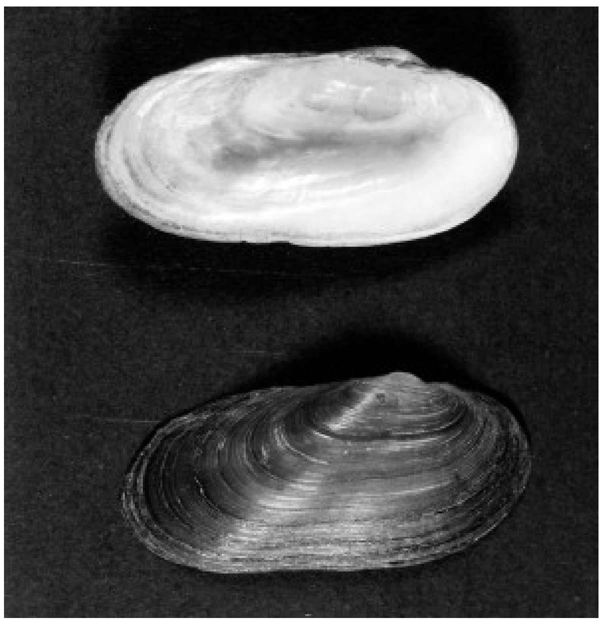
COSEWIC
Assessment and Status Report

on the

Mudpuppy Mussel
Simpsonaias ambigua

in Canada



ENDANGERED
2001

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

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Cover illustration:
Mudpuppy Mussel — Photo of internal (above) and external (below) shell morphology of *Simpsonaias ambigua* collected from the East Sydenham River, Ontario.

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COSEWIC
Assessment Summary

Assessment Summary – May 2001

Common name
Mudpuppy Mussel

Scientific name
Simpsonaias ambigua

Status
Endangered

Reason for designation
Declines in extent of occurrence and area of occupancy; total population extremely fragmented, with all three extant sites in one river (Sydenham River); entire population could be eliminated by a single upstream catastrophic event. Habitats already exposed to high silt loading from agricultural practices, and pollution from point and non-point sources; mudpuppy mussel is host-specific, using only the mudpuppy as host. Any threats to mudpuppy are also threats to mussels.

Occurrence
Ontario

Status history
Designated Endangered in May 2001. Assessment based on a new status report.

COSEWIC
Executive Summary

Mudpuppy mussel
Simpsonaias ambigua

Description

The Mudpuppy Mussel, *Simpsonaias ambigua* (Say, 1825), is a small species of freshwater mussel that is the only living member of the genus *Simpsonaias*. The shell is thin, fragile, oval to elliptical in shape, considerably elongated, and flattened in males to slightly distended at the posterior end in females. It is much thicker at the front end than the back end. The shell is rounded at both ends, and the top and bottom edges are nearly straight and parallel. The beak, which is the raised part at the top of the shell, is slightly swollen and sculptured with four to five double-looped ridges. The outside of the shell is smooth, yellowish tan to dark brown in colour, and has no markings. The inside of the shell is bluish white, iridescent on the back half, and sometimes tinged with salmon near the depression on the inside of the beak. There is a thin, well-marked depression running along the length of the inside of the shell. As in all mussels, the two halves of the shell are joined together by a hinge. The triangular teeth at the front edge of the hinge are very small, low, and rounded — one in each half of the shell. The elongated teeth found along the inside of the hinge in some species is absent in *S. ambigua*. Maximum shell length is about 50 mm.

Distribution

The Mudpuppy Mussel was historically known from 14 states and the province of Ontario. Although it is often overlooked during traditional mussel surveys because of its small size and unique habitat, there is a general consensus that the species has declined throughout its North American range. It is no longer found in 60% of formerly occupied rivers and streams in the United States. In Canada, there are only 3 known historical records for *S. ambigua*, and these are from the Sydenham and Detroit rivers. The species is believed to have been extirpated from the Detroit River, along with most other mussels, due to the impact of the Zebra Mussel, *Dreissena polymorpha*. It is still found in the Sydenham River. Nearshore areas in Lake Erie and Lake St. Clair that were recently found to be refuges from the Zebra Mussel for other native mussels should be surveyed to determine if they also harbour the Mudpuppy Mussel. The species is presumed extirpated from Iowa, New York, Tennessee, and possibly Michigan. The Nature Conservancy has assigned it a Global Rank of G3 (rare and uncommon globally), and it has an SRANK of S1 (very rare) in 6 states and Ontario.

Population size and trend

Simpsonaias ambigua is generally believed to be a rare species, although it is difficult to find and may well be undersurveyed. It has been described as almost colonial, since hundreds of specimens may be found under a single rock with no other populations apparent for some distance. There are no estimates of population size for this species from any location in any jurisdiction; however, the failure to find live animals even after intensive searches in several areas where it previously occurred is believed to indicate a decline. In Canada, the Mudpuppy Mussel appears to be restricted to a 50-km reach of the East Sydenham River in southwestern Ontario, where 17 live animals were found at 4 different sites during extensive surveys in 1997-99. Although the data are few, there is no evidence that the population in the Sydenham River is declining.

Habitat

The Mudpuppy Mussel is most often found burrowed in sand or silt under large, flat rocks in shallow areas with swift current, although it is sometimes found in mud and on gravel bars. Essentially, it is found in areas with enough cover to meet the nesting and sheltering requirements of its larval host, the Mudpuppy (*Necturus maculosus*). It is often found in large numbers, with up to several hundred individuals packed tightly together under a single flat rock. The reason why Mudpuppy Mussels are found in such large concentrations is related to the close association between the mussel and its host. It has been hypothesized that Mudpuppies feed on adult *S. ambigua* as they move from one hiding place to another, becoming heavily infested with larvae in the process. When the larvae have transformed, they are most likely released in the salamander's retreat, i.e., under another large, flat stone.

Biology

Simpsonaias ambigua has separate sexes. It is believed to be a long-term brooder, which means that spawning occurs in late summer and the larvae (which are called glochidia) are held over winter for release the following spring or summer. Glochidia are approximately 260 µm in height and length, clear white in colour, triangular in shape, and have well-developed hooks. The Mudpuppy Mussel is unique in that it is the only species of freshwater mussel that uses an amphibian host, the Mudpuppy (all others use fishes). Time to transformation on the Mudpuppy was reported to be 19-28d at 20ºC. Lifespan and age at sexual maturity are not known. Like all species of freshwater mussels, *S. ambigua* probably utilizes bacteria and algae as its primary food source.

Limiting factors

Simpsonaias ambigua is a very poorly known species of freshwater mussel, and the factors limiting its occurrence in North America are completely unknown. However, it may be surmised that threats to the continued existence of this species are similar to those for other species, i.e., impoundments, siltation, channel modification, pollution, and Zebra Mussels. The Mudpuppy Mussel may escape serious infestation by Zebra Mussels because of its habitat, although a population in the Kentucky River is said to be impacted. Siltation may be the main limiting factor for this species, due to the effects on its host. There is some evidence that siltation has extirpated the Mudpuppy from certain areas, mainly by reducing its access to nesting sites and hiding places. Siltation has undoubtedly increased in the Sydenham River as a result of intensifying agriculture. Mudpuppies will also avoid areas that do not provide enough cover such as flat rocks, logs, and other debris, thereby limiting the distribution of the Mudpuppy Mussel. Status of the Mudpuppy population in this system is not known and should be assessed. Exposure to agricultural chemicals and road run-off may also threaten the Sydenham River population of *S. ambigua*.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) determines the national status of wild species, subspecies, varieties, and nationally significant populations that are considered to be at risk in Canada. Designations are made on all native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fish, lepidopterans, molluscs, vascular plants, lichens, and mosses.

COSEWIC MEMBERSHIP

COSEWIC comprises representatives from each provincial and territorial government wildlife agency, four federal agencies (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biosystematic Partnership), three nonjurisdictional members and the co-chairs of the species specialist groups. The committee meets to consider status reports on candidate species.

DEFINITIONS

Species	Any indigenous species, subspecies, variety, or geographically defined population of wild fauna and flora.
Extinct (X)	A species that no longer exists.
Extirpated (XT)	A species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A species facing imminent extirpation or extinction.
Threatened (T)	A species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A species of special concern because of characteristics that make it particularly sensitive to human activities or natural events.
Not at Risk (NAR)**	A species that has been evaluated and found to be not at risk.
Data Deficient (DD)***	A species for which there is insufficient scientific information to support status designation.

