Roche 2002). Nesting occurs in sand or soil some distance from the water's edge (Roche 2002). Cow pastures have been utilized for oviposition along the Thames River, likely due to a lack of more suitable nesting grounds (S. Gillingwater, pers. comm.). Hibernation habitat tends to be in areas with patches of sand and gravel (Graham and Graham 1992).

Pluto and Bellis (1986) suggest that juvenile and adult map turtles use different microhabitats. They found that within Pennsylvanian populations, large turtles (>125 mm) were more often found in the deep, slow areas of a river, whereas small turtles (<66.5 mm) frequented shallow, slow areas.

Reproduction – Little is known regarding the attainment of sexual maturity of the northern map turtle (Ernst *et al.* 1994b). Vogt (1980) found females in Wisconsin to still be sexually immature at 10-12 years of age. Courtship and mating occur while northern map turtles are still congregated in their hibernacula (Vogt 1980). In Ontario, observations from the Ontario Herpetofaunal Summary (OHS) indicate nesting occurs in mid-June to late July on well-drained sites with soft-ploughed soil or clear dry sand (Oldham 1997, Roche 2002). Females may travel a considerable distance for suitable nesting habitat. Nesting habitat can range from areas of no cover which provide maximum solar radiation to incubate the eggs (Vogt and Bull 1984) to beach areas where nests are laid at the base of vegetation. In Ontario, clutches (usually one per female per year) generally have 10-16 eggs (White and Moll 1991). Hatchlings usually emerge in late August or early September, although delayed emergence (overwinter and emerge in late May or June the following year) can occur with eggs laid later in the season (Roche 2002). There is evidence of delayed emergence in two Ontario populations (S. Gillingwater, unpub. data).

Diet – The northern map turtle is a carnivore that specializes on molluscs, although other prey items (insects and crayfishes) can be consumed (Roche 2002). As females have larger crushing jaws used for breaking open clams and large snails, this tends to be the majority of their diet. Whereas males and juveniles will consume insects, crayfishes, and smaller molluscs (Vogt 1981). Despite the recent proliferation of zebra mussels in the Great Lakes region, experimental manipulation demonstrated that map turtles would only consume zebra mussels if more preferred prey items were scarce (Serrouya *et al.* 1995).

Threats and Limiting Factors in the Thames River – Any water barriers, habitat alterations or human activities along riverbanks may destroy important nesting and basking habitats. Dams prevent migration to suitable nesting sites increasing adult mortality from raccoon predation and road mortality (Roche 2002). These impacts have been noted for the Thames River watershed (S. Gillingwater, pers. comm.). Artificially raising of water levels flood and destroy nesting sites (Flaherty 1982). Sarcophagid fly infestations also impact hatching success of eggs; in Rondeau Provincial Park, 100% of northern map turtles nests were invaded by maggots of this fly, killing embryos and hatchlings (Gillingwater and Brooks 2002). Increased human disturbance and recreational activities likely result in the exclusion of northern map turtles from potentially suitable habitat due to their wary nature (Roche 2002). Any impacts on the northern map turtle's primary prey item (molluscs) also impact the species (Roche 2002). Adult female mortality has been noted to be unusually high at the Long Point National Wildlife Area and to a lesser extent at Rondeau Provincial Park (S. Gillingwater pers. com.). A shortage of Canadian data on population sizes, trends, mortality rates, reproductive success and age structure, in addition to the aforementioned threats, may make this species particularly susceptible to population decline (Roche 2002).

Eastern Ribbonsnake (*Thamnophis sauritis*) – Special Concern

Distinguishing Characteristics and General Biology – The following description is from Smith (2002). The eastern ribbonsnake is a slender snake with a relatively long tail (tail length accounts for 33% or more of the total length). This species has strongly keeled scales and number of scale rows is usually 19, decreasing to 17 posteriorly. The irises are reddish and the tongue is pale red with darker tips. The dorsal colour of the eastern ribbonsnake is dark brown to black with a pale green, yellow or white unmarked belly. The chin and throat are white to fawn coloured. Scale rows three and four contain three longitudinal yellow stripes on a dark dorsal background. Below this yellow stripe is a brown stripe on scale rows one and two. Adult length ranges from 460 mm to 862 mm.

The active period for eastern ribbonsnakes in Ontario is generally April to October (Lamond 1994, Harding 1997); however extreme activity ranges have been recorded from end of March to early December (M. Oldham, unpubl. data, OHS).

Distribution – The eastern ribbonsnake is one of four subspecies of the eastern ribbonsnake (*Thamnophis sauitus sp.*) and is the only subspecies found in Canada (Smith 2002). This subspecies is found around the southern Great Lakes in Ontario, south through Michigan, Indiana, Illinois, Ohio, Pennsylvania, New York, Vermont, New Hampshire and Maine. Southern Nova Scotia and eastern and southern Wisconsin contain isolated populations (Smith 2002).

Very few records exist in the Ontario Herpetofaunal Atlas for eastern ribbonsnakes on the Thames and are all located in the Lower Thames between London and Chatham in Middlesex County (Oldham and Weller 2000) (Figure 15). Anecdotal observations exist for eastern ribbonsnakes near the London area in 1997 by the Upper Thames River Conservation Authority.

Status – Global and United States: The eastern ribbonsnake is considered Secure globally (T5 – T given to a subspecies) and nationally in the United States (T5). *Canada and Thames River*: The Ontario subspecies population was designated as Special Concern by COSEWIC in 2002, but is not currently (June 2004) listed under SARA (Government of Canada 2004, NatureServe 2004). It has been given a national rank of Apparently Secure in Canada (N4) and is Rare to Uncommon in Ontario (S3) (NHIC 2004). Despite thorough field searches for other reptile species along the Thames River watershed in 2002, no incidental eastern ribbonsnake observations were recorded.

Habitat – The eastern ribbonsnake is semi-aquatic and inhabits the edges of streams, ponds, wetlands or lakes (Lamond 1994). Low, dense vegetation near quiet, shallow water and sunlit basking areas are other habitat preferences (Minton 1972). Hibernacula in Ontario are believed to be animal burrows or rock crevices (Lamond 1994)

Reproduction – Sexual maturity is reached in the second or third year for eastern ribbonsnakes in the Great Lakes region (Harding 1997). In Ontario, courtship and mating occur soon after emergence in April, although fall mating may also occur (Harding 1997). Gravid females may move some distance from water before giving birth (Harding 1997). Ribbonsnakes are viviparous, and likely give birth in the fall (Smith 2002). Litter size is presumed to be positively correlated with the snout-to-vent length of the female, and ranges from 5-12 young. Ribbonsnakes produce fewer young than the majority of other species of the same genus (Smith 2002).

Diet – Amphibians (93% of which were frogs and toads) comprised the majority of the diet of eastern ribbonsnakes in a study from Michigan and New York populations (Brown 1979). Other prey items such as small fishes, caterpillars and other arthropods may occasionally be consumed, especially by juveniles (Froom 1981, Smith 2002). The eastern ribbonsnake feeds in the morning or early evening and prey is detected by both olfaction and vision (Ernst and Barbour 1989).

Threats and Limiting Factors in the Thames River – One of the most significant threats to the eastern ribbonsnakes in Ontario is the complete lack of species information necessary to analyze population trends and recognize habitat (Smith 2002). Possible threats to Ontario populations may be loss or degradation of suitable habitat, a decline in amphibian prey items, direct human persecution, road mortality, and predation by birds, mammals and other snakes (Smith 2002). These factors are likely impacting eastern ribbonsnakes in the Thames River watershed. Recruitment of young may be low for Ontario populations, as during the Hamilton Herpetofaunal Atlas, only one of 71 ribbonsnakes found was a juvenile (Lamond 1994).

Knowledge Gaps - Reptiles

As little is known about the past or present distribution and status of many of the aquatic reptile species at risk in the Thames River watershed, more search effort is required to confirm the presence or absence of these species within the watershed. As noted in the draft queen snake recovery strategy (Gillingwater 2003), surveys conducted at appropriate intervals using consistent methodologies are needed at all present and historical sites to maintain consistent long-term data. This would apply to species other than the queen snake, such as spotted turtles, spiny softshells and eastern ribbonsnakes.

Complete lack of species information, including biology and ecology of all life stages, is a knowledge gap for most of the aquatic reptile species at risk. Information on habitat identification and use, seasonal dispersal, population isolation, size and trends, age structure, reproductive success, survival, recruitment and mortality rates are needed. In some cases, basic biological information is completely missing; for example, it is unknown when eastern ribbonsnakes give birth (Smith 2002). Biological information is necessary to evaluate long term survival habitat and population dynamics to direct recovery efforts. For some species, the population, ecology and impacts of their specialized prey items (crayfishes) are also necessary.

Recent and Current Research on Thames River Reptile Species at Risk

Recovery teams are currently drafting recovery strategies for the spiny softshell (Fletcher et al. 1999) and the queen snake (Gillingwater 2003). The national recovery strategy goal for the spiny softshell is to down-list the species from Threatened to Special Concern (Fletcher et al. 1999). Spiny softshell habitat enhancement, nest protection and maintenance, mark-recapture PIT tag study and a predation study will continue (S. Gillingwater, pers. comm.).

In the queen snake recovery strategy, the outlined goal is to halt further decline of Ontario populations (Gillingwater 2003). Surveys and monitoring (including mark-recapture PIT tag studies), micro-habitat investigations and habitat enhancements are ongoing. Future research includes investigation into prey selection and abundance (S. Gillingwater, pers. comm.).

FISHES

The unique features of the Thames River provide a broad range of habitats that maintain one of the most diverse fish communities in Canada (UTRCA 1998). There are about 93 fish species reported from the Thames River (J. Schwindt, unpub. data), representing about 56% of the 165 species reported in Ontario (Mandrak and Crossman 1992). Hybrids and migratory fish species have also been found in the main branch of the river, and the migratory species may also travel to other sections to spawn.

Recent habitat changes, the construction of dams and impoundments, siltation, and the introduction of species (e.g. common carp (*Cyprinus carpio*), zebra mussels) are all factors that affect the fish community. Holm and Crossman (1986) indicated water quality and fish habitat conditions had deteriorated markedly based on comparisons of surveys from the 1920s and 1940s to 1985. Turbidity and siltation increased, stream flow rates changed by habitat disruptions including impoundments. They also noted a general decline of species with a preference for clear, fast water and an increase in abundance of species more tolerant of turbidity. These changes pose a distinct disadvantage to most freshwater fishes in the watershed.

Many sampling methods have been used to collect data on the fishes of the Thames River such as boat and backpack electrofishing, seine netting, gill netting, trawling, and minnow trapping (J. Schwindt pers. comm; Holm and Boehm 1998).

Twelve freshwater fish species in the Thames River watershed have been designated at risk (Extinct/Extirpated, Endangered, Threatened or Special Concern) by COSEWIC (Table 1). These twelve fish species, either currently, or historically, found in the Thames River watershed are: eastern sand darter (*Ammocrypta pellucida*), gravel chub (*Erimystax x-punctatus*), lake chubsucker (*Erimyzon sucetta),* greenside darter (*Etheostoma blennioides*), northern brook lamprey (*Ichthyomyzon fossor*), bigmouth buffalo (*Ictiobus cyprinellus*), spotted sucker (*Minytrema melanops*), river redhorse (*Moxostoma carinatum*), black redhorse (*Moxostoma duquesnei*), silver shiner (*Notropis photogenis*), northern madtom (*Noturus stigmosus*) and pugnose minnow (*Opsopoeodus emiliae*).

Gravel chub (*Erimystax x-punctatus*) – Extirpated

Distinguishing Characteristics and General Biology - The following description is from Page and Burr (1991). The gravel chub is a small minnow whose body is nearly cylindrical in shape and tapers from head to tail. It has large eyes located toward the top of the head. The body is olive green on top and shades to silvery-white on the belly. There are darker X- or W-shaped markings found on the upper side of the body. The lateral line is nearly straight and there is one terminal barbel at both corners of the mouth. The gravel chub reaches a maximum total length of about 90 mm.

Distribution – The distribution of the gravel chub is discontinuous from Kansas to New York, and southern Minnesota to Arkansas (NatureServe 2004). In Canada, it was only known from the Thames River drainage from two locations, the Muncey Indian Reserve (1923) and southwest of Moravian Indian Reserve at Muncey (1958) (Parker *et al.* 1988) (Figure 16). These sites are approximately 300 km from the nearest American records (Ohio) (Parker *et al.* 1988).