* Formerly described as “Vulnerable” from 1990 to 1999, or “Rare” prior to 1990.

** Formerly described as “Not In Any Category”, or “No Designation Required.”

*** Formerly described as “Indeterminate” from 1994 to 1999 or “ISIBD” (insufficient scientific information on which to base a designation) prior to 1994.

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list.

Environment Canada / Environnement Canada

Canadian Wildlife Service / Service canadien de la faune

Canada

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COSEWIC Status Report

on the

Mudpuppy mussel
Simpsonais ambigua

in Canada

2001

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SPECIES INFORMATION

Description

The Mudpuppy Mussel, *Simpsonaias ambigua* (Say, 1825), is a small freshwater mussel that is distinguished from other mussels by its elongate elliptical shell shape, incomplete hinge teeth, double-looped beak sculpture, and rayless, brown periostracum. It may be confused with *Anodontoides ferussacianus*, which has a similar shell shape and beak sculpture but lacks pseudocardinal teeth and grows considerably larger (Strayer and Jirka 1997). Figure 1 is a photograph of 13 live individuals collected from the East Sydenham River, Ontario in October 1999, and Fig. 2 showS the external and internal morphology of the shell. The following description of the Mudpuppy Mussel's shell was adapted from Simpson (1914), Clarke (1985), Cummings and Mayer (1992), and Parmalee and Bogan (1998):

The shell is thin, fragile, oval to elliptical in shape, considerably elongated, and compressed in males to slightly inflated posteriorly in females. It is much thicker anteriorly than posteriorly. The anterior and posterior ends are rounded; the dorsal and ventral margins are nearly straight and parallel. The posterior ridge is rounded. The beaks are located approximately one-quarter of the distance from anterior to posterior, and are slightly elevated above the hinge line and somewhat compressed. Beak sculpture consists of four to five double-looped ridges. The periostracum (shell surface) is smooth, yellowish tan to dark brown in colour, and rayless. The nacre is bluish white, sometimes tinged with salmon near the shallow beak cavities, and iridescent on the posterior half of the shell. The pallial line is well marked. Pseudocardinal teeth are very small, low, and rounded — one in each valve. Lateral teeth are absent. For a description of the soft parts of *S. ambigua*, the reader is referred to Clarke (1985:63-64).

Figure 1. Live *Simpsonaias ambigua* found in the East Sydenham River, Ontario, in October 1999. Individuals were living under the flat rock on which they are displayed.

Figure 2. Internal (above) and external (below) shell morphology of *Simpsonaias ambigua* collected from the East Sydenham River, Ontario.

The Mudpuppy Mussel may attain a maximum shell length of 48 mm (Clarke 1985), 50 mm (Parmalee and Bogan 1998), or 51 mm (Cummings and Mayer (1992). Clarke (1981) states that Canadian specimens of *S. ambigua* can reach a length of 42 mm, but shells up to 49 mm long have been collected from the Sydenham River, Ontario in recent years (this report). Clarke (1985) found that the relative dimensions of the shell, i.e., the height:length and width:length ratios, may be quite variable.

Taxonomic status of the species

Simpsonaias ambigua was first described by Say in 1825. The type locality was given only as the "North-west Territory", and the type specimens have apparently been lost (Clarke 1985). Synonyms that have been used for this species, as cited by Parmalee and Bogan (1998), include:

Alasmodonta ambigua Say, 1825; Say, 1825:131
Margaritana ambigua (Say, 1825); Küster, 1862:300, pl. 99, fig. 7
Simpsoniconcha ambigua (Say, 1825); Simpson, 1900a:673
Simpsonaias ambigua (Say, 1825); Frierson, 1914:7
Hemilastena ambigua (Say, 1825); Simpson, 1900a:673
Unio hildrethianus Lea, 1834; Lea, 1834:36, pl. 3, fig. 8
Margarita (Unio) hildrethianus (Lea, 1834); Lea, 1836:28
Margaron (Margaritana) hildrethianus (Lea, 1834); Lea, 1852c:43
Strophitus hildrethiana (Lea, 1834); Conrad, 1853:263
Baphia hildrethiana (Lea, 1834); H. and A. Adams, 1857:499
Margaritana hildrethiana (Lea, 1834); B.H. Wright, 1888b:no pagination
Alasmodonta dubia Férussac, 1835; Férussac, 1835:26

Simpsonaias ambigua is the only member of the genus *Simpsonaias*. Clarke (1985) states that its phylogenetic position is obscure, since it is "…not closely related to any other living species." The American Fisheries Society recently published a revised compilation of the generally accepted common and scientific names for molluscs in the United States and Canada (Turgeon *et al*. 1998), which we consider to be the authority for the current classification of *S. ambigua*: PHYLUM Mollusca, CLASS Bivalvia, SUBCLASS Palaeoheterodonta, ORDER Unionoida, SUPERFAMILY Unionoidea, FAMILY Unionidae, SUBFAMILY Anodontinae, GENUS *Simpsonaias*, SPECIES *Simpsonaias ambigua*.

DISTRIBUTION

Historical distribution in North America

Historically, *Simpsonaias ambigua* was known from Arkansas, Illinois, Indiana, Iowa, Kentucky, Michigan, Minnesota, Missouri, New York, Ohio, Pennsylvania, Tennessee, West Virginia, Wisconsin, and Ontario (TNC 2000a). It was found in the Lake St. Clair, Lake Huron, and Lake Erie drainages; and in the Ohio, Cumberland, and upper Mississippi river systems (Clarke 1985). Appendix 1 presents the known occurrences of this species in the United States.

In Canada, *S. ambigua* was known only from the Province of Ontario (Clarke 1981). The National Water Research Institute's Lower Great Lakes Unionid Database was used to identify historical species occurrence records for *S. ambigua* in Ontario. At the time of writing, the database consisted of 5902 records (defined as the occurrence of given species at a given location on a given date) for 40 species collected from 2056 sites in the lower Great Lakes drainage basin since 1860. Data sources included natural history museums, the published literature, unpublished reports, and collectors' field notes; for a detailed description of the Database and its data sources, see Metcalfe-Smith *et al*. (1998b). Only 3 historical records exist for this species (Appendix 2; Fig. 3). It was reported from one location in the Detroit River in 1934, and two locations in the Sydenham River in the 1960s. A range map for *S. ambigua*, which is based on known occurrences in the United States and Canada, is presented in Fig. 4.

Current distribution in North America

Although the Mudpuppy Mussel is often overlooked during traditional mussel surveys because of its unique habitat preference (see Habitat below), results of intense searches for the species in areas where it had previously been reported indicate a decline in its range (TNC 1999). This decline is reflected in the current State or Subnational Rank (SRANK) and Status for the species in each jurisdiction (Table 2). Figure 5 illustrates the current range and SRANKs for the Mudpuppy Mussel in North America.

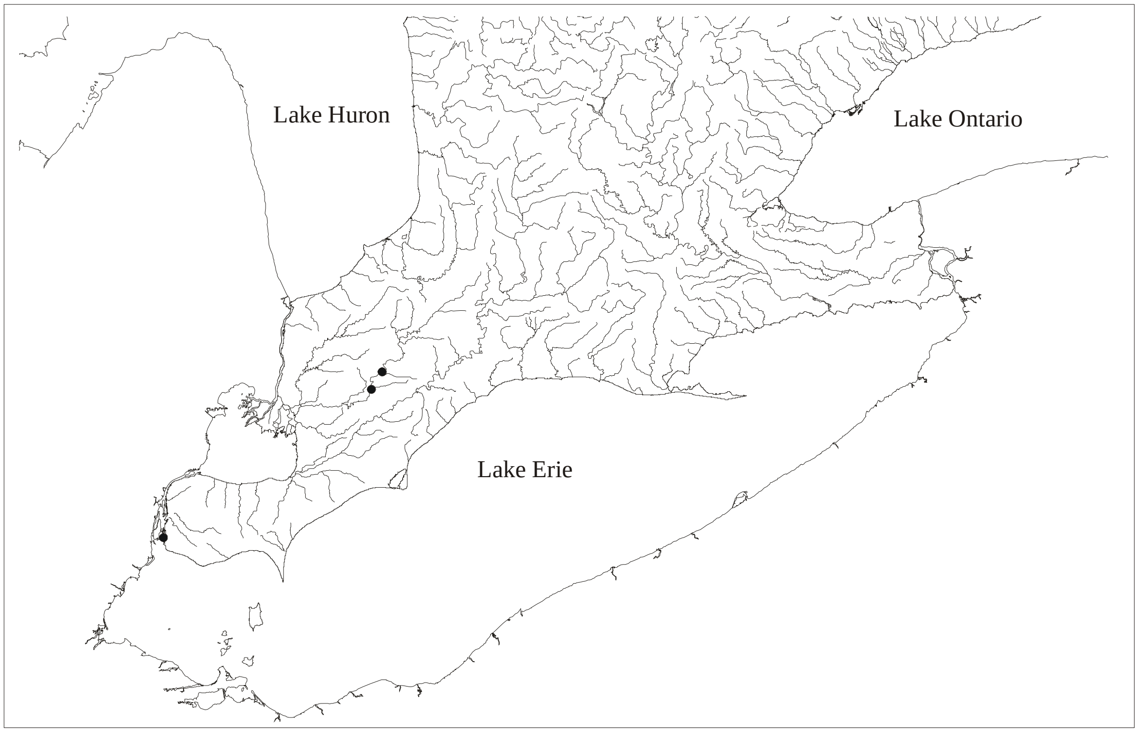

Figure 3. Historical distribution of *Simpsonaias ambigua* in Ontario (all records for live animals and shells are included).

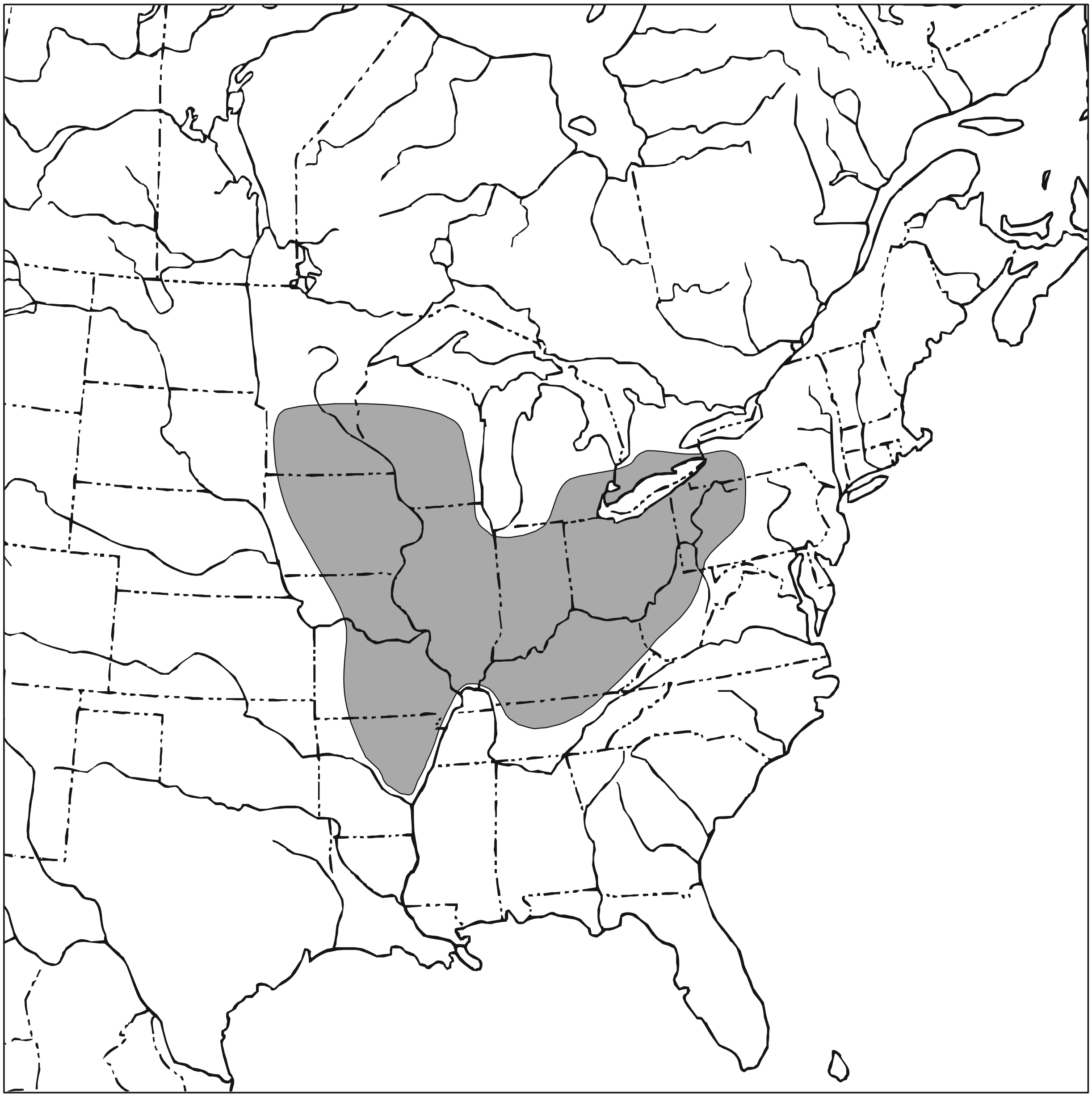

Figure 4. Historical distribution of *Simpsonaias ambigua* in North America.

Table 1. Records for *Simpsonaias ambigua* collected during mussel surveys of 66 sites on five southwestern Ontario rivers from 1997 to 1999 (Metcalfe-Smith *et al*. 1998c, 1999, unpublished data). Shell length in mm is given for each specimen. Site locations are shown in Fig. 6.

Site	Date	Nearest Urban Centre	Locality Description	Lat.	Long.	Collectors[1]	Sampling Effort (P-H)	Live Specimens	Fresh Shells	Weathered Shells
Sydenham River:										
SR-3	19/08/97	Alvinston	5 km downstream of Alvinston at bridge crossing	42.779	-81.835	1	4.5		one[4]	
SR-5	20/08/97	Florence	Bridge at Florence, just west of town	42.651	-82.010	1	4.5		26 W[5]; 44 H[5]	
SR-4	20/08/97	Shetland	1.8 mi NE of Shetland, near Shetland Conservation Area	42.717	-81.954	1	4.5		42 H	
SR-7	21/08/97	Shetland	.8 km west of Shetland	42.697	-81.990	1	4.5		31, 38, 42 & 42 H	38 H
SR-6	21/08/97	Croton	Upstream of Dawn Mills, 2.3 km downstream of bridge at Croton	42.604	-82.072	1	4.5		27, 28, 30, 31, 38, 39, 47, 47 & 49 W; 24, 25, 25, 28, 28, 30, 30, 30, 31 & 31 H	29, 30, 33, 34, 34 & 43 H
SR-9	25/09/97	Warwick	4 km southwest of Warwick	42.975	-81.971	2	4.5			38 W
SR-6	23/06/98	Croton	Upstream of Dawn Mills, 2.3 km downstream of bridge at Croton	42.604	-82.072	3	?[2]	19		36, 36, 41 & 48 W; 37, 38, 38, 40 & 41 H
SR-17	28/08/98	Florence	3.4 km N (& slightly W) of bridge at Florence	42.679	-82.017	4	4.5		one[4]	
SR-7	18/05/99	Shetland	.8 km west of Shetland	42.697	-81.990	5	?[2]	29	37, 39 & 42 H	45 W; 29, 36 & 44 H
SR-12	27-29/07/99	Dawn Mills	Bridge at Dawn Mills	42.589	-82.126	6	11.0[3]		40 W	
SR-6	05/10/99	Croton	Upstream of Dawn Mills, 2.3 km downstream of bridge at Croton	42.604	-82.072	7	7.5	13 & 15	31 & 44 W; 40 H	32 & 40 W; 25, 31 & 41 H
SR-5	06/10/99	Florence	Bridge at Florence, just west of town	42.651	-82.010	7	4.5	16, 20, 27, 27, 28, 28, 29, 30, 32, 35, 36, 42 & 44	29, 29, 34 & 44 W; 14, 24 & 40 H	39, 41, 43 & 47 H
Thames River:										
TR-14	13/08/98	London	Story Book Gardens Park, just d.s. of a ~5m high dam, W end of London	42.961	-81.331	8	4.5		38 H	
TOTALS								**17**	**43**	**30**

[1] 1 = J. Smith, S. Staton & E. Walker; 2 = S. Staton, T. Breedon & B. Gray; 3 = J. Smith, S. Staton & I. Scott; 4 = S. Staton, E. Walker & B. Hess; 5 = J. Smith, S. Staton and J. Di Maio; 6 = J. Smith, J. Di Maio & J. Kraft; 7 = J. Smith, J. Di Maio & D. Zanatta; 8 = S. Staton, E. Walker & K. Hill.
[2] search time unknown; found incidentally while collecting specimens of another species for a related study.
[3] collected during quadrant surveys.
[4] broken shell; could not measure.
[5] H = half shell (valve); W = whole shell.