Status – Global and United States: The gravel chub is considered Apparently Secure globally (G4) and nationally in the United States (N4) (NatureServe 2004). *Canada and Thames River:* The species was designated by COSEWIC as Endangered in 1985, uplisted to Extirpated in 1987 and this status was reconfirmed in 2000 (COSEWIC 2004). The gravel chub is currently (June 2004) listed under Schedule 1 of SARA (Government of Canada 2004). It is Presumed Extirpated from Canada (NX) and, therefore, Ontario has the same rank (SX) (NatureServe 2004). It was given a General Status in Canada as Not Assessed (6) and Extirpated (0) in Ontario (CESCC 2001). The OMNR has also given it a rank of Extirpated (NHIC 2004). Despite numerous attempts to collect this species from the Thames River, it has not been found since 1958.

Habitat – The sites from which the gravel chub were previously found were described in Holm and Crossman (1986). Pool and riffle habitat predominated and the depth was 1-3 m. Substrate material was composed of sand, rock and stone with areas of soft organics and silt. Gravel chub has been described to inhabit clear to moderately turbid streams with permanent flow (Trautman 1981). The Thames River sites were quite turbid (secchi <1 m) from siltation, with algae as the only type of vegetation in the 1980's (Holm and Crossman (1986).

Reproduction – Nothing is known about the reproduction of the extirpated Thames River population of gravel chub. In the United States, spawning likely occurs in early spring in shallow (about 1 m), swift, gravelly riffles (Cross 1967, NatureServe 2004).

Diet – Food probably consists of epibenthic insects (Parker and McKee 1980), likely obtained from probing under rocks and into crevices with its sensitive snout (Parker *et al.* 1988).

Threats and Limiting Factors in the Thames River –Habitat requirements of the gravel chub are relatively narrow and they are susceptible to high turbidity and siltation. Holm and Crossman (1986) reported that the habitat of the Thames River gravel chub capture sites had shifted from clear, fast water to higher levels of silt and sand, likely leading to the extirpation of this species. Agricultural and industrial developments may have been the cause of the increase in siltation in the Thames River.

Northern madtom (*Noturus stigmosus*) – Endangered

Distinguishing Characteristics and General Biology - The following description is from Holm and Mandrak (1998). The northern madtom is a member of the bullhead catfish family and is one of five catfishes of the genus *Noturus* found in Canada. This species has an overall colour pattern that is mottled with three irregular dark saddles on the back in front of the dorsal fin, behind the dorsal fin and at the adipose fin. The dorsal and adipose fins have pale distal margins. Three or four irregular, crescent-shaped bars are on the caudal fin. Two pale spots are found just anterior to the dorsal fin. Maximum total length is 132 mm.

Distribution - The northern madtom occurs sporadically in the Mississippi River, Ohio River, Lake St. Clair and western Lake Erie drainages. In Ontario, the species is only known from the upper Detroit River, Lake St. Clair, and the Thames and Sydenham rivers (Holm and Mandrak 1998).   The first record of the northern madtom in Canada was from a trawl in Lake St. Clair near the origin of the Detroit River in 1963 (Goodchild 1993). Sampling efforts near its capture site had since have failed to locate the species, until 1994 where it was captured in the Canadian waters of the Detroit River (Holm and Mandrak 1998). It has since been captured in Lake St. Clair at the mouth of Belle River (Holm and Mandrak 1998).

The northern madtom is known from the Thames River from only one location near Wardsville where specimens were collected in 1991 and 1997 (Holm and Boehm 1998) (Figure 17).

Status – Global and United States: The northern madtom is considered Rare to Uncommon globally (G3) and nationally in the United States (N3) (NatureServe 2004). *Canada and Thames River:* The species was designated as Special Concern by COSEWIC in 1998 then uplisted to Endangered in 2002. It is currently (June 2004) listed on Schedule 3 of SARA, pending possible placement on Schedule 1 (Government of Canada 2004). It is designated as Critically Imperiled/Imperiled in Canada (N1N2) and in Ontario (S1S2) (NatureServe 2004). The northern madtom has a General Status rank of Not Assessed (6) in Canada and At Risk (1) in Ontario (CESCC 2001). It is listed as a provincially Threatened species by OMNR (NHIC 2004). A sustainable, reproducing population seems to be established in the Thames River (Holm and Mandrak 1998).

Habitat - The northern madtom prefers clear to turbid waters of large creeks to big rivers with moderate to swift current over a variety of substrate types and is occasionally associated with aquatic macrophytes (Holm and Mandrak 1998). Given the extremely restricted distribution of the northern madtom, there may be very specific, but undescribed habitat characteristics (Holm and Mandrak 1998). In the Thames River between Thamesville and Delaware, the species was collected in an area with numerous riffles. The Wardsville site in the Thames River where specimens were collected had moderate current, maximum depth of capture was 1.2 m, water temperature was 23-26°C, conductivity was 666 µS, and pH was 7.9 (Holm and Mandrak 1998).

Reproduction - The northern madtom is a cavity spawner, with nests having been found beneath large rocks as well as in a variety of anthropogenic debris (Holm and Mandrak 1998). Observations of northern madtom spawning and nests in the Detroit River in late July, estimated that clutch size was approximately 32-160 (MacInnis 1998). The northern madtom has low fecundity, but the nest-guarding behaviour of males enhances the survival of eggs and young (MacInnis 1998).

Diet - The northern madtom appears to be an opportunistic, nocturnal feeder (Rohde 1980). Gut contents of a Thames River specimen contained mostly caddisflies (*Potamyia flava* and *Hydropsyche scalaris*) and mayflies (*Emphemerella* and probably *Stenonema*) (Holm and Mandrak 1998).

Threats and Limiting Factors in the Thames River – The northern madtom is a small, secretive, nocturnal fish that is difficult to capture using traditional sampling techniques. Sampling at night in suitable habitats is probably the most effective means of searching for this species. Therefore, information about the Thames River population and any threats or limiting factors is poorly understood. Evidence suggests that it tolerates a wide variety of habitat conditions, though it may be affected by poor water quality (Holm and Mandrak 1998). The Sydenham River population appears to be lost and those populations face similar agricultural stressors as the Thames River populations (Dextrase *et al.* 2000), which are likely subject to heavy sediment and nutrient loading (Holm and

Mandrak 1998). Availability and quality (silt-free) of suitable nesting sites may be a limiting factor. If the round goby (*Neogobius melanostomus*) invades the middle reaches of the Thames River, it could potentially impact any remaining populations of the northern madtom for resource availability as both are benthic species. However, the nest-guarding behaviour of male northern madtoms (which do not abandon nests when disturbed) (MacInnis 1998), and their nocturnal activity pattern may allow this species to co-exist with introduced gobies. As the Thames records are among the most northerly for this species, it can be assumed that temperature is an important limiting factor (Holm and Mandrak 1988). It is unknown whether the other madtom species (brindled madtom (*Noturus miurus*) and stonecat (*Noturus flavus*)) present in similar habitats in the Thames River have an impact on the northern madtom.

Eastern sand darter (*Ammocrypta pellucida)* – Threatened
Distinguishing Characteristics and General Biology – The following description is from Holm and Mandrak (1994). The eastern sand darter is a slender, elongate and translucent member of the perch family (Percidae). The body is pale white, yellowish or silvery in colour with 10-14 dark spots located below the lateral line scale row. Adult average size ranges from 46-71 mm, although maximum recorded length was 81 mm.

Distribution - The eastern sand darter occurs throughout most of the Ohio River basin from western New York south to western Kentucky. It also has a disjunct distribution in the Great Lakes, Lake Champlain and St. Lawrence River drainages (NatureServe 2004). In Canada, it occurs in the drainages of southern Lake Huron and lakes St. Clair and Erie (Holm and Mandrak 1998).

A large number of eastern sand darters (48) were collected in the Thames River at Muncey in 1923 (Holm and Mandrak 1994). This species was later found between Wardsville and the Moravian Indian Reserve in 1958 and in the 1970s, they were found upstream and downstream of Muncey. Surveys conducted by the Royal Ontario Museum from 1989-1991, found the eastern sand darter at most historical locations (Holm and Mandrak 1994). They have been found in Komoka Creek as well as the Thames River (J.

Schwindt, unpub. data). The eastern sand darter was recorded in eleven samples in the main branch of the Thames River from upstream of Thamesville to downstream of London. Sampling at six locations in 1991 established the range from south of Bothwell to near Middlemiss (southeast of Melbourne). A 1997 sample confirmed the species' presence at a site near Wardsville (Holm and Boehm 1998). Specimens were collected further upstream at three sites near Delaware, most recently in 1989 (Figure 18), however, no specimens were found several kilometres upstream of these sites in 1998 and 2002.

Status – Global and United States: The eastern sand darter is designated as Rare to Uncommon globally (G3) as well as nationally in the United States (N3) (NatureServe 2004). *Canada and Thames River*: The species was listed as Threatened in Canada by COSEWIC in 1994 and is on Schedule 1 of SARA (Government of Canada 2004). It has a national status of Rare to Uncommon in Canada (N3) and a status of Imperiled (S2) in Ontario (NatureServe 2004). The General Status rank in Canada is Not Assessed (6) and is May be at Risk (2) in Ontario (CESCC 2001). The OMNR designated this species at Threatened in Ontario (NHIC 2004). It is difficult to assess the status of the eastern sand darter population in the Thames River as only a few records have been reported for most locations.

Habitat - The eastern sand darter inhabits large creeks, rivers and lakes with sandy bottoms (Page and Burr 1991). The species is found almost exclusively on sand substrates, and, according to Daniels (1993), few temperate stream fishes are as strongly associated with a particular habitat variable as is the eastern sand darter. In rivers, these habitats tend to be patchy and are normally found on the depositional side of a bend in the river or on the downstream end of the sand bar in areas of low current (<20 cm/sec) (Daniels 1993, Facey 1998). Although spawning does occur on the same sandy substrates on which it lives, it is unknown whether this habitat preference continues throughout its life history. Other habitat parameters vary with capture location: vegetation ranged from absent to some present, current ranged from still to swift, waters were clear or highly turbid (Holm and Mandrak 1994).

Reproduction – In Ohio, females reach sexual maturity at age 1+ (36 mm SL) (Holm and Mandrak 1994). Spawning has not been observed for this species in Ontario, but likely occurs between late June and late July (Holm and Mandrak 1994). The number of mature ova in fecund females averages 71 (30-170) (Holm and Mandrak 1994). Well-oxygenated sandy substrates free of silt are probably important to egg survival (Holm and Mandrak 1994).

Diet - The eastern sand darter feeds primarily on chironomid larvae, although simuliid larvae, oligochaetes, cladocerans and entomostaceans may also be consumed (Holm and Mandrak 1994).

Threats and Limiting Factors in the Thames River – The sandy habitat of the eastern sand darter are somewhat temporary in that they can be created or destroyed or moved by flood events and ice action. Siltation is generally considered detrimental to eastern sand darter populations, causing declines in available substrate oxygen and egg survivorship (Holm and Mandrak 1994). However, land-use practices and the numerous dams and impoundments in London and throughout the Upper Thames catchment alter channel structure and interfere with the deposition of sand are also likely detrimental to the eastern sand darter. These impacts have probably contributed to the range-wide declines reported for this species. The availability of silt-free, soft sand substrates is likely the most important limiting factor for eastern sand darters in the Thames River. The impact of high nutrient levels and toxic chemicals is unknown, but is likely not positive. If the round goby becomes established in the Thames River, it may pose a significant risk to the remaining populations of eastern sand darter as both are benthic species and may compete for resources.

Lake Chubsucker (*Erimyzon sucetta*) – Threatened

Distinguishing Characteristics and General Biology – The following description is from Mandrak and Crossman (1993). The lake chubsucker is a robust, slightly compressed member of the sucker family (Catostomidae). The body has a moderately deep-arched back, thick tail fin base and a wide head with a blunt snout. The colour is deep olive to greenish-bronze on the dorsal surface, and green-yellow to yellow-white on the ventral surface. The lateral band, if present, can be continuous, or broken into blotches. The dark-edged scales above the lateral line give a cross-hatched appearance. The total length of specimens captured in Ontario seldom exceeds 254 mm.

Distribution – The lake chubsucker is found throughout the eastern states of the United States. In Canada, it is restricted to the southwestern Ontario drainages of lakes Erie, St. Clair and Huron.