Table 2. State Rank (TNC 2000a) and State Status of *Simpsonaias ambigua* in each jurisdiction.

State/Province	SRANK[1]	State Status	State Status Reference[2]
Arkansas	S1?	none	C. Osborne 1999 (pers. comm.)
Illinois	S1	Endangered	K.S. Cummings 1999 (pers. comm.)
Indiana	S2	Special Concern	R. Hellmich 1999 (pers. comm.)
Iowa	SX	none	H. Howell 1999 (pers. comm.)
Kentucky	S2S3	none	R. Cicerello 1999 (pers. comm.)
Michigan	S1	Endangered	R.R. Goforth 2000 (pers. comm.)
Minnesota	S2	Threatened	M. Davis 1999 (pers. comm.)
Missouri	S1?	Endangered	Buchanan (1980)
New York	SH	none	K. Schneider 1999 (pers. comm.)
Ohio	S2	Threatened	G.T. Watters 1999 (pers. comm.)
Pennsylvania	S1?	none	C.T. Beir 1999 (pers. comm.)
Tennessee	S2	Endangered	TN Dept. of Env. and Cons. (1997)
West Virginia	S1	none	J. Clayton 1999 (pers. comm.)
Wisconsin	S2S3	Threatened	J.M. Burnham 2000 (pers. comm.)
Ontario	S1	none	

[1] State Ranks are assigned by state Natural Heritage Programs using methodology developed by The Nature Conservancy. State Ranks are assigned based upon the best available information, and are defined as follows:

- SX: Extirpated (believed to be extirpated from the state).
- SH: Historical (occurred historically, but suspected to still be extant).
- S1: Critically imperiled because of extreme rarity, or because some factor(s) make it especially vulnerable to extirpation from the state (typically 5 or fewer occurrences, or very few remaining individuals).
- S2: Imperiled because of rarity, or because some factor(s) make it very vulnerable to extirpation (6 to 20 occurrences or few remaining individuals).
- S3: Rare and uncommon (21 to 100 occurrences).

[2] See Acknowledgements for affiliations.

In the United States, *S. ambigua* is thought to be extant in only 32 of the 80 rivers and streams for which historical records are available (see Appendix 1). It is believed to be extirpated from Iowa, and only historical records exist for New York (TNC 2000a). Parmalee and Bogan (1998) state that "in all probability" it is also extirpated from Tennessee. The Nature Conservancy has assigned *S. ambigua* a global rank of G3 (rare and uncommon globally), and an SRANK of S1 in six states and S2 in four others (TNC 2000a, Fig. 5; see Table 2 for definitions of SRANKS). The species is listed as endangered in Illinois, Michigan, and Tennessee; threatened in Minnesota, Ohio, and Wisconsin; and of Special Concern in Indiana. It is also listed by the American Fisheries Society as a species of special concern, which is defined as “A species or subspecies that may become endangered or threatened by relatively minor disturbances to its habitat, and deserves careful monitoring of its abundance and distribution” (Williams *et al*. 1993).

Until recently, *S. ambigua* was ranked SH (historical; no occurrences verified in the past 20 years) in Ontario by the Ontario Natural Heritage Information Centre (D.A. Sutherland, NHIC, pers. comm., December 1996). Prior to 1997 (see below), the only live record for the species was a single live specimen taken from the East Sydenham River near Shetland in 1967. It was not found during surveys of Lake Erie or Lake St. Clair in the 1990s (see Population Numbers, Sizes and Trends). No live mussels of any species were collected during recent surveys of the Detroit River, which is heavily infested with Zebra Mussels, *Dreissena polymorpha* (T.M. Frietag, U.S. Army Corps of Engineers, Michigan, pers. comm., November 1999).

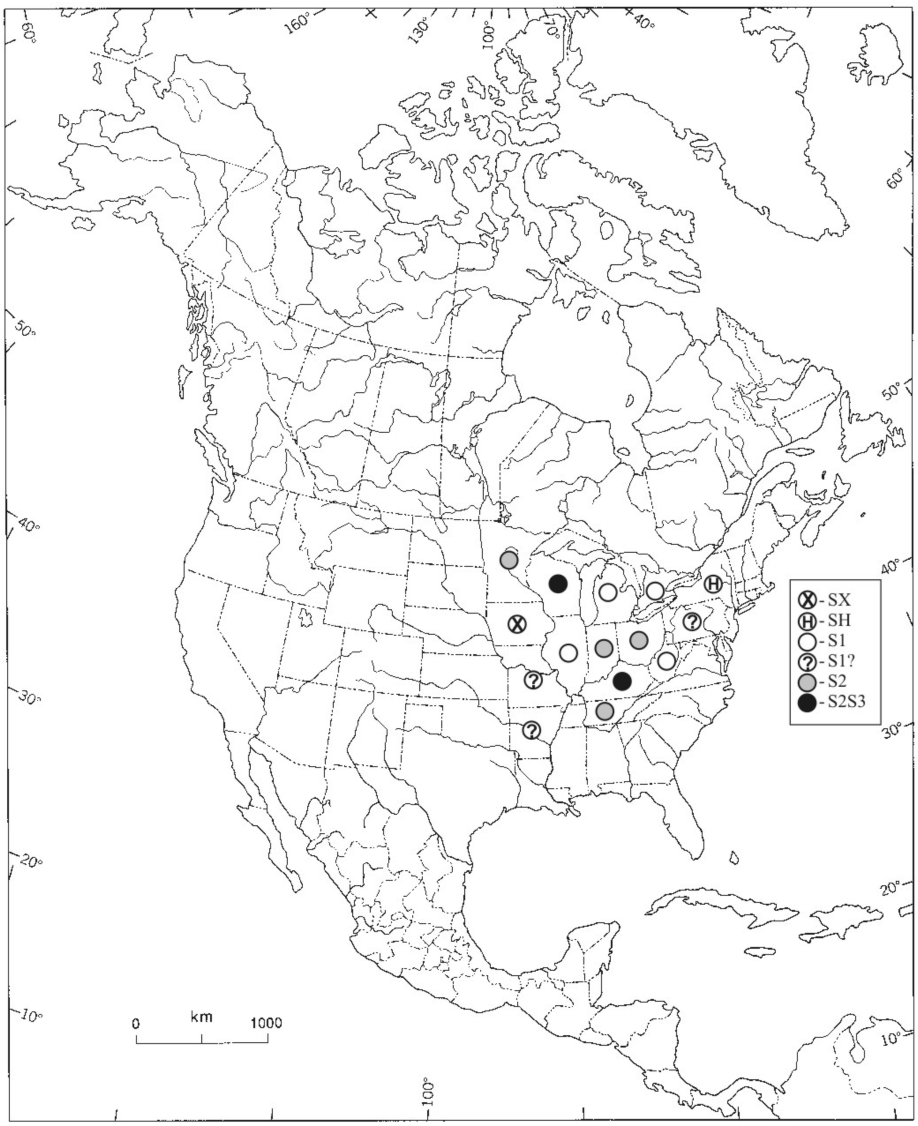

Figure 5. Current range and S-RANKS of *Simpsonaias ambigua* in North America.

Intensive surveys conducted at 66 sites on tributaries to Lake Erie, Lake St. Clair and lower Lake Huron in 1997-1998 (Metcalfe-Smith *et al*. 1998c, 1999), and additional collections at some of these sites in 1998 and 1999, yielded a total of 90 specimens from 8 different sites on the Sydenham River and one site on the Thames River (Table 1). Seventeen of these specimens were found alive, all of which were taken from 3 sites in the middle reach of the East Sydenham River (Fig. 6). Fresh shells[1] were also found at these and several other sites in this reach, and a single fresh valve was found at the Thames River site. One site on the north branch of the Sydenham River (Bear Creek) produced a single weathered valve[1]. The current distribution of the Mudpuppy Mussel in Ontario appears to be restricted to the middle reach of the East Sydenham River, with the possibility of an isolated population in the upper Thames River. Based on these findings, *S. ambigua* has been downlisted from SH to S1 in Ontario (D.A. Sutherland, NHIC, pers. comm., September 1999).

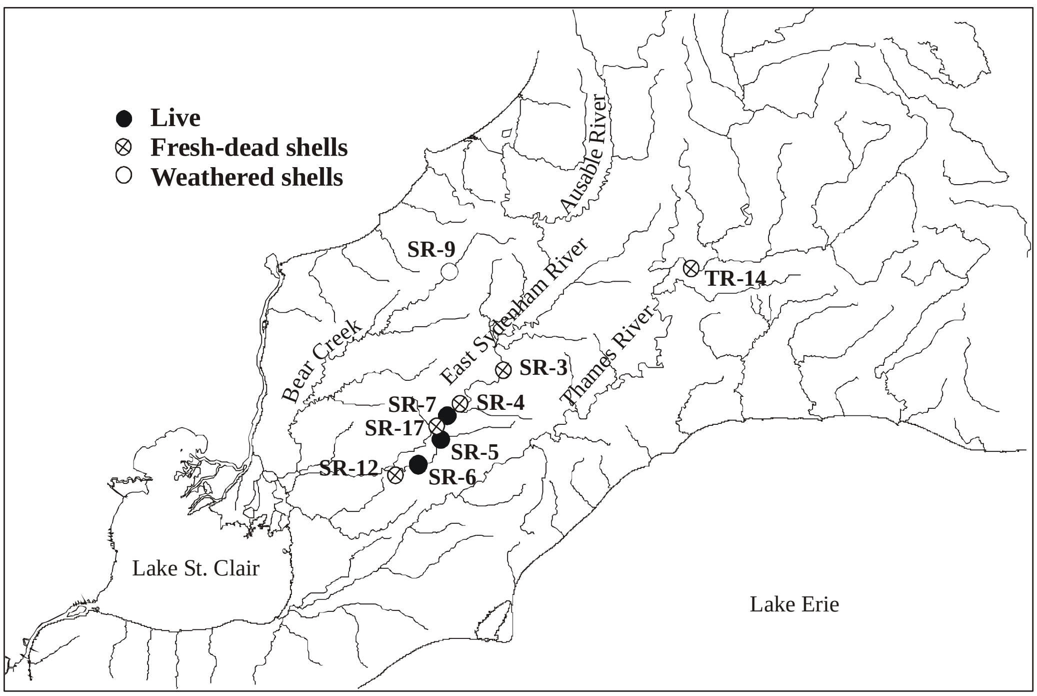

Figure 6. Current distribution of *Simpsonaias ambigua* in Ontario, based on records from recent surveys (Metcalfe-Smith *et al*. 1998c, 1999, unpublished data). See Table 1 for locations.

[1]Shells that exhibited dull nacre, and wear to the periostracum and hinge teeth, were defined as “weathered”; shells in this condition could be decades old. Shells having an intact periostracum, shiny nacre, and little or no wear of the hinge teeth were defined as “fresh”. Shells in this condition were estimated to be one to three years old (D.L. Strayer, Institute of Ecosystem Studies, Millbrook, NY, pers. comm., July 1996).

PROTECTION CURRENTLY PROVIDED

Canada

Canada does not have federal endangered species legislation at present, although the proposed Species at Risk Act (SARA) was introduced into the House of Commons on 11 April 2000 (Environment Canada 2000a). The proposed legislation follows the signing of the Accord for the Protection of Species at Risk by the federal, provincial, and territorial ministers responsible for wildlife in 1996, which committed all of Canada's jurisdictions to "establish complementary legislation and programs that provide for effective protection of species at risk throughout Canada" (Environment Canada 2000a).

Ontario is one of five provinces that have stand-alone Endangered Species Acts (B.T. Fowler, Chair, Lepidoptera and Mollusca Subcommittee, COSEWIC, pers. comm., October 1999). Ontario's Endangered Species Act, which came into effect in 1971, prohibits wilful destruction of, or interference with, a regulated endangered species or its habitat. The maximum penalty for violating Ontario's Endangered Species Act is a fine of $50,000, imprisonment for two years, or both (Rishikof 1997). Should *S. ambigua* be listed as endangered in Ontario, it would be afforded protection.

The Federal Fisheries Act may also protect the habitat of *S. ambigua* in Canada. Fish are broadly defined under the Act to include shellfish, although the intent was to protect marine shellfish harvested for human consumption. The Fisheries Act prohibits fishing without a licence and makes it illegal to harm fish habitat, which is defined as "spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes." The maximum penalty for fishing without a licence is a fine of up to $500,000 and/or imprisonment for up to two years, and the maximum penalty for destroying fish habitat is a fine of up to $1,000,000 per day and/or imprisonment for up to three years. The protection of fish and their habitat may indirectly protect the habitat of *S. ambigua*.

As mussels are considered fish under the Federal Fisheries Act, the collection of live mussels is theoretically "fishing" and would fall under the Ontario Fishery Regulations that are made under the Federal Fisheries Act. The Provincial Policy Statement under Section 3 of the Planning Act provides for protection from development and site alteration in significant portions of the habitats of threatened and endangered species. Other mechanisms for protecting mussels and their habitat in Ontario include the Ontario Lakes and Streams Improvement Act, which prohibits the impoundment or diversion of a watercourse if it would lead to siltation; and the voluntary Land Stewardship II program of the Ontario Ministry of Agriculture, Food, and Rural Affairs, which is designed to reduce erosion on agricultural lands. Streamside development in Ontario is managed through flood plain regulations enforced by local Conservation Authorities. Most of the land along the reach of the Sydenham River where *S. ambigua* was found alive in recent years is privately owned and in agricultural use (M. Andreae, St. Clair Region Conservation Authority, pers. comm., March 1998).

United States

The United States Endangered Species Act (USESA), originally passed in 1973, is the primary federal statute for protecting species at risk in that country. The U.S. Fish and Wildlife Service is required to adopt a recovery plan for every species listed as endangered or threatened under the Act. The USESA also provides for possible land acquisition, in cooperation with state agencies. Listing under the USESA prohibits the "taking" of a listed species, which includes conducting any habitat modification that would harm the species. Violation of the Act can result in fines of up to $100,000, up to a year in jail, and forfeiture of any property used in breaking the law. There are currently 69 species of freshwater mussels listed as endangered (61) or threatened (8) in the United States (USFWS 2000). *Simpsonaias ambigua* is not federally listed at the present time; however, it would be indirectly protected where it co-occurs with any listed species. It was previously listed as a Category 2 Federal Candidate, which was defined as a species for which there was some evidence for vulnerability but not enough data for listing as endangered or threatened (Cummings and Mayer 1992). This designation was discontinued in 1996, and state and local governments are no longer asked to take Category 2 candidates into account in their environmental planning (Roth 1997).

Most states have their own Endangered Species Acts, but rely heavily on the USESA for enforcement and funding. Of the 14 states in which *S. ambigua* historically occurred, only Arkansas and West Virginia *do not* have legislation to protect endangered species (Defenders of Wildlife 1996). As previously noted, *S. ambigua* is listed as Endangered in Illinois, Michigan and Tennessee; threatened in Minnesota, Ohio, and Wisconsin; and of Special Concern in Indiana. All of these states prohibit the taking of listed species, and also provide for the possible acquisition of land or aquatic habitat. Only Michigan requires the implementation of a recovery plan for listed species. Penalties for violating the Endangered Species Act in these states range from $25 to $10,000 in fines, and/or up to a year in prison (Defenders of Wildlife 1996). There are several protected occurrences of the Mudpuppy Mussel, including the St. Croix National Scenic Waterway and the lower Wisconsin State Riverway in Wisconsin. Also, The Nature Conservancy has purchased land on Big Darby Creek in Ohio (TNC 1999).