Lake chubsuckers have not been found in the Thames River watershed since the late 1960s, where it had been collected from Jeanettes Creek (Figure 19).

Status – Global and United States: The lake chubsucker is considered Secure globally (G5) and nationally in the United States (N5) (NatureServe 2004). *Canada and Thames River*: This species was designated by COSEWIC as Special Concern in 1994, but was uplisted to Threatened in 2001 and is found on Schedule 1 of SARA (Government of Canada 2004). It has a national status of Imperiled in Canada and Ontario (N2 and S2) (NatureServe 2004). The General Status rank in Canada is Not Assessed (6) and is At Risk (1) in Ontario (CESCC 2001). The OMNR designated this species as Threatened in Ontario (NHIC 2004). As this species has not been collected in the Thames River watershed, despite high sampling effort, for several decades, it is assumed to have been extirpated from the watershed.

Habitat – The lake chubsucker is found in clear, still waters with abundant vegetation. This habitat is generally found in backwaters, drainage ditches, floodplain lakes, marshes, oxbows, sloughs and wetlands (Mandrak and Crossman 1993).

Reproduction – In Ontario, lake chubsuckers spawn in marshes from late April to June. The eggs are broadcast over submerged vegetation and hatch at water temperatures of 22 to 29°C (Mandrak and Crossman 1993).

Diet – This species consumes plankton, small crustaceans, molluscs, aquatic insects, algae and other plant material (Mandrak and Crossman 1993).

Threats and Limiting Factors in the Thames River- It is likely that the level of turbidity and siltation in the lower Thames River is a limiting factor for lake chubsuckers, which prefer clear waters.

Black redhorse (*Moxostoma duquesnei*) – Threatened

Distinguishing Characteristics and General Biology - The following description is from Mandrak and Reid (2004). The black redhorse is one of seven redhorse species found in the sucker family (Catostomidae). It has a laterally compressed and relatively shallow body. The inferior mouth, under a long rounded snout has a narrow upper lip, a thick, slightly concave lower lip with deep cleft and long plicae with no transverse grooves. It has a lateral line count of 47-50. The dorsal surface and upper sides are gray or olive-brown with a silver-blue overtone. The sides are lighter, usually silvery-blue, with the ventral surface silver to milky white. The scales are dark edged and all fins are slate gray. The dorsal fin is triangular in shape. The maximum known age and length is 16 years and 658 mm, respectively (Coker *et al.* 2001, Mandrak and Reid 2004). It is very difficult to distinguish the black redhorse from other redhorse species, particularly the golden redhorse (*Moxostoma erythrurum*). Golden redhorse also has slate gray fins and a convex dorsal fin, but has a lateral line scale count of 40-42 (note that scale count extreme ranges can overlap between the black and golden redhorses) (Holm and Boehm 1999).

Distribution – The black redhorse extends through much of the Mississippi River system, north into Canada in the Great Lakes basin. Canadian populations are geographically disjunct in southwestern Ontario from those in the United States. The black redhorse has been reported only from the drainages of lakes Huron and Erie, and a single location in the Lake Ontario watershed (Mandrak and Reid 2004).

Little is known about the black redhorse population in the Thames River. It was first reported from the North Thames in 1979 (Holm and Boehm 1998). A small number of breeding adults was found near the original capture site in 1982 (Parker and Kott 1988). One juvenile specimen was observed in 1997 from a new location in Flat Creek (Holm and Boehm 1998). The black redhorse has recently been recorded (2000-2002) from Medway Creek, Thames River, Avon River, Stoney Creek, North Thames, Thames Creek, and Waubuno Creek (J. Schwindt, unpub. data) (Figure 20).

Status – Global and United States: The black redhorse is considered Secure globally (G5) and nationally in the United States (N5) (NatureServe 2004). *Canada and Thames River*: The species was designated as Threatened by COSEWIC in 1988 and is currently (June 2004) listed under Schedule 2 of SARA (Government of Canada 2004). It has been ranked as Imperiled both in Canada (N2) and Ontario (S2) (NatureServe 2004). The General Status rank for Canada is Not Assessed (6) and At Risk (1) in Ontario (NHIC 2004). It has also been designated as Threatened in Ontario by the OMNR (NHIC 2004). Although sampling for black redhorses in the Thames River watershed has not been extensive, specimens have been recently found in the main branch and most of the tributaries where it was collected historically, as well as many new locations in 2002 and 2003 (Mandrak and Reid 2004). In fact, the Thames River contains one of the two largest populations of black redhorse in Canada (Mandrak and Reid 2004).

Habitat – In Canada, the black redhorse has been reported from moderately-sized rivers with silt, sand, gravel, rubble and bedrock substrates (Parker and Kott 1988, Holm and Boehm 1998, Mandrak and Reid 2004). Capture sites have been characterized as well-oxygenated and relatively fertile with July water temperatures averaging 20º C (Parker and Kott 1988). It is rarely associated with vegetation (Mandrak and Reid 2004). Holm and Boehm (1998) described the depth at which black redhorses are found as 0.1-1.8 m. Gravel and cobble substrates in fast shallow waters are required for spawning (Parker and Kott 1988). Parker (1989) described young-of-year (YOY) habitat in the Thames and Nith rivers as shallow pools and slackened current.

Reproduction – Age at sexual maturity ranges from 2-5 years (Mandrak and Reid 2004). In Canada, the black redhorse spawns in late May or early June. Spawning activity intensifies as the water temperature approaches 15º C and lasts 7-8 days (Parker and Kott 1988). Fecundity was found in the Grand River to be 4,126 to 11,551 eggs per female (Kott and Rathman 1985). The non-adhesive, fertilized eggs (2.6-2.9 mm in diameter) are deposited in the gravel of the spawning shoal (Kott and Rathman 1985, Mandrak and Reid 2004). The period of egg incubation for black redhorses is unknown.

Diet – Black redhorses consume benthic crustaceans and insects, and sometimes macrophytes (Coker *et al.* 2001). Juvenile black redhorses (less than 65 mm) feed on plankton, progressing to soft-bodied invertebrates with increasing size to adulthood (Parker and Kott 1988).

Threats and Limiting Factors in the Thames River- The black redhorse is restricted in Ontario to low silt areas of moderate to high gradient streams. The black redhorse is intolerant of very turbid waters (McAllister *et al.* 1985). Various surveys in the United States have shown that populations decline following impoundment of their habitat (Parker and Kott 1988). There are over 78 dams in the Upper Thames watershed alone, reducing the amount of suitable habitat, blocking spawning migrations, and isolating populations (Mandrak and Reid 2004). Black redhorses may also be caught by anglers or by bow fishermen (Mandrak and Reid 2004, Cooke *et al.* 2005). The extent to which this occurs in the Thames River is unknown.

Northern brook lamprey (*Ichthyomyzon fossor*) – Special Concern

Distinguishing Characteristics and General Biology – The following description is from Lanteigne (1992). The back and sides of the adult northern brook lamprey are dark slate while the lower portions are pale grey or silvery-white. The ventral surface is tinted with orange, especially in sexually mature females, and the lateral line organs are non-pigmented. It has blunt and degenerate disc teeth and endolateral, unicuspid teeth. Total length can reach up to about 16 cm. The ammocoete period lasts about six years and is followed by a short transformation period of two or three months.

Recent work using mitochondrial and nuclear DNA from adult and juvenile lampreys from the Great Lakes basin suggest there are no diagnostic markers to differentiate northern brook lamprey from silver lamprey (*I. unicuspis*) (F. Neave, pers. comm).

Distribution – The northern brook lamprey occurs in the western Great Lakes basin of Wisconsin and Michigan, in the eastern Great Lakes basin of Michigan, Ohio and Pennsylvania, in the Ohio basin of Illinois, Indiana, Ohio and Kentucky and in the lower Missouri basin (Lanteigne 1992, NatureServe 2004). In Canada, the species occurs in the Great Lakes basin from Lake Superior to Lake Erie but appears to be absent from the Lake Ontario drainage. It occurs in the Ottawa River at Ottawa and the St. Lawrence River. The range of the northern brook lamprey extends as far west as the Nelson River drainage of Manitoba (Lanteigne 1992).

The only historical records for the northern brook lamprey in the Thames River are from 1884 in London, and 1931 from West Zorra (J. Schwindt, unpub. data). However, in June 2004, during annual benthic surveys conducted by the Upper Thames River Conservation Authority, a group of about six specimens were observed on Waubuno Creek, a South Thames tributary (J. Schwindt, pers. comm.) (Figure 21).

Status – Global and United States: The northern brook lamprey is Apparently Secure globally (G4) and nationally in the United States (N4) (NatureServe 2004). *Canada and Thames River*: The species was designated as Special Concern in 1991 by COSEWIC and is listed under Schedule 3 of SARA (COSEWIC 2004). It is Rare to Uncommon in Canada (N3) and Ontario (S3) (NatureServe 2004). The General Status rank of northern brook lamprey in Canada was Not Assessed (6) and Sensitive (3) in Ontario (CESCC 2001). OMNR gave it a status of Vulnerable (NHIC 2004). As only three observations of northern brook lampreys have been made in the Thames River watershed in the last 120 years, population status within the system is unknown. However, as the 2004 observation was of six spawning individuals (J. Schwindt, pers. comm.) it seems likely an established population exists in the watershed.

Habitat – Adults are found in somewhat turbid streams of various sizes. A substrate of coarse gravel may be required for spawning adults. Ammocoetes of the northern brook lamprey require fairly soft substrate in which to burrow in water about 15-61 cm deep with vegetation (Lanteigne 1992). They have a preference for warmer sections of streams and tributaries receiving large surface flow of warm water from wetlands and lakes (Morman 1979).

Reproduction – Northern brook lampreys spawn after transformation then die soon after. Morman (1979) outlined three physical factors in streams essential for successful spawning: gravel substrate with some amount of silt-free sand or other fine material; a unidirectional current; and suitable water temperatures (about 16-20°C). Nests are located beneath large stones and after fertilization become covered by substrate (Hardisty and Potter 1971). After a nine day incubation period, pro-ammocoetes emerge from the substrate and drift downstream where they burrow into silt beds (Piavis 1971).

Diet – By directing their mouth towards the current, ammocoetes feed in their burrows on desmids, diatoms, protozoans, and detritus strained from the water or sediment (Lanteigne 1998). Unlike many other members of the lamprey family (Petromyzontidae), the adults are not parasitic and do not feed (Scott and Crossman 1973).

Threats and Limiting Factors in the Thames River - Low water levels are likely a significant ammocoete mortality factor (Scott and Crossman 1973). Siltation and pollution may limit successful spawning, which requires clean, gravel substrate. Habitat deterioration and contamination may affect larvae. In areas of sea lamprey (*Petromyzon marinus*) control programs utilizing a non-selective lampricide, northern brook lampreys are inadvertently destroyed (Parker *et al.* 1988). However, lampricide treatment has never occurred in the Thames River (R. Young, DFO, pers. comm).

Greenside darter (*Etheostoma blennioides*) – Special Concern

Distinguishing Characteristics and General Biology – The following description is from Dalton (1991). The greenside darter has a medium-sized head with large prominent eyes on each side of the apex and a small mouth below a bluntly, rounded snout. Its two dorsal fins are close together, the anterior one having strong spines and the posterior one with soft rays. Pelvic fins are placed anteriorly close behind the pectoral fins. The dorsal surface is olive-green or olive-brown lightening to pale green down the sides. Pelvic, anal and caudal fins are also pale green. There are five to eight large, green W- or U-shaped markings on its sides (especially in juveniles), fading down into the white or cream-coloured ventral surface. The greenside darter is the largest member of the genus *Etheostoma* in the Family Percidae, reaching lengths of 11 cm. Their life span is generally three years, but some can live up to five years.

Distribution - The greenside darter occurs in southern Great Lakes drainages (lakes Huron, St. Clair, Erie and Ontario), throughout much of the Mississippi basin (except southern Illinois and Indiana), and along the Atlantic slope from New York to Virginia (NatureServe 2004). In Canada, the greenside darter is known from several drainages in southwestern Ontario: Gold Creek, Ausable River, Sydenham River, Thames River, Nairn Creek, Lake St. Clair, and Big Creek. The species has also recently spread throughout much of the upper part of the Grand River watershed after a presumed introduction about 10 years ago (Portt *et al.* 2004).