Most states have also enacted legislation making it illegal to possess more than a certain number of mussels, if any. For example, Missouri allows the possession of only five live or dead mussels per day without a Commercial Musseling Permit (Missouri Department of Conservation 2000); Pennsylvania allows possession of up to 50 mussels per day (C.W. Beir, Pennsylvania Natural Diversity Inventory, pers. comm., November 1999); and Wisconsin allows the taking of up to 50 pounds of mussels a day without a Commercial Clamming Permit (Wisconsin Department of Natural Resources 1998). The collection of freshwater mussels is prohibited in Alabama, Indiana, Michigan, Mississippi, New York, Ohio, Virginia and West Virginia (personal communications with state agency representatives).

POPULATION NUMBERS, SIZES AND TRENDS

The habitat of the Mudpuppy Mussel is unique for a freshwater mussel; it is most often found burrowed in soft mud under large flat stones (see Habitat). Because it is difficult and time-consuming to turn over large rocks in search of this mussel, it is seldom encountered during routine mussel surveys. As a result, it is extremely difficult to estimate population numbers, sizes and trends for this species. In many cases, the presence of live animals must be inferred from the presence of fresh shells.

United States

Shimek (1888) speculated that *S. ambigua* is considered rare only because "they are seldom found by those who are unfamiliar with their habits." He found several thousand specimens while searching the rocky bottom of the Iowa River west of Iowa City in the summer of 1887. It is true that the species is sometimes found in great densities. For example, Call (1900, cited in Baker 1928) found more than 200 live specimens under a rock with an area of 1 $ft.^2$; Shimek (1888) found 324 animals living under a single slab of limestone measuring 16 by 18 inches; and Balding (1992) found large numbers of specimens tightly packed together under rocks at several sites on the lower Chippewa River, Wisconsin. By most accounts, however, the Mudpuppy Mussel is a rare species. Baker (1928) found dead shells on a gravel bar in the Wisconsin River near Kilbourn, but failed to find any live specimens even after several days of searching. Howard (1951) searched Hickory Creek, a tributary of the Des Plaines River near Joliet, Illinois, on two occasions looking for gravid specimens for life history studies. He found a total of 22 live mussels, but did not specify his search time. Buchanan (1980) surveyed 198 sites in the Meramec River basin in eastern Missouri in the late 1970s, and found a total of 20,589 freshwater mussels. Searches were conducted by wading or diving until "…we were confident that representatives of all species present had been collected" (15 min - 11.5 h/site). Only 5 specimens of *S. ambigua* were found at a single site on the main stem of the Bourbeuse River. Balding (1992) intensively surveyed 37 sites on the lower Chippewa River, Wisconsin in 1986-1989 and found 2161 live mussels of 24 species. Mudpuppy Mussels were found at 8% of the sites, but their habitat was not searched at every site and their occurrence may have been under-represented. Watters (1996) surveyed 30 sites on Fish Creek, a tributary of the St. Joseph River in Indiana and Ohio, in 1996 by "…handpicking during conditions of low water." *Simpsonaias ambigua* was represented by a freshly dead shell at only one site.

Although *S. ambigua* is easily overlooked during mussel surveys, the failure to find live animals even after intensive searches in areas where it previously occurred is believed to indicate a decline (TNC 1999). It is presumed to have been lost from Iowa, New York and Tennessee, and has not been recorded from Michigan since 1985 (R.R. Goforth, Michigan Natural Features Inventory, pers. comm., January 2000). Although extant populations are known from the remaining 11 states in which it formerly occurred, its range appears to be declining in most jurisdictions. For example, the Mudpuppy Mussel historically inhabited 9 streams in Illinois, but is now suspected to occur in only 2: the Embarras and Vermillion rivers (K.S. Cummings, Illinois Natural

History Survey, pers. comm., November 1999). In Indiana, it is currently restricted to 6 of 16 previously inhabited streams (R. Hellmich, Indiana Natural Heritage Data Center, pers. comm., December 1999). It is presently known from 3 streams in Ohio, down considerably from the 22 it used to occupy (D. Rice, Ohio Department of Natural Resources, pers. comm., December 1999). Its status in Ohio should probably be upgraded from threatened to endangered (G.T. Watters, Ohio State University, pers. comm., December 1999). *Simpsonaias ambigua* is still found in 7 of the 11 streams it historically occupied in West Virginia (J. Clayton, West Virginia Department of Natural Resources, pers. comm., December 1999), and 9 of the 16 streams it formerly occupied in Wisconsin (J.M. Burnham, Wisconsin Department of Natural Resources, pers. comm., February 2000). Overall, *S. ambigua* is now believed to occur in just 40% of the streams that supported it in the past.

Canada

To our knowledge, there are only three historical records for *S. ambigua* in Canada (see Appendix 2). One record is for a fresh whole shell collected from the Detroit River at Bois Blanc Island by Bryant Walker in 1934 (Clarke 1985; specimen held at the University of Michigan Museum of Zoology, Ann Arbor). He also collected a shell from Belle Isle in American waters in the same year. T.M. Frietag (U.S. Army Corps of Engineers, Detroit, Michigan, pers. comm., November 1999) collected three fresh whole shells from the Detroit River at the upstream end of Belle Isle in 1983, but found no live mussels of any species at this location during recent SCUBA surveys. As the Detroit River is now heavily infested with Zebra Mussels, most native mussels are likely extirpated from the system. Schloesser *et al*. (1998) reported the loss of 8 species and a 95% reduction in abundance of unionids in the Detroit River between 1986, when Zebra Mussels were introduced into the system, and 1992/1994. There are very few historical records for this species from the lower Great Lakes and their tributaries (both Canadian and American waters) when compared with the large numbers of records from the Ohio and Cumberland drainages (see Clarke 1985), and it has not been found during recent surveys in Lake Erie (Schloesser *et al*. 1997, Schloesser and Masteller 1999, Nichols and Amberg 1999), Lake St. Clair (Nalepa *et al*. 1996), or the St. Clair River (Mackie *et al*. 2000). This distribution pattern suggests that *S. ambigua* is at the northernmost limit of its range in the Great Lakes region and may be naturally rare here. Baker (1928) remarked that the species was rare in Wisconsin and "…fails to attain the dimensions of the localities farther south."

There are two historical records for *S. ambigua* from the Sydenham River in the Lake St. Clair drainage. One fresh whole shell and a fresh valve were collected from the East Sydenham River near Florence in 1965 by C.B. Stein and J.E. Stillwell, and one live animal was collected from the East Sydenham River near Shetland in 1967 by H.D. Athearn and M.A. Athearn. Arthur H. Clarke surveyed 11 sites on the Sydenham River in 1971 using a sampling effort of 1 person-hour (p-h)/site and 16 sites in 1991 with a sampling effort of 0.4-8.0 p-h/site, but did not find any trace of *S. ambigua* (Clarke 1973, 1992). Similarly, Mackie and Topping (1988) conducted 1 p-h searches at 32 sites in the system in 1985, and found no live animals or shells.

Metcalfe-Smith *et al*. (1998c, 1999) surveyed 66 sites on the Grand River (Lake Erie drainage), Thames and Sydenham Rivers (Lake St. Clair drainage), and Ausable and Maitland Rivers (lower Lake Huron drainage) in 1997 and 1998 to assess the conservation status of rare species of freshwater mussels in southwestern Ontario. They used the timed-search method, which is the most effective method for detecting rare species (Strayer *et al*. 1997), and an intensive sampling effort of 4.5 p-h/site. Sites that were known to support rare species and/or diverse mussel communities in the past were targeted. Several sites were revisited in 1998 or 1999 for additional searches. All live mussels collected during these searches were returned to the river unharmed at the end of the survey. When handling rare species, particular care was taken to replace them in the same location and orientation in which they were found. No live specimens or shells of *S. ambigua* were found at any of the 24 sites on the Grand River, 8 sites on the Ausable River, or the single site on the Maitland River, nor was the species previously reported from any of these systems. A single fresh valve was found at site TR-14 on the Thames River in the city of London in 1998 (Fig. 6). This specimen represents the first record for *S. ambigua* in the Thames River, and indicates the presence of at least one small population in the upper reaches of the river.

Simpsonaias ambigua was found alive at 3 of the 17 sites surveyed on the Sydenham River in 1997-99, and fresh whole shells and/or valves were found at these and 4 other sites (Fig. 6). All of these sites are in the middle reach of the East Sydenham River. One weathered whole shell was also found at a site on the north branch of the Sydenham River (Bear Creek). A fresh valve was found at the site where Athearn and Athearn had found a live individual in 1967 (site SR-4); and 13 live animals, 5 fresh whole shells, 4 fresh valves, and 4 weathered valves were found during two visits to the site where Stein and Stillwell had found one fresh whole shell and a fresh valve in 1965 (site SR-5). Altogether, 17 live animals, 42 fresh shells/valves and 30 weathered shells/valves were collected from 8 different sites on the Sydenham River in 1997-99 (Table 1), indicating the presence of a significant population of Mudpuppy Mussels in a 50-km stretch of the East Sydenham River between Alvinston (site SR-3) and Dawn Mills (site SR-12).

It is worth noting that none of the live specimens of *S. ambigua* were collected during regular timed search surveys. The individuals found at SR-6 in 1998 and SR-7 in 1999 were encountered incidentally while collecting specimens of another species for a related study. The individuals recorded at SR-6 and SR-5 in 1999 were taken during searches that were specifically targeted for this species, i.e., we looked for areas with large flat rocks, and systematically overturned the rocks and searched the substrate beneath for the mussels. All 13 of the live specimens collected from site SR-5 were found under a single flat rock (see Fig. 1). Our findings emphasize the importance of conducting targeted searches for this species. The Nature Conservancy (1986) also pointed out that *S. ambigua* may not be found by the usual mussel collection methods and that most populations are located by the presence of fresh shells.

Information on sex ratios and size class structure can be used to indicate population health and reproductive success. Unfortunately, Mudpuppy Mussels are not prominently sexually dimorphic and we were not confident about telling the sexes apart, so we are unable to provide any information on sex ratio for the Sydenham River population. The broad range of sizes for live specimens (13-44 mm) and fresh shells (14-49 mm; Fig.7) indicates that several year classes are represented, and suggests there is ongoing recruitment. As shown in Table 1, fresh shells were larger on average than live individuals (34.0 vs. 27.5 mm, respectively). These data suggest a pattern of higher mortality among larger, older individuals, which would be expected in a healthy population.

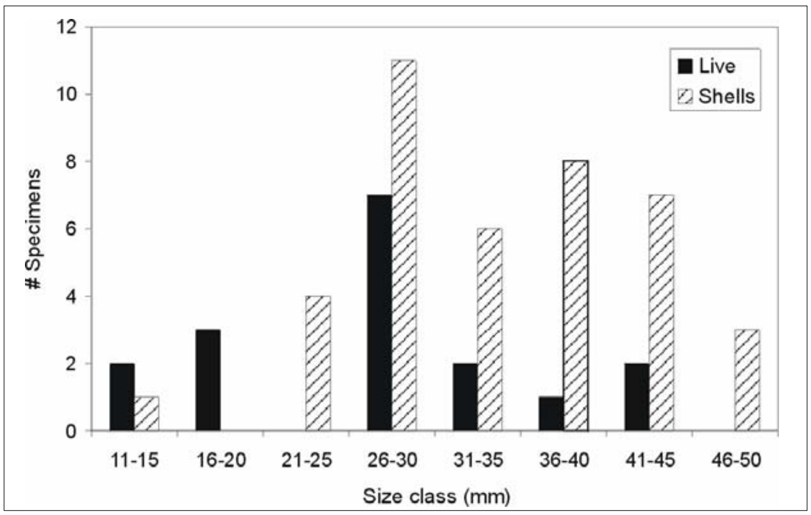

Figure 7. Size class distribution for live specimens and fresh shells of *Simpsonaias ambigua* found in the East Sydenham River in 1997-1999.

HABITAT

Habitat and microhabitat requirements

According to Ortmann (1919), the Mudpuppy Mussel may be found wherever its glochidial host, the Mudpuppy (*Necturus maculosus*), takes refuge. Gendron (1999) describes the Mudpuppy as a nocturnal and secretive, perennially aquatic salamander. It colonizes a variety of freshwater habitats, including rivers, streams, creeks and lakes, where it prefers clear water and is intolerant of heavy siltation. It is found on a variety of substrates, including bedrock, gravel, sand, or mud. It avoids very swift current, but is often found in areas with moderate flow. Mudpuppies choose areas with enough cover to meet their sheltering and nesting requirements. Flat rocks, submerged logs, wooden slabs, and other debris are used as retreats. In Ontario and Quebec, the Mudpuppy has been observed "…in shallow waters among bottom leaves and under flat rocks, along creeks, streams and ponds (Gendron 1999).

The Nature Conservancy (TNC 1999) states that the Mudpuppy Mussel is most commonly found in sand or silt under flat stones in areas of swift current, where it may be locally abundant. Such a habitat is consistent with the habitat of its host. Howard (1915) found live specimens of *S. ambigua* under flat, flagstone-like stones in Hickory Creek, Illinois; Call (1900, cited in Baker 1928) said that it may be found in mud and on gravel bars, but is most abundant in the mud under flat stones; Clarke (1985) found one live specimen buried in gravel under a flat limestone rock several metres below a riffle in about 20 cm of water, at a site on Eagle Creek, Kentucky in 1982; Gordon and Layzer (1989) report that records are available from shallow sections of creeks to large rivers with calm to swift mid-depth current velocities, where it may be found in mud to cobble and boulder but primarily under large, flat rocks; and Cummings and Mayer (1992) describe the habitat of this mussel as medium to large rivers on mud or gravel bars and under flat slabs or stones. During surveys in the Meramec River Basin in Missouri, Buchanan (1980) found Mudpuppy Mussels "…under large flat rocks in a gravel, cobble and boulder substrate in 3 inches of water in swift current." This is precisely the habitat where we found 13 live specimens at site SR-5 on the East Sydenham River near Florence in 1999.

As noted earlier (see Population Numbers, Sizes and Trends), Mudpuppy Mussels are often found in great numbers, with up to several hundred individuals packed tightly together under a single flat rock. Balding (1992) aptly said that the species can almost be considered colonial. The reason why Mudpuppy Mussels are found in such large concentrations is related to the close association between the mussel and its host (Parmalee and Bogan 1998). Howard (1951) speculated that the Mudpuppy feeds on adult *S. ambigua* as it moves from one hiding place to another. During the process, it becomes heavily infested with glochidia. When the glochidia have matured, they are most likely released in the salamander's retreat, i.e., under another large, flat stone. The young mussels would be unlikely to be dispersed by currents from these sheltered locations; rather, they would be afforded a secure place in which to grow and perpetuate their life cycle (Oesch 1984).

Habitat trend

According to Neves (1993), the "decline, extirpation and extinction of mussel species is almost totally driven by habitat loss and degradation." Williams *et al*. (1993) identified habitat destruction from dams, dredging, channelization, siltation and pollution, and the introduction of nonindigenous molluscs, as the primary reasons for the decline of mussels across North America. Richter *et al*. (1997) evaluated the impacts of a wide range of anthropogenic stressors and their sources on a variety of freshwater fish, amphibian and invertebrate species at risk, and concluded that suspended sediment and nutrient loadings from agricultural activities, exotic species, and altered hydrology due to impoundments were the dominant problems for mussels. Freshwater mussel communities in the Great Lakes region are exposed to many of these threats.