Over 500 records exist for the greenside darter in the Thames River dating back to 1884. Sampling conducted from 1999 to 2002, concentrating primarily on agricultural drainage ditches (usually considered marginal habitat), found greenside darters at 52 of 236 sample sites throughout the Thames catchment (Figure 22).

Status – Global and United States: The greenside darter is Secure globally (G5) and nationally in the United States (N5). *Canada and Thames River*: This species was designated as Special Concern by COSEWIC in 1990 (COSEWIC 2004) and is listed on Schedule 3 of SARA (Government of Canada 2004). It is designated as Apparently Secure in Canada (N4) and in Ontario (S4) (NatureServe 2004). The General Status rank given to the greenside darter in Canada was Not Assessed (6) and Secure (4) in Ontario (CESCC 2001). It was designated by OMNR as Not in Any Category (NIAC) (NHIC

2004). It appears that the greenside darter is abundant throughout the Thames River, its main branches, and most of the tributaries that have been sampled.

Habitat - The greenside darter inhabits rocky, deep riffles of creeks and small to medium rivers, and is occasionally found along the shores of large lakes (Page and Burr 1991). Greatest abundance is reached in deep riffles that are swift with a rubble and boulder substrate (Dalton 1991). Although the greenside darter is most often found in streams of low turbidity, it exists in the relatively turbid waters of the Thames River (Dalton 1991). Juveniles and adults may be found in similar habitats.

Reproduction – Sexual maturity is reached by one year with spawning occurring in the spring once the water temperature is above 11^{o}C and may be protracted over several weeks (Dalton 1991). Older females lay more eggs than younger ones (Dalton 1991). The adhesive eggs are usually laid on filamentous algae (usually *Cladophora*), but also moss or angiosperms close to rocks in riffle areas and hatch in about three weeks (Scott and Crossman 1973, Dalton 1991).

Diet - Feeding on plankton begins eight days after hatching and diet changes to aquatic insects with size (Dalton 1991). Juveniles consume chironomid larvae, large Daphnia, copepods and blackfly larvae, while adults consume larvae of chironomids, Simulium, Trichoptera and Ephemeridae (Scott and Crossman 1973, Dalton 1991). Food is consumed from rock surfaces in riffles (Dalton 1991).

Threats and Limiting Factors in the Thames River - Dalton (1991) suggested that the specialized feeding and spawning areas (riffle habitats) were at risk from several anthropogenic disturbances including impoundments, contaminants associated with industry and agriculture, siltation, and low water flows. Factors impacting their benthic aquatic insect prey, such as pesticides, industrial and agricultural contaminants and other pollutants will also affect greenside darters (Dalton 1991). Although the greenside darter may be limited by turbidity in the lower parts of the Thames River, it appears to be maintaining its range and abundance levels throughout much of the system under current conditions. The greenside darter does not appear to be as sensitive to the common threats in the watershed that are affecting other species in this system.

Bigmouth buffalo (*Ictiobus cyprinellus*) – Special Concern

Distinguishing Characteristics and General Biology - The following description is from Goodchild (1989). The bigmouth buffalo is a member of the sucker family (Catostomidae) with a large ovoid head and a sharply oblique, terminal mouth. The dorsal fin is long and the lightly forked caudal fin is very broad. The back and head are dull brown to olive in colour, while the sides are lighter. The underside is white and the fins are dusky grey. The scales on the body are relatively large. The bigmouth buffalo reaches lengths of up to one metre and the maximum reported age in most waters is less than 10 years (Paukert and Long 1999). The species is the target of a commercial fishery in Saskatchewan (Hlasny 2003).

Distribution - The bigmouth buffalo ranges widely in the Mississippi River basin from Louisiana north to Ohio, southern Michigan, Wisconsin, Minnesota, North Dakota and Montana and the southern Great Lakes and the Nelson River drainage (Hudson Bay basin) (NatureServe 2004). In Canada, the bigmouth buffalo has a disjunct distribution in central Saskatchewan, southern Manitoba and western Ontario (Goodchild 1989). In Ontario, the species is known from lakes Erie and St. Clair and their tributaries, as well as from Lake Ontario and Lake of the Woods (evidence suggests Lake of the Woods fish were introduced).

The bigmouth buffalo has been captured from Jeanettes Creek (1980) and the Raleigh Plains Drain (1989), both tributaries of the lower portion of the Thames River between Chatham and Lake St. Clair (Figure 23).

Status – Global and United States: The bigmouth buffalo is Secure globally (G5) and nationally in the United States (N5) (NatureServe 2004). *Canada and Thames River*: The bigmouth buffalo was listed in 1989 as Special Concern in Canada by COSEWIC and is currently (June 2004) under Schedule 3 of SARA (Government of Canada 2004). An update status report is currently being completed (Mandrak and Cudmore, unpub. data). It is ranked as Apparently Secure in Canada (N4) and unranked in Ontario (SU) (NatureServe 2004). It was given a General Status rank of Not Assessed (6) in Canada and Undetermined (5) in Ontario (CESCC 2001). The OMNR designated the bigmouth buffalo as Not In Any Category (NIAC) (NHIC 2004). The bigmouth buffalo appears to be expanding its distribution in southern Ontario as it has been discovered in many new drainages in the last 10 years (Welland River, Sydenham River, Grand River, Hamilton Harbour).

Little sampling has been undertaken to confirm the status of this population in the Thames River.

Habitat – The bigmouth buffalo occupies slow waters of small to large rivers, pools of large streams, ponds, impoundments and shallow lakes (Goodchild 1989, Page and Burr 1991). The species exhibits a preference for warm, highly eutrophic waters (Goodchild 1989).

Reproduction - Bigmouth buffalo reach sexual maturity in their third year and migrate to spawning areas in spring (Goodchild 1989). Adhesive eggs are scattered over plant debris usually in shallow bays or small tributary streams, but the species will invade streams, ditches and backwaters during spring flooding (Goodchild 1989).

Diet - The bigmouth buffalo has been described as primarily a planktivorous feeder, consuming mainly crustacean zooplankton, such as cladocerans, copepods, chironomids, and ostracods. Benthic insects, molluscs and larger crustaceans are also consumed (Goodchild 1989). Differing diets of the same life stages in different water bodies suggest that the bigmouth buffalo is an opportunistic feeder with the capability of both pelagic and benthic foraging habits (Goodchild 1989).

Threats and Limiting Factors in the Thames River - The bigmouth buffalo is not as sensitive to human disturbance and in fact may benefit from habitat changes that are detrimental to other species. The species has a high tolerance for turbidity and extremely low oxygen levels (Goodchild 1989). Therefore, efforts to reduce erosion and nutrient loading may limit opportunities for the bigmouth buffalo in the Thames River. Hlasny (2003) noted that alterations to habitat, such as channelization, removal of meander loops and setting of water levels, negatively impact the bigmouth buffalo. Loss of vegetated areas in lakes and the requirement of spring flooding to trigger spawning may reduce spawning success (Goodchild 1989, Hlasny 2003).

Silver shiner (*Notropis photogenis*) **–** Special Concern

Distinguishing Characteristics and General Biology - The following description is from Baldwin (1988) and Page and Burr (1991). The silver shiner has a slender, silvery body with a wide, black lateral band. It has a long snout and two black crescents between the nostrils. The dorsal fin is almost directly above the pelvic fin, a characteristic that distinguishes the silver shiner from other similar minnow species. The maximum recorded length rarely exceeds 13 cm and it is assumed that their lifespan is about three years.

Distribution - The silver shiner is distributed throughout much of the Ohio River basin except the western lowlands, south to northern Georgia in the Tennessee River drainage, the western Lake Erie tributaries and the Grand and Thames River systems in Ontario (NatureServe 2004).

The silver shiner population on the Thames River watershed appears to be centered near the city of London (within a 40 km radius of the city) in the North Thames, Medway, South Thames, Middle Thames and the main branch (Baldwin 1988). The earliest reports of silver shiners from the Thames River recorded in the Royal Ontario Museum were from the South Thames (1936) and North Thames Rivers (1946). Recent surveys from 2000-2002 have recorded the silver shiner from the Thames River, Otter Creek and Stoney Creek (J. Schwindt, unpub. data) (Figure 24).

Status – Global and United States: The silver shiner is considered Secure globally (G5) and nationally in the United States (N4) (NatureServe 2004). *Canada and Thames River*: The silver shiner was designated as a species of Special Concern by COSEWIC in 1987 and is currently (June 2004) listed on Schedule 3 of SARA (Government of Canada 2004). It has been given a rank of Imperiled/Rare to Uncommon in Canada (N2N3) and in Ontario (S2S3) (NatureServe 2004). The silver shiner has been given a General Status rank of Not Assessed (6) in Canada and Sensitive (3) in Ontario (CESCC 2001). The OMNR has designated the silver shiner Not in Any Category (NIAC) (NHIC 2004). Surveys conducted in 1980 found the silver shiner to be locally abundant in the Thames River watershed (Parker and McKee 1980). However, a survey conducted in 1997 at four historic sites found only one silver shiner at one site in the North Thames (Holm and Boehm 1998).

Habitat – The silver shiner is most abundant in moderate- to large-sized rivers with moderate to high gradients (Baldwin 1988). Alternating deep, swift pools and riffles or the turbulent waters below dams have characterized capture habitat (Parker and McKee 1980). Baldwin (1983) found no relationship between the presence of silver shiners and turbidity or other water quality factors. Spawning, early nursery or overwintering habitats areas are unclear (Baldwin 1988).

Reproduction – Most silver shiners mature during their second summer (Parker and McKee 1980). Spawning has never been observed in Ontario, however evidence suggests that the spawning period is relatively short (two weeks) in late May or June (Baldwin 1983). Reproductive rate is unknown, but increasing populations in Canada suggest that reproduction more than replaces mortality (Baldwin 1988).

Diet – Silver shiners can be characterized as opportunistic surface feeders primarily consuming adult and larval insects, especially Diptera (Baldwin 1988).

Threats and Limiting Factors in the Thames River – There are insufficient data to identify the factors that limit silver shiner populations; however several aspects may be suggested.

Habitat loss, environmental contamination, channelization, turbidity, pollution, and impoundments may all contribute to a decline in the species' preferred habitat and movement capabilities (Baldwin 1988). Stream gradient may also limit the distribution of the silver shiner (Parker and McKee 1983).

Pugnose minnow (*Opsopoeodus emiliae*) – Special Concern

Distinguishing Characteristics and General Biology – The following description is from Cudmore and Holm (1999). The pugnose minnow is a member of the carp and minnow family (Cyprinidae) with a very small, upturned mouth. Its black lateral band extends from the tail to the snout and a cross-hatch pattern can be found on the upper body. This species is unique in that, unlike other Canadian minnows, it usually has nine principal dorsal rays. The pugnose minnow reaches a maximum length of 6.4 cm and lives for about three years.

Distribution - The pugnose minnow is widely distributed in the Gulf States and the Mississippi River basin and is found in a few drainages of lakes Erie, St. Clair and Michigan. In Ontario, the pugnose minnow occurs in Lake St. Clair and several tributaries of the lake (Cudmore and Holm 1999).

Only two records exist for the pugnose minnow in the Thames River watershed. The species was first collected from the Thames River watershed near Komoka in 1968. A second specimen was collected from a Thames River tributary (McDougall Drain) located west of Chatham in 1984 (Figure 25).

Status – Global and United States: The pugnose minnow is Secure globally (G5) and nationally in the United States (N5) (NatureServe 2004). *Canada and Thames River*: The pugnose minnow was designated as Special Concern by COSEWIC in 2000 and is currently (June 2004) on Schedule 1 of SARA (Government of Canada 2004). It is ranked in Canada as Rare to Uncommon (N3) and as Imperiled (S2) in Ontario (NatureServe 2004). It has been given a General Status rank of Not Assessed (6) in Canada and ranked as Sensitive (3) in Ontario (CESCC 2001). The OMNR has designated the pugnose minnow as Vulnerable (NHIC 2004). In the Thames River, large numbers of individuals have never been encountered, and, despite attempts at historical locations, the species has not been collected in recent years.

Habitat – Generally, clear, slow-moving waters with densely, abundant aquatic vegetation are preferred by this species (Scott and Crossman 1973, Trautman 1981). In Ontario, the pugnose minnow has been captured at sites with a range of water clarity (Cudmore and Holm 1999).

Reproduction - Spawning by the pugnose minnow in Ontario likely occurs in late spring to early summer over about a week (Cudmore and Holm 1999). The adhesive eggs are deposited in a single layer (about 120 eggs per spawning session) on a flat surface, such as the underside of a rock (Cudmore and Holm 1999).

Diet - The upturned mouth of this species suggests it is likely a mid-water or near-surface feeder (Scott and Crossman 1973). One Ontario specimen had adult Diptera and larval Trichoptera in its gut (Cudmore and Holm 1999). It is assumed that the pugnose minnow consumes a variety of small insects and crustaceans, filamentous algae, larval fishes and fish eggs (Cudmore and Holm 1999).

Threats and Limiting Factors in the Thames River – Erosion and associated turbidity negatively affect the densely vegetated habitats that this species prefers. Filling and drainage of riparian wetland habitats would also further limit this species in the Thames River watershed. Male pugnose minnows have an elaborate courtship display which may require clearer water to be effective (Cudmore and Holm 1999).

River redhorse (*Moxostoma carinatum*) – Special Concern

Distinguishing Characteristics and General Biology – The following description is from Reid *et al.* (2004). The river redhorse is a member of the genus *Moxostoma* in the sucker family (Catostomidae). The lips of the river redhorse, located subterminally, are deeply plicate and have no transversal ridges and papillae. The dorsal surface of the species is brown or olive-green, with brassy, yellowish-green or coppery sides and a white underside. The dorsal and caudal fins are crimson in colour; the lower fins are orange to reddish. The dorsal fin is straight or slightly concave and the caudal fin is forked, with the upper lobe usually longer and more pointed than the lower lobe. Scale counts on adults are usually 12 around the caudal peduncle and 42-47 along the lateral line. The maximum known age for river redhorse in Canada is unknown, but the species is long-lived.

Distribution – The river redhorse is found throughout the central and eastern Mississippi River system and the Gulf Slope from Florida to Louisiana. The range extends north into the lower Great Lakes basin and St. Lawrence River (NatureServe 2004).

In the Thames River it was first found in 2003 at two locations near the Big Bend Conservation Area (Figure 26).

Status – Global and United States: The river redhorse is Apparently Secure globally (G4) and nationally (N4) in the United States (NatureServe 2004). *Canada and Thames River*: It was designated as Special Concern by COSEWIC in 1987 (Government of Canada 2004) and an update status report is currently being completed (Reid *et al.* 2004). The river redhorse is currently (June 2004) on Schedule 3 of SARA (Government of Canada 2004). It is ranked in Canada and in Ontario as Imperiled (N2 and S2, respectively) (NatureServe 2004). It has been given a General Status rank of Not Assessed in Canada (6) and Sensitive (3) in Ontario (CESCC 2001). The OMNR has designated the river redhorse as Vulnerable (NHIC 2004). As only two specimens have been found at two locations within the Thames River watershed, population abundance, distribution or status cannot be determined.

Habitat – The preferred habitat of the river redhorse have moderate to swift current, with riffle-runs and clean, coarse substrates and access to suitable, shallow (less than 2 m), riverine spawning habitat is essential (Reid *et al.* 2004). Areas of abundant aquatic vegetation, slow currents and soft substrates can also support river redhorses (Reid *et al.* 2004).

Reproduction – River redhorses in Ontario reach an age of maturity later than those in southern populations. Along the Trent River, males in spawning condition were 5-16 years old, while females were 7-16 years old (Reid *et al.* 2004). This species spawns in late May or early June to late June at water temperatures of about 18°C (Reid *et al.* unpub.). It is suspected, but unknown, if river redhorses excavate redds in the substrate, (Reid *et al.* 2004).

Diet – The adult river redhorse feeds on Ephemeroptera and Tricoptera larvae, crayfishes, as well as molluscs, while juveniles consume microcrustaceans (Reid *et al.* 2004).

Threats and Limiting Factors in the Thames River - Dams and impoundment impact river redhorse populations by further isolating populations, preventing movement and altering stream habitat conditions (Portt *et al.* 2004, Reid *et al.* 2004, Cooke *et al.* 2005). Recreational angling may also be impacting river redhorse in the Grand River (Portt *et al.* 2004), however, it is unknown if this occurs in the Thames River. The limited ability of field biologists to identify river redhorses makes it difficult to determine population abundance and distribution. As there are seven species of molluscs in the Thames River that are endangered, there may be an impact on river redhorse via decreased availability of diet items. The low abundance and disjunct distribution of river redhorse in Ontario, combined with narrow habitat requirements and limited amount of available habitat all contributes to the river redhorse being vulnerable to environmental changes (Reid *et al.* 2004). The life history strategy of river redhorses (late age at maturity, longevity and seasonal spawning), tends to result in low juvenile survivorship and the population relies on a relative few successful spawning bouts by a given individual in its lifetime (Reid *et al.* 2004). This life history strategy makes the river redhorse vulnerable to repeated unnatural perturbations to their habitat (Reid *et al.* 2004).

Spotted sucker (*Minytrema melanops*) – Special Concern

Distinguishing Characteristics and General Biology – The following description is from Reid and Mandrak (2004). The spotted sucker is a member of the sucker family (Catostomidae) and is distinguished from other members of this family by the presence of 8-12 parallel rows of dark spots on the base of the scales. Adults are deep-bodied and narrow in breadth. The dorsal surface is brown to dark green with silver to bronze sides and is white to silver ventrally. The spotted sucker is a medium-size catostomid averaging between 230 and 380 mm in length.

Distribution – The spotted sucker is found in central and eastern North America, throughout much of the Mississippi River basin and along the lower coastal plain from Texas to North Carolina. It is found in the Great Lakes basin in the drainages of lakes Huron, Michigan, Erie and St. Clair (NatureServe 2004). It is restricted in Canada to the extreme southwestern portion of Ontario.

Historically the spotted sucker was found in 1973 and 1980 in the Thames River watershed. Recently, spotted suckers were found in 2003 near the Conservation Areas of Chatham, Thames Grove and Big Bend (Figure 27).

Status – Global and United States: The spotted sucker is Secure globally (G5) as well as nationally in the United States (N5) (NatureServe 2004). *Canada and Thames River*: It was designated as Special Concern by COSEWIC in 2001 and is currently (June 2004) on Schedule 1 of SARA (Government of Canada 2004). It has been designated as Imperiled in Canada (N2) as well as in Ontario (S2) (NatureServe 2004). The spotted sucker has a General Status rank in Canada as Not Assessed (6) and Sensitive (3) in Ontario (CESCC 2001). The OMNR has designated this species as Vulnerable in Ontario (NHIC 2004). In the Thames River, large numbers of individuals have never been encountered. Only one individual was found in 1973 and in 1980; while in 2003, six individuals were found. With this lack of information, determination of population abundance, distribution and status within the Thames River watershed is difficult.

Habitat – The spotted sucker usually inhabits long, deep pools of small- to medium-sized rivers over hard clay, sand, gravel or rubble substrates (Page and Burr 1991); however they have also been collected in large rivers, oxbows and backwater areas, impoundments, small turbid creeks and shores of lakes (Reid and Mandrak 2004). It has been reported that spotted suckers are associated with abundant aquatic macrophytes, however this associated can not be substantiated with Canadian populations (Reid and Mandrak 2004). Spawning occurs in riffle areas (Reid and Mandrak 2004).

Reproduction – Age of sexual maturity of spotted suckers is unknown in Canada, however, a single female from the Thames River was found in breeding condition and aged at five years (Parker and McKee 1984). This species spawns in late spring to early summer and the semi-buoyant eggs hatch within 7-12 days after fertilization (Reid and Mandrak 2004).

Diet – Spotted suckers consume a variety of invertebrate items such as molluscs, copepods, chironomids, diatoms and other small crustaceans (Pflieger 1975).

Threats and Limiting Factors in the Thames River – Dams and impoundments are known to negatively impact catostomids (Reid and Mandrak 2004). In the United States, the decline of some populations has been attributed to habitat degradation from siltation from increased erosion and turbidity (Trautman 1981). However, recent habitat studies on species at risk in the Sydenham River suggest that spotted suckers are being found in turbid areas (Poos *et al.* 2004). It is assumed that availability of suitable habitat is a limiting factor of spotted sucker populations; however lack of information on the biology of the species and the distribution and abundance of this species and their habitat requirements prevents the identification of limiting factors.

Knowledge Gaps - Fishes

Population information and data on the biology and ecology of many fish species at risk, and the threats and limiting factors they are faced with, is extremely lacking. For example, population abundance, distribution or status within the Thames River is completely unknown for both the river redhorse and spotted sucker. Habitat requirements for the different life stages are completely unknown for most of the fish species at risk in the Thames River watershed. Information on certain aspects of habitat and reproductive characteristics are unknown for northern madtom, eastern sand darter, silver shiner, river redhorse and spotted sucker. Even basic knowledge of species identification is lacking: redhorse species are nearly impossible to identify in the field; recent work suggests that northern brook and silver lampreys may be the same species; and, it is unknown if silver shiners are a reproductively-isolated (from the United States) population in Canada. The impacts of realized threats and limiting factors for many species have not been well researched and, are therefore poorly understood. In some cases (e.g. silver shiner, spotted sucker), threats and limiting factors are unknown.

Additional sampling is required using appropriate techniques to determine the range and numbers of most of the fish species at risk present in the Thames River. There are also sections of the watershed where very little or no sampling has occurred (especially in the Lower Thames River).

Recent and Current Research on Thames River Fish Species at Risk

In 2003, DFO conducted a fish species at risk survey and gear comparison study in the main branch of the Lower Thames River from the mouth to Chatham and, at Big Bend. This work continued from Chatham to London in 2004 and included tributaries of the Lower Thames (N. Mandrak, pers.comm.). Fish species at risk surveys were conducted in the upper Thames by the Upper Thames River Conservation Authority (J. Schwindt, pers.comm.).

DFO is leading a mark-recapture pilot project involving eastern sand darters in the Lower Thames between London and Chatham. The fishes are batch-tagged via a subcutaneous injection of a Visual Implant Fluorescent Elastomer. This study, started in the summer of 2004, aims to obtain estimates of abundance, growth and mortality of eastern sand darters (S. Doka and M. Koops, pers.comm.).

CONSERVATION PRIORITIES

SPECIES AT RISK

To aid in prioritizing recovery actions, conservation priority rankings were assigned to all species at risk in the Thames River watershed and are defined as:

Possibly Extirpated - COSEWIC status of Extirpated, and/or presumed extirpated within the Thames River watershed by recent research surveys;

High - COSEWIC status of Endangered or Threatened and/or globally rare (G1, G2, G3);

Medium - COSEWIC status of Special Concern or Under Review, provincially rare (S1, S2, S3) and/or locally rare or declining;

Low - COSEWIC status of Special Concern, provincially stable (S4, S5) and/or locally stable or expanding. It is important to note that a low priority ranking does not necessarily equate to low conservation concern.

A summary of the conservation status and the conservation priority ranks for each species at risk in the Thames River watershed is provided in Table 2. Five of the 25 species at risk in the Thames are ranked as Possibly Extirpated (snuffbox, round hickorynut, mudpuppy mussel, stinkpot, lake chubsucker and gravel chub). Conservation efforts for these species will likely focus on surveys to further determine the status and/or investigations into possibly repatriating the species to the Thames. There are 11 High priority species that are unlikely to persist in the Thames or elsewhere without the reversal of current threats: wavy-rayed lampmussel, round pigtoe, kidneyshell, rayed bean, spotted turtle, spiny softshell, queen snake, northern madtom, black redhorse and eastern sand darter. The eastern ribbonsnake, northern brook lamprey, bigmouth buffalo, silver shiner, pugnose minnow, river redhorse and spotted sucker are ranked as Medium priority. Species considered Low priority, appear to be stable in the Thames River watershed and elsewhere; therefore, where funding is limited, conservation efforts should be focused on the Medium and High priority species. Of the 25 aquatic species at risk in the Thames River watershed, two are considered Low priority: northern map turtle and greenside darter.

THREATS

Fourteen of the 25 aquatic species at risk (including six High priority species) are affected by siltation and turbidity. Therefore, efforts to reduce sedimentation through improved land management practices and riparian restoration will benefit a wide range of aquatic species. Any efforts to reduce sedimentation must also recognize that "natural" sand bank erosion is necessary to maintain sand substrate habitats preferred by some species at risk (e.g. eastern sand darter, spiny softshell). Hardening of the shoreline and the establishment of vegetation on sandy or gravel banks will be detrimental to nesting sites for the spiny softshell and northern map turtle. The bigmouth buffalo, and possibly the greenside darter and spotted sucker, do well in turbid waters, thus efforts to reduce turbidity may limit habitat availability for these species.

CONCLUSIONS

While the Thames River watershed supports a diversity of freshwater mussels, aquatic reptiles and fishes, 25 species have been designated at risk (Extinct/Extirpated, Endangered, Threatened or Special Concern) by COSEWIC. Of these 25 species, six have already been possibly extirpated from the system, while another ten have been ranked as High priority. Siltation and turbidity from agricultural, industrial and urban sources affects the majority of the species at risk in the Thames River watershed. To protect remaining populations from becoming more at risk and to look into re-introducing species or populations that have been extirpated from the Thames River watershed, further research is needed to document local conditions, obtain up-to-date population data for all Thames River species, particularly for those at risk, identify sensitive areas and collect information in areas of the Thames which lack data.

Information from this report, along with *The Thames River Watershed: Background Study for Nomination under the Canadian Heritage Rivers System* (UTRCA 1998) and *The Upper Thames River Watershed Report Cards* (UTRCA 2001) will contribute to a report synthesizing the background information in order to assign conservation priorities to the Thames River watershed habitat types and subwatersheds and provide a summary of the species at risk and their threats. Together, this species at risk report and the synthesis report will be used to prepare an ecosystem recovery strategy for the aquatic species at risk in the Thames River watershed. As information continues to be gathered from ongoing work, any updated information will be presented in the recovery strategy.

Acknowledgements
Terry Chapman (UTRCA) created all maps for this report.

This report grew out of a previously drafted document by C.A. MacKinnon and S.E. Madzia – those who reviewed that document were: Madeline Austen, Kim Barrett, Scott Gillingwater, Teresa Piraino, Cathy Reeves, Hal Schraeder, John Schwindt, Shawn Staton, Dave Zanatta, the Thames River Recovery Team and its advisors.

Sincere thanks goes to the Thames River Recovery Team for their input during the writing and review process. Scott Gillingwater, Gerry Mackie, Nick Mandrak, Kelly McNichols, Todd Morris, Janice Smith and Shawn Staton generously provided input or advice.

Financial support for the production of this report was provided by Fisheries and Oceans Canada, the Ontario Ministry of Natural Resources and the Upper Thames River Conservation Authority. Data were supplied by Fisheries and Oceans Canada, the Lower Thames Valley Conservation Authority, the National Water Research Institute, the Natural Heritage Information Centre, the Royal Ontario Museum and the Upper Thames River Conservation Authority.

LITERATURE CITED

Adler, K.K. and S.G. Tilley. 1960. A fish and a snail in the diet of *Natrix septemvittata* (Say). J. Ohio Herpetological Society. 2: 28-29.

Anthony, J.L. and J.A. Downing. 2001. Exploitation trajectory of a declining fauna: a century of freshwater mussel fisheries in North America. Can. J. Fish. Aquat. Sci. 58(10): 2071-2090.

Baker, S.M and D.J. Hornbach. 1997. Acute physiological effects of zebra mussel (*Dreissena polymorpha*) infestation on two unionid mussels, *Actinonaias ligamentina* and *Amblema plicata*. Can. J. Fish. Aquat. Sci. 54: 512-519.

Baldwin, M. E. 1983. Habitat use, distribution, life history, and interspecific associations of *Notropis photogenis* (silver shiner; Osteichthyes: Cyprinidae) in Canada, with comparisons with *Notropis rubellus* (rosyface shiner). M. Sc. Thesis. Carleton University, Ottawa. 189 pp.

Baldwin 1988. COSEWIC updated status report on the silver shiner, *Notropis photogenis* in Canada. Prepared for the Committee on the Status of Endangered Wildlife in Canada. 23 pages.

Behler, J.L., and F. W. King. 1979. The Audubon Society field guide to North American reptiles and amphibians. A.A. Knopf, Inc., New York, New York. 719pp.

Bobyn, M.L. and R.J. Brooks. 1994. Incubation conditions as potential factors limiting the northern distribution of snapping turtles, *Chelydra serpentina*. Can. J. Zool. 72: 131-132.

Bogan, A.E. 1993. Freshwater bivalve extinctions (mollusca: Unionoida): a search for causes. Am. Zool. 33:599-609.

Branson, B. A. and E. C. Baker. 1974. An ecological study of the queen snake, *Regina septemvittata* (Say) in Kentucky. Tulane Studies in Zoology and Botany 18(4): 153-171.

Brown, E.E. 1979. Stray food records from New York and Michigan snakes. The American Midland Naturalist 102(1): 200-203.

Campbell, C. A. 1977. The range, ecology and status of the queen snake (*Regina septemvittata*) in Canada. Unpubl. manuscript, KIZ10-65293 for Canadian Wildlife Service.

Campbell, C. A. and D. W. Perrin. 1979. A survey of the queen snake (*Regina septemvittata*) in southwestern Ontario. Wildlife Branch, Ontario Ministry of Natural Resources.

Carolinian Canada. 2004. www.carolinian.org. Accessed: August 2004.

Canadian Endangered Species Conservation Council (CESCC). 2001. Wild Species 2000: the General Status of Species in Canada. Ottawa, Canada.

Clarke, C. F. 1977. The freshwater naiads of Ohio, Part 1: St. Joseph River of the Maumee. Sterkiana 65-66: 14-36

Clarke, A. H. 1981. The freshwater molluscs of Canada. National Museums of Canada, Ottawa, Canada. Malacological Review 6: 63-64.

Coker, G.A., C.B. Portt and C.K. Minns. 2001. Morphological and ecological characteristics of Canadian freshwater fishes. Can. MS Rpt. Fish. Aquat. Sci. 2554: iv+86p.

Conant, R. 1960. The queen snake, *Natrix septemvittata*, in the interior highlands of Arkansas and Missouri, with comments upon similar disjunct distribution. Proc. Acad. Nat. Sci. Philadelphia. 122: 25-40.

Conant, R. and J. T. Collins. 1991. Reptiles and amphibians: eastern and central North America (3rd edition). Houghton Mifflin Company, New York. Xxx+450 pp.

Congdon, J.D., A.E. Dunham and R.C. Van Loben Sels. 1993. Delayed sexual maturity and demographics of Blanding's turtles (*Emydoidea blandingii*): implications for conservation and management of long-lived organisms. Conserv. Biol. 7: 826-833.

Cook, F.R. 1981. Amphibians and reptiles of the Ottawa district. Trail and Landscape. 15: 75-109.

Cook, F. R. 1984. Introduction to Canadian amphibians and reptiles. National Museum of Canada, Ottawa, Ontario. 200 pages.

Cooke, S.J., C.M. Bunt, S.J. Hamilton, C.A. Jennings, M.P. Pearson, M.S. Cooperman and D.F. Markle. 2005. Threats, conservation strategies, and prognosis for suckers (Catostomidae) in North America: insights from regional case studies of a diverse family of non-game fishes. Biol. Cons. 121: 317-331.

Committee on the Status of Endangered Wildlife in Canada (COSEWIC). 2004. http://www.cosewic.gc.ca/eng/sct5/index_e.cfm. Accessed June 2004.

Crocker, D.W. and D.W. Barr. 1968. Handbook of the crayfishes of Ontario. Misc. Pub. Royal Ontario Museum. University of Toronto Press, Toronto, Ontario.

Cross, F. B. 1967. Handbook of fishes of Kansas. University of Kansas Museum of Natural History, Miscellaneous Publication 45: 1-357.

Cudmore, B. C., and E. Holm. 1999. Updated status of the pugnose minnow. *Opsopoeodus emiliae*, in Canada. Prepared for the Committee on the Status of Endangered Wildlife in Canada. 9 p. + fig.

Cummings, K. S., and C. A. Mayer. 1992. Field guide to freshwater mussels of the Midwest. Illinois Natural History Survey Manual 5. 194 pages.

Dalton, K.W. 1991. Status of the Greenside Darter, *Etheostoma blennioides*, in Canada. The Canadian Field-Naturalist 105(2): 173-178.

Daniels, R. A. 1993. Habitat of the eastern sand darter, *Ammocrypta pellucida*. Journal of Freshwater Ecology 8(4): 287-295.

DeGraaf, R. M. and D. D. Rudis. 1983. Amphibians and reptiles of New England: habitats and natural history. University of Massachusetts Press, Amhurst. 85pp.

De Solla, S.R., M.L. Fletcher and C.A. Bishop. 2003. Relative contributions of organochlorine contaminants, parasitism, and predation to reproductive success of spiny softshells (*Apolone spiniferus spiniferus*) from southern Ontario, Canada. Ecotox. 12: 261-270.

Dextrase, A., J. Metcalfe-Smith, J. DiMaio, D. Sutherland, A. Zammit and E. Holm. 2000. Species at risk in the Sydenham River watershed. Background report for the Sydenham River Recovery Team.

Edmonds, J. H. 1998. Population ecology of the stinkpot turtle (*Sternotherus odoratus*) in Georgian Bay, Ontario. M.Sc. Thesis. University of Guelph, Guelph, Ontario. 108 pages.

Edmonds, J. H. 2002. COSEWIC Status Report on stinkpot turtle, *Sternotherus odoratus*, in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 18pp.

Ernst, C. H. 1967. A mating aggregation of the turtle, *Clemmys guttata*. Copeia 2: 473-474.

Ernst, C. H. 1975. Growth of the spotted turtle, *Clemmys guttata*. Journal of Herpetology 9(3): 313-318.

Ernst, C. H. 1976. Ecology of the spotted turtle, *Clemmys guttata* (Reptilia, Testudines, Testudinidae) in southeastern Pennsylvania. Journal of Herpetology 10(1): 25-33.

Ernst, C. H. and Barbour, R. W. 1989. Snakes of eastern North America. George Mason University Press, Fairfax, Virginia, 282 pp.

Ernst, C. H., Barbour, R. W., and Lovich, J. E. 1994a. *Sternotherus odoratus* (Latreille, in Sonnini and Latreille, 1802) Stinkpot or common musk turtle. *In* Turtles of the United States and Canada. Smithsonian Institution Press, Washington, U.S.A., pp. 139-149.

Ernst, C. H., J. E. Lovich, and R. W. Barbour. 1994b. Turtles of the United States and Canada. Smithsonian Institution Press, Washington and London. 578 pp.

Facey, D. E. 1998. The status of the eastern sand darter, *Ammocrypta pellucida*, in Vermont. Canadian Field-Naturalist 122:596-601.

Flaherty, N.C. 1982. Home range, movement, and habitat selection in a population of map turtle, *Graptemys geographica* (Le Sueur), in southwestern Quebec. M.Sc. thesis. McGill University, Montreal, Quebec.

Fletcher, M. L. 1997. Management of softshell turtle habitat: year 2, 1997. Upper Thames River Conservation Authority. 30pp.

Fletcher, M.L. 1999. Management of softshell turtle habitat: year 4. Final Year. Upper Thames River Conservation Authority, London, Ontario. 18 pp.

Fletcher, M. 2002. COSEWIC Status Report on spiny softshell, *Apalone spinifera*. Prepared for the Committee on the Status of Endangered Wildlife in Canada. 17 pp.

Fletcher, M.L., and S.D. Gillingwater. 1994. A Survey of the spiny softshell turtle along the Thames and Sydenham rivers 1994. 32pp.

Fletcher, J.L., S. Graff and S.D. Gillingwater. 1995. Site specific examination of spiny softshell turtle populations on the Thames and Sydenham rivers. Upper Thames River Conservation Authority, London, Ontario. 17 pp.

Fletcher, M., M.J. Oldham and M.E. Obbard. 1999. National Recovery Plan for the spiny softshell turtle (*Apalone spinifera spinifera*) in Canada. DRAFT. Report to the Recovery of Nationally Endangered Wildlife (RENEW) Committee.

Froom, B. 1971. Ontario Turtles. Department of Lands and Forests, Conservation Information Section, Operations Branch, Toronto, Ontario. 24 pp.

Froom, B. 1981. Ontario snakes. Department of Lands and Forests, Conservation Information Section, Operations Branch, Toronto, Ontario. 36 pp.

Gartshore, M.E., and P.E. Carson. 1990. Queen snakes and spiny softshell turtles on the Thames River, Aylmer District. Unpublished report to the Ministry of Natural Resource, Aylmer. 18 pp.

Gendron, A. D. 1999. Status report on the mudpuppy, *Necturus maculosus*, in Canada. Prepared for the Committee on the Status of Endangered Wildlife in Canada: 86p.

Gillingwater, S.D. 2003. National recovery strategy for the queen snake, *Regina septemvittata*. Draft.

Gillingwater, S.D. and R.J. Brooks. 2002. A selective herpetofaunal survey, inventory and biological research study of Rondeau Provincial Park. Report to Endangered Species Recovery Fund (WWF).

Gist, D. H., and J. M. Jones. 1989. Sperm storage within the oviduct of turtles. Journal of Morphology 199: 379-384.

Goodchild, C. D. 1989. COSEWIC status report on the bigmouth buffalo, *Ictiobus cyprinellus* in Canada. Prepared for the Committee on the Status of Endangered Wildlife in Canada. 37 pages.

Goodchild, C. D. 1993. COSEWIC status report on the northern madtom, *Noturus stigmosus* in Canada. Prepared for the Committee on the Status of Endangered Wildlife in Canada. 12 pages.

Government of Canada. 2004. Species at Risk Act – public registry. www.sararegistry.gc.ca Accessed: June 2004.

Gordon, M. E., and J. B. Layzer. 1989. Mussels (Bivalvia: Unionidae) of the Cumberland River: review of life histories and ecological relationships. Biological Report 89(15). U.S. Department of the Interior, Fish and Wildlife Service, Washington, D. C. vii + 99pp.

Graham, T.E. and A.A. Graham. 1992. Metabolism and behavior of wintering common map turtles, *Graptemys geographica*, in Vermont. Can. Field-Nat. 106: 517-519.

Gray, E.E. 1956. Wilderness Christmas: The Moravian Mission to the Delaware Indians. Macmillan, Toronto. 91pp.

Haag, W.R., D.J. Berg, D.Q. Garton, and J.L. Farris. 1993. Reduced survival and fitness in native bivalves in response to fouling by the introduced zebra mussel (*Dreissena polymorpha*) in western Lake Erie. Can. J. Fish. Aquat. Sci. 50:13-19.

Hamr, P. 1998. Conservation status of Canadian freshwater crayfishes. Report to World Wildlife Fund Canada and the Canadian Nature Federation's Endangered Species Program. Toronto. 86pp.

Harding, J. H. 1997. Amphibians and reptiles of the Great Lakes region. The University of Michigan Press, Ann Arbor. xvi + 378 pp.

Hardisty, M. W., and I. C. Potter. 1971. The behaviour, ecology and growth of larval lampreys and the general biology of adult lampreys. In: The biology of lampreys, vol. 1. Academic Press, London, 423 pp.

Hlasny, R.E. 2003. Assessment of the bigmouth buffalo population of Pasqua Lake. Saskatchewan Environment Report. Draft.

Hoggarth, M.A. 1993. Glochidial functional morphology and rarity in the Unionidae. *In* Conservation and Management of Freshwater Mussels, Proceedings of the Upper Mississippi River Conservation Committee Symposium. *Edited by* K.S. Cummings, A.C. Buchanan and L.M. Koch. Illinois Natural History Survey, Champaign, Illinois.

Holm, E., and D. Boehm. 1998. Sampling for fishes at risk in southwestern Ontario, 1997. A report prepared for the Ontario Ministry of Natural Resources Southcentral Region and Aylmer District. Centre for Biodiversity and Conservation Biology, Royal Ontario Museum. October, 1998 (Revised December 2001).

Holm, E. and D. Boehm. 1999. Characters of adult *Moxostoma* in Ontario. ROM Ontario Fish Identification Workshop. 2pp.

Holm, E. and E.J. Crossman. 1986. Report on the search for an Ontario population of *H. x-punctata* and on a search for the species. Royal Ontario Museum Report to Ontario Ministry of Natural Resources. Toronto, Ontario. March 1986.

Holm, E., and N. E. Mandrak. 1994. COSEWIC status report on the eastern sand darter, *Ammocrypta pellucida,* in Canada. Prepared for the Committee on the Status of Endangered Wildlife in Canada. 12 pp.

Holm, E., and N. E. Mandrak. 1996. The status of the Eastern sand darter, *Ammocrypta pelluci*da, in Canada. Canadian Field-Naturalist 120(3): 462-469.

Holm, E, and N.E. Mandrak. 1998. Updated status of the northern Madtom, *Noturus stigmosus,* in Canada with addendum prepared by Alan Dextrase (OMNR) and Erling Holm (ROM), June 20, 2002. COSEWIC Status Report, 15 p. + fig.

Hove, M. C. 1995. Host research on round pigtoe glochidia. Triannual Unionid Report 8:8

Johnson, B. 1989. Familiar amphibians and reptiles of Ontario. Natural Heritage/ Natural History Inc., Toronto, Ontario.

Judd, W.W. 1955. Observations on the habitat and food of the queen snake, *Natrix septemvittata*, at London, Ontario. Can. Field-Nat. 69: 167-168.

Judd, W.W. 1968. Crayfish in the vicinity of London, Ontario. National Museum of Canada Natural History Papers. Number 41, June 1968. 9 pp.

Kott, E. and N. Rathmann. 1985. Distribution and fecundity of the black redhorse sucker (*Moxostoma duquesnei*) in the Upper Grand River basin. Wilfrid Laurier University, Waterloo, Ontario. Research Paper No. 8575.

Lamond, W. G. 1994. The reptiles and amphibians of the Hamilton area – an historical summary and the results of the Hamilton Herpetofaunal Atlas. Published by the Hamilton Naturalists' Club, Hamilton, Ontario. 174 pp.

Lanteigne, J. 1992. Status of the northern brook lamprey, *Ichthyomyzon fossor* in Canada. Can. Field-Nat. 106: 7-13.

Lindsay R. V. 1965. Egg-laying habits of the musk turtle. Ontario Field Biologist 19: 9-10.

Litzgus, J.D., J.P. Costanzo, R.J. Brooks and R.E. Lee, Jr. 1999. Phenology and ecology of hibernation in spotted turtles (*Clemmys guttata*) near the northern limit of their range. Can. J. Zool. 77: 1348-1357.

Litzgus, J.D. and R.J. Brooks. 2000. Habitat and temperature selection of *Clemmys guttata* in a northern population. J. Herpetology. 34: 178-185.

Litzgus, J.D. 2004. Update COSEWIC status report on spotted turtle, *Clemmys guttata*. COSEWIC status report. Draft.

MacInnis, A. J. 1998. Reproductive biology of the northern madtom, *Noturus stigmosus* (Acinopterygii: Ictaluridae) in Lake St. Clair, Ontario. The Canadian Field-Naturalist 122(2): 255-259.

Mackie, G. L. 1996. Diversity and status of Unionidae (Bivalvia) in the Grand River, a tributary of Lake Erie, and its drainage basin. Prepared for the Lands and Natural Heritage Branch, Ontario Ministry of Natural Resources, Peterborough, Ontario. 39 pages.

Mahmoud, I. Y. 1968. Feeding behaviour in Kinosternid turtles. Herpetologica 25(4): 301-303.

Mandrak, N.E. and E.J. Crossman. 1992. A checklist of Ontario freshwater fishes. Royal Ontario Museum, Toronto, Ontario. 176 pp.

Mandrak, N.E. and E.J. Crossman 1993. Status report on the lake chubsucker, *Erimyzon sucetta*, in Canada. Prepared for the Committee on the Status of Endangered Wildlife in Canada.

Mandrak, N.E. and S. Reid. 2004. Update COSEWIC status report on black redhorse, *Moxostoma duqeusnei* (LeSueur). Prepared for the Committee on the Status of Endangered Wildlife in Canada. Draft.

McAllister, D.E., B.J. Parker, and P.M. McKee. 1985. Rare, endangered and extinct fishes in Canada. National Museum of Natural Sciences. Syllogeus 54.

McNichols, K. and G. Mackie. 2004. Fish host determination of endangered freshwater mussels in the Sydenham River, Ontario, Canada. ESRF 2003/2004 Final Report.

McPherson, R. J., and Marion, K. R. 1981. Seasonal testicular cycle of the stinkpot turtle (*Sternotherus odoratus)* in central Alabama. Herpetologica, 37: 33-40.

Mendonca, M. T. 1987. Timing of reproductive behaviour in male musk turtles, *Sternotherus odoratus*: effects of photoperiod, temperature and testosterone. Animal Behaviour 35: 1002-1014.

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. Plenary presentation at the 3rd National Ecological Monitoring and Assessment Network Meeting, Saskatoon, Saskatchewan, 25 January 1997.

Metcalfe-Smith, J. L., S. K. Staton, G. L. Mackie, and E. L. West. 1998. Assessment of the current status of rare species of freshwater mussels in southern Ontario. Environment Canada, National Water Research Institute, Burlington, Ontario. NWRI Contribution Number 98-019.

Metcalfe-Smith, J. L., S. K. Staton, G. L. Mackie, and I. M. Scott. 1999. Range, population stability and environmental requirements of rare species of freshwater mussels in southern Ontario. Environment Canada, National Water Research Institute, Burlington, Ontario. NWRI Contribution Number 99-058.

Metcalfe-Smith, J. L., S. K. Staton and E. L. West. 2000. Status of the wavy-rayed lampmussel, *Lampsilis fasciola* (Bivalvia: Unionidae), in Ontario and Canada. The Canadian Field Naturalist 124: 457-470.

Metcalfe-Smith, J. L., and D. T. Zanatta. 2003. COSEWIC Status Report on the kidneyshell, *Ptychobranchus fasciolaris.* Committee on the Status of Endangered Wildlife in Canada. 32 pp.

Metcalfe-Smith, J. L., and D. J. McGoldrick. 2003. Update on the Status of the wavy-rayed lampmussel (*Lampsilis fasciola*) in Ontario waters. Prepared for the Sydenham River Recovery Team and the Interdepartmental Recovery Fund. 23 pages.

Metcalfe-Smith, J.L. and B. Cudmore-Vokey. 2004. National general status assessment of freshwater mussels (Unionacea). National Water Research Institute Report No. 04-027.

Minton, Jr. S. A. 1972. Amphibians and reptiles of Indiana. The Indiana Academy of Science, Indianapolis, Indiana: 346 pp.

Morman, R. H. 1979. Distribution and ecology of lampreys in the lower peninsula of Michigan, 1957-1975. Great Lakes Fish. Comm. Tech. Rep. 33. 59 pp.

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

Morris, T.J. 2004a. National recovery strategy for the round hickorynut (*Obovaria subtrotunda*, Rafinesque 1820) and the kidneyshell (*Ptychobranchus fasciolaris*, Rafinesque 1820): 2004-2009. Draft June 2004.

Morris, T.J. 2004b. National recovery strategy for the wavy-rayed lampmussel (*Lampsilis fasciola*, Rafinesque 1820). 2004-2009. Draft June 2004.

Morris, T.J. and J. Di Maio. 1998. Current distribution of freshwater mussels (Bivalvia: Unionidae) in rivers of southwestern Ontario. Malacological Review. 31: 9-17.

Natural Heritage Information Centre (NHIC). 2004. http://www.mnr.gov.on.ca/MNR/nhic/species.cfm. Accessed June 2004.

NatureServe. 2004. NatureServe Explorer: An online encyclopedia of life. Version 3.1. NatureServe, Arlington, Virginia. Available: http://www.natureserve.org/explorer. (Accessed: June 8, 2004).

Nedeau, E. J., M. A. McCollough, and B. I. Swartz. 2000. The freshwater mussels of Maine. Maine Department of Inland Fisheries and Wildlife, Augusta, Maine. 128pp.

Neves, R.J. and M.C. Odum. 1989. Muskrat predation on endangered freshwater mussels in Virginia. J. Wild. Manage. 53: 934-941.

Newton, T.J. and G.W. Cope. 2004. Sensitivity of mussels to aquatic contaminants. Presentation at the American Fisheries Society, August 25, 2004. Madison, Wisconsin.

Obbard, M. E. 1991. Status report on the spiny softshell, *Apalone spinifera*, in Canada. Prepared for the Committee on the Status of Endangered Wildlife in Canada. 61 pp.

Oldham, M. J. 1990. Draft Status Report on the spotted turtle, *Clemmys guttata*. Prepared for the Committee on the Status of Endangered Wildlife in Canada. 89 pp.

Oldham, M. J. ed. 1997. Ontario Herpetofaunal Summary. Natural Heritage Information Centre. Ontario Ministry of Natural Resources.

Oldham, M. J. and W. F. Weller. 2000. Ontario Herpetofaunal Atlas. Natural Heritage Information Centre, Ontario Ministry of Natural Resources. http://www.MNR.gov.on.ca/MNR/nhic/herps/ohs.html updated 15-01-2001.

Page, L. M., and Burr, B. M. 1991. A field guide to freshwater fishes. Houghton Mifflin Company, Boston. 432 pp.

Parker, B.P. 1989. Status of the black redhorse, *Moxostoma duquesnei*, in Canada. Can. Field-Nat. 103: 175-179.

Parker, B. P. and Kott, E. 1988. COSEWIC status report on the black redhorse, *Moxostoma duquesnei* in Canada. Prepared for the Committee on the Status of Endangered Wildlife in Canada. 10 pp.

Parker, B. and P. McKee. 1980. Rare, threatened and endangered fishes in southern Ontario: status reports. A report for the Department of Supply and Services, Department of Fisheries and Oceans, and National Museum of Natural Sciences. Beak Consultants Ltd., Mississauga.

Parker, B., and McKee, P. M. 1983. Status report on the silver shiner, *Notropis photogenis*, in Canada. Unpublished report to the Committee on the Status of Endangered Wildlife in Canada. 15 pp.

Parker, B., P. McKee, and R. R. Campbell. 1988. COSEWIC status report on the gravel chub, *Erimystax x-punctatus* in Canada. Prepared for the Committee on the Status of Endangered Wildlife in Canada. 10 pp.

Parmalee, P. W., and A. E. Bogan. 1998. The freshwater mussels of Tennessee. The University of Tennessee Press, Knoxville, Tennessee. Xii + 328 pp.

Paukert, C.P. and J. M. Long. 1999. New maximum age of bigmouth buffalo, *Ictiobus cyprinellus*. Proc. OK Acad. Sci. 79: 85-86.

Pflieger, W.L. 1975. The fishes of Missouri. Missouri Department of Conservation, Jefferson City, Missouri.

Piavis, W. G. 1971. A distributional study of Missouri fishes. Publ. Mus. Nat. Hist., University of Kansas, 20(3): 225-570.

Poos, M.S., N.E. Mandrak and R.L. McLaughlin. 2004. Fish species at risk on the Sydenham River: the trade-offs involved in protection and restoration. American Fisheries Society, Madison, Wisconsin, August 2004. Abstract.

Portt, C., G. Coker and K. Barrett. 2004. Recovery strategy for fish species at risk in the Grand River, Ontario. Draft Recovery Strategy submitted to RENEW Secretariat.

Pluto, T.G. and E.D. Bellis. 1986. Habitat utilization by the turtle, *Graptemys geographica*, along a river. J. Herpetol. 20(1): 22-31.

Raney, E.C. and R.M. Roecker. 1947. Food and growth of two species of watersnakes from western New York. Copeia 3: 171-174.

Reid, S. and N.E. Mandrak. 2004. Update COSEWIC status report on spotted sucker, *Minytrema melanops* (Rafinesque). Prepared for the Committee on the Status of Endangered Wildlife in Canada. Draft.

Reid, S., H. McLean, N.E. Mandrak, N. Vachon and P. Dumont. 2004. Update COSEWIC status report on river redhorse, *Moxostoma carinatum*. Prepared for the Committee on the Status of Endangered Wildlife in Canada. Draft.

Richter, B.D., D.P. Braun, M.A. Mendelson and L.L. Master. 1997. Threats to imperiled freshwater fauna. Conserv. Biol. 12: 1081-1093.

Roche, B. 2002. COSEWIC Status Report on northern map turtle, *Graptemys geographica*. Prepared for the Committee on the Status of Endangered Wildlife in Canada. 36 pp.

Rohde, F.C. 1980. *Noturus stigmosus* Taylor, northern madtom. p. 469 *In* Atlas of Northern American freshwater fishes. *Edited by* D.S. Lee, C.R. Gilbert, C.H. Hocutt, R.A. Jenkins, D.E. McAllister and J.R. Stauffer, Jr. North Carolina State Museum of Natural History, North Carolina Biological Survey Number 1980-12.

Schloesser, D.W., T.F. Nalepa, and G.L. Mackie. 1996. Zebra mussel infestation of unionid bivalves (Unionidae) in North America. Am. Zool. 36: 300-310.

Scott, W. B. and E. J. Crossman. 1973. Freshwater fishes of Canada. Bulletin 184. Fisheries Research Board of Canada, Ottawa, Canada. Xi + 966 pp.

Serrouya, R., A. Ricciardi and F. Whoriskey. 1995. Predation on zebra mussels (*Dreissena polymorpha*) by captive-reared map turtles (*Graptemys geographica*). Canadian Journal of Zoology 73: 2238-2253.

Sherman, R.A. 1994. Life history information critical to the management of the state endangered snuffbox mussel, *Epioblasma triquetra* (Bivalvia: Unionidae) in Michigan. M.Sc. thesis. University of Michigan, School of Natural Resources and the Environment. Ann Arbor, Michigan.

Smith, K. 2002. COSEWIC Status Report on eastern ribbonsnake, *Thamnophis sauritis*. Prepared for the Committee on the Status of Endangered Wildlife in Canada. 26 pp.

Smith, K. 1999. COSEWIC Status Report on the queen snake, *Regina septemvittata* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 31 pp.

Snider, A.T. and J.K. Bowler. 1992. Longevity of reptiles and amphibians in North American collections (2nd Edition). Society for the Study of Amphibians and Reptiles. Herpetological Circular No. 21.

Stokes, G.D. and W.A. Dunson. 1982. Permeability and channel structure of reptilian skin. Am. J. Physiology. 252: F681-F689.

Strayer, D. L. 1983. The effects of surface geology and stream size on freshwater mussel (Bivalvia: Unionidae) distribution in southeastern Michigan, U.S.A. Freshwater Biology 13: 253-264.

Strayer, D. L., and K. J. Jirka. 1997. The pearly mussels of New York State. Memoirs of the New York State Museum 26: 123 pp + 27 plates.

Strayer, D.L. and A.R. Fetterman. 1999. Changes in the distribution of freshwater mussels (Unionidae) in the Upper Susquehanna River Basin, 1955-1965 to 1996-1997. Am. Midl. Nat. 142: 328-339.

The Nature Conservancy (TNC). 1987. Element stewardship abstract for Rayed Bean (*Villosa fabalis*). Unpublished. Arlington, Virginia. 3 pp.

The Nature Conservancy (TNC). 1996. Invertebrate characterization abstract (global): *Villosa fabalis*. Unpublished. Arlington, Virginia. 3 pp.

The Nature Conservancy (TNC). 1999. Element global ranking form for Simpsonaias ambigua. Unpublished. Arlington, Virginia.

The Nature Conservancy (TNC). 2000. Element global ranking form for *Epioblasma triquetra*. Unpublished data. Arlington, Virginia.

Trautman, M. B. 1981. The fishes of Ohio with illustrated keys. Ohio State University Press, Columbus, Ohio. 782 pp.

Turgeon, D.D., A.E. Bogan, E.V. Coan, W.K. Emerson, W.G. Lyons, W.L. Pratt, C.F.E. Roper, A. Scheltema, F.G. Thompson and J.D. Williams. 1988. Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks. American Fisheries Society, Bethesda, MD.

Upper Thames River Conservation Authority (UTRCA). 1998. The Thames River watershed: A background study for nomination under the Canadian Heritage Rivers System. Upper Thames River Conservation Authority, London, Ontario.

Upper Thames River Conservation Authority (UTRCA). 2001. The Upper Thames River watershed report cards - 2001. Upper Thames River Conservation Authority, London, Ontario. 24 pp + 2 appendicies.

Upper Thames River Conservation Authority. 2004. UTRCA Water Report. Upper Thames River Conservation Authority, London, Ontario. 14 pp.

Van der Schalie, H. 1970. Hermaphroditism among North American freshwater mussels. Malacologia 10: 93-122.

Vogt, R. C. 1980. Natural history of the map turtle *Graptemys pseudogeographica* and *Graptemys ouachitensis* in Wisconsin. Tulane Studies in Zoology and Botany 22(1): 17-48.

Vogt, R. C. 1981. Food partitioning in three sympatric species of map turtle, genus *Graptemys* (Testudinata, Emydidae). American Midland Naturalist 105(1): 103-121.

Vogt, R.C. and J.J. Bull. 1984. Ecology of hatchling sex ratio in map turtles. Ecology. 65: 582-586.

Water Quality Branch (WQB). 1989. The application of an interdisciplinary approach to the selection of potential water quality sampling sites in the Thames River basin. Environment Canada, Water Quality Branch, Ontario Region.

Watson, E. T., J. L. Metcalfe-Smith, and J. Di Maio. 2001a. COSEWIC Status Report on the mudpuppy mussel *Simpsonaias ambigua*. Committee on the Status of Endangered Wildlife in Canada. 31 pp.

Watson, E. T., J. L. Metcalfe-Smith, J. Di Maio. 2001b. COSEWIC Status Report on the snuffbox, *Epioblasma triquetra*. Prepared for the Committee on the Status of Endangered Wildlife in Canada. 33 pp.

Watters, G.T. 1994. North American freshwater mussels, Part II: identification, collection , and the art of zen malacology. Am. Conchologist. 22:12-13.

Watters, G. T. 1999. Morphology of the conglutinate of the kidneyshell freshwater mussel, *Ptychobranchus fasciolaris*. Invert. Biol. 128(3): 289-295.

West, E. L., J. L. Metcalfe-Smith, and S. K. Staton. 2000. Status of the rayed bean, *Villosa fabalis* (Bivalvia: Unionidae) in Ontario and Canada. The Canadian Field-Naturalist 124: 258-258.

White, D. Jr. and D. Moll. 1991. Clutch size and annual reproductive potential of the turtle *Graptemys geographica* in a Missouri stream. Journal of Herpetology 25(4): 493-494.

Wilcox, I., C. Quinlan, C. Rogers, M. Troughton, I. McCallum, A. Quenneville, E. Heagy and D. Dool. 1998. The Thames River watershed: A background study for nomination under the Canadian Heritage Rivers System. Upper Thames River Conservation Authority for the Thames River Coordinating Committee.

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(9): 6-22.

Wood, J.T. 1949. Observations on *Natrix septemvittata* (Say) in southwestern Ohio. Am. Midl. Nat. 42: 744-750.

Woolnough, D. 2002. Life history of endangered freshwater mussels of the Sydenham River, southwestern Ontario, Canada. M.Sc. Thesis. University of Guelph, Guelph, Ontario

Zanatta, D.T., G.L. Mackie, J.L. Metcalfe-Smith and D.A. Woolnough. 2002. A refuge for native freshwater mussels (Bivalvia: Unionidae) from impacts of the exotic zebra mussel (*Dreissena polymorpha*) in Lake St. Clair. J. Great Lakes Res. 28(3): 479-489.

Zanatta, D. T. and J. L. Metcalfe-Smith. 2003a. COSEWIC assessment and status report on round hickorynut, *Obovaria subrotunda*, in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa. vi+31pp.

Zanatta, D.T. and J.L. Metcalfe-Smith. 2003b. COSEWIC status report on Round Pigtoe, *Pleurobema sintoxia*. Committee on the Status of Endangered Wildlife in Canada. iv+37pp.

PERSONAL COMMUNICATIONS

Dr. Susan Doka, Fisheries and Oceans Canada

Lucas Foerster, Species at Risk Technician, Upper Thames River Conservation Authority

Scott Gillingwater, Species at Risk Specialist, Upper Thames River Conservation Authority

Dr. Marten Koops, Fisheries and Oceans Canada

Gerald Mackie, University of Guelph

Dr. Nick Mandrak, Fisheries and Oceans Canada

Kelly McNichols, University of Guelph

Dr. Todd Morris, Fisheries and Oceans Canada

Fraser Neave, Fisheries and Oceans Canada

Teresa Piraino, Species at Risk Technician, Upper Thames River Conservation Authority

John Schwindt, Aquatic Biologist, Upper Thames River Conservation Authority

Lisa Twolan, Environment Canada

Robert Young, Fisheries and Oceans Canada