The introduction of the Zebra Mussel to the Great Lakes in the late 1980s (Hebert *et al*. 1989) led to dramatic declines of native mussels in Lake St. Clair (Nalepa *et al*. 1996), the Detroit River (Schloesser *et al*. 1998), and western Lake Erie (Schloesser and Nalepa 1994). It was originally thought that unionids would be completely extirpated from Great Lakes waters by the Zebra Mussel. However, healthy and diverse communities were recently discovered in Lake Erie in nearshore areas with firm substrates (Schloesser *et al*. 1997) and coastal marshes (Nichols and Amberg 1999), and in similar habitats around the St. Clair River delta in Lake St. Clair (Mackie *et al*. (2000). *Simpsonaias ambigua* was not among the species recorded during any of these investigations, although it is unlikely that its microhabitat was adequately searched.

As previously noted (see Population Numbers, Sizes and Trends), fresh shells of *S. ambigua* were found in the vicinity of Belle Isle in the upper Detroit River in 1934 and 1983, but no evidence of the species was found during recent SCUBA surveys (T.M. Frietag, U.S. Army Corp of Engineers, Detroit, Michigan, pers. comm., November 1999). Schloesser *et al*. (1998) surveyed 17 sites on the Detroit River prior to the Zebra Mussel invasion (1982-83), 13 sites post-invasion (1992), and 9 sites in 1994. The Mudpuppy Mussel was not found during any of these surveys, even though many sites in the vicinity of Belle Isle were sampled on all three occasions. Zebra Mussels were observed to destroy a population of the Northern Riffleshell, *Epioblasma torulosa rangiana*, which had been temporarily relocated from the Black River to the Detroit River to protect it from a dredging operation, in 1992 (Trdan and Hoeh 1993). Although it is possible that *S. ambigua* has been extirpated from the Detroit River by the Zebra Mussel, there are too few data to confirm or refute this. Its host, the Mudpuppy, is still found in the Detroit River; 70 specimens were collected in 1995 using traps specifically designed for capturing Mudpuppies (Gendron 1999).

Southwestern Ontario is the most heavily populated and intensively farmed region of Canada; thus, agricultural, urban and industrial impacts have likely resulted in a loss of habitat for *S. ambigua* throughout this region. The Thames River has lost a significant proportion of its mussel community; 30% of species known from historical records were not found alive during the surveys of 1997-1999 (Metcalfe-Smith *et al*. 1999). This decline in mussel diversity likely reflects a significant loss of mussel habitat throughout the system. Livestock farming is the main form of agriculture in the upper portion of the Thames River, whereas cash crop farming predominates in the lower Thames. By 1989, only 8% of the basin was still forested. The upper Thames, where a single fresh valve of *S. ambigua* was found in 1998, supports a large urban population with 22 sewage treatment plants and two industries discharging their wastes into this part of the system (WQB 1989). Tile drainage systems, wastewater drains, manure storage and spreading, and insufficient soil conservation practices all contribute to the impairment of water and habitat quality in the Thames River. Soil and streambank erosion is severe, causing high suspended sediment loads in the lower reaches. There has been a steady increase in phosphorus and nitrogen inputs to the Thames River, and some of the highest livestock phosphorus loadings for the entire Great Lakes basin are attributable to the Upper Thames watershed (WQB 1989). Despite recent efforts to improve water quality throughout the basin, poor water quality still exists in some areas. For example, mean ammonia concentrations exceed the federal freshwater aquatic life guideline in all sub-basins, and mean copper concentrations exceed the guideline in several sub-basins (WQB 1989).

The Sydenham River supports the most diverse and intact mussel fauna of any river in Canada; 30 of the 34 species historically known from the river were found alive in 1997-1999. This river lacks the urban impacts of the Thames River, which may explain why its mussel communities have remained healthier. Population growth in the basin has been modest: the population of the major municipalities in the Sydenham basin increased by about 40% from about 26,000 in 1967 (Osmond 1969) to 37,000 in 1996 (based on the Statistics Canada census of 1996). There have also been major improvements in sewage treatment. In 1965, only Strathroy, Petrolia and Wallaceburg treated their sewage (DERM 1965), whereas all towns and villages now have some form of sewage treatment (current information provided by the Ontario Ministry of the Environment). Land use in the watershed is predominantly agricultural, i.e., cash crops, pasture and woodlot, and 96% of the land is privately owned (M. Andreae, St. Clair Region Conservation Authority, pers. comm., March 1998). Flooding is a problem in some areas, so there is an extensive land drainage system (DERM 1965). Mackie and Topping (1988) observed diminishing dissolved oxygen concentrations with distance downstream in both branches of the Sydenham River in 1985, and suggested that this was an indication of deteriorating water quality. Arthur H. Clarke surveyed the river for mussels in 1971 (Clarke 1973) and again in 1991 (Clarke 1992), and reported that most of the riffle areas had become covered in silt over that 20-year period. The East Sydenham River supports a greater diversity of mussel species (28) than Bear Creek (19), and most rare species, including *S. ambigua*, are found only in the East Sydenham River (Metcalfe-Smith *et al.*, in preparation). Thus, it will be very important for the preservation of these species to determine if water and/or substrate quality are deteriorating in this branch. An examination of 30 years' of water quality data collected by the Ontario Ministry of the Environment between 1965 and 1996 showed that chloride and conductivity have been increasing steadily over time in the East Sydenham River. These findings could indicate that runoff of contaminants from roads and/or agricultural activities is increasing.

GENERAL BIOLOGY

Reproduction and early development

Freshwater mussels are generally dioecious, and *S. ambigua* is no exception. A few species reproduce primarily as hermaphrodites, and hermaphroditic individuals have been encountered in low frequencies in populations of many predominantly dioecious species (Kat 1983). Hermaphroditism is believed by some to be an adaptation for boosting reproductive success under unfavourable environmental conditions (van der Schalie 1970). Hermaphroditism has not been reported for *S. ambigua*, nor does the species appear to have been examined for this condition.

The life cycle pattern of the Mudpuppy Mussel is perennial and iteroparous. All freshwater mussels have a parasitic stage in their life cycle and all are parasitic on fish except for *S. ambigua*, which uses an aquatic salamander, the Mudpuppy (*Necturus maculosus*), as its host. The life cycle of the Mudpuppy Mussel is illustrated in Fig. 8. During spawning, male mussels release sperm into the water and females living downstream take in the sperm through their incurrent siphons. Ova are fertilized and the developing embryos are held in modified portions of the outer gills, called marsupia, until they reach an intermediate larval stage termed the glochidium. Simpson (1914, cited in Clarke 1985) described the marsupia in a gravid specimen of *S. ambigua* as "…filling the entire outer gills and forming enormously thickened pads…embryos very large…". Once the glochidia have matured, the female discharges them into the water column in one of two ways (Gordon and Layzer 1989): through the anal siphon (method used by most members of the Anodontinae), or by eruption of the distal extremities of the marsupial water tubes (method used by the more advance genera of the Lampsilinae). The glochidia must then attach to the proper host and encyst in the host's tissues in order to complete their metamorphosis to the juvenile stage. After transformation, the juvenile detaches from the host and falls to the substrate where it completes its development into a free-living adult.

There is little known about the reproductive period of *S. ambigua*. It is believed to be a long-term brooder (bradytictic), which means that fertilization occurs in the late summer and glochidia are held over winter for release the following spring or summer (Baker 1928). The only information on the gravid period comes from Barnhart (1998), who recovered a gravid female on 9 April 1998 from a holding cage in the Big River, Missouri, where it had been kept since its transfer from the Meramec River the previous August.

Howard (1915) described the glochidia as being clear white in colour, triangular in shape and with well-developed hooks. Dimensions were given as 0.265-0.274 mm in height and 0.247-0.555 mm in length. Hoggarth (1993) reported that valve height and length in this species are both 260 mm. Many rare species of unionids, including *S. ambigua*, have glochidia that are morphologically depressed (i.e., valve height is equal to or less than valve length). According to Hoggarth (1993), morphologically depressed glochidia are less likely to make initial contact with a host than elongate glochidia due to a smaller valve gape, but are better adapted to holding on tightly once contact has been made. He suggested that species with morphologically depressed glochidia have a lower rate of recruitment, and may therefore be more at risk of extinction once numbers of breeding adults drop below a critical threshold level. Most members of the Anodontinae are fin parasites, and their glochidia have large micro-spined hooks on the edges of their valves that penetrate the host's tissues to ensure a secure attachment (McMahon 1991). Glochidia of the Mudpuppy Mussel also have hooks that likely ensure a firm attachment to the external gills of their host.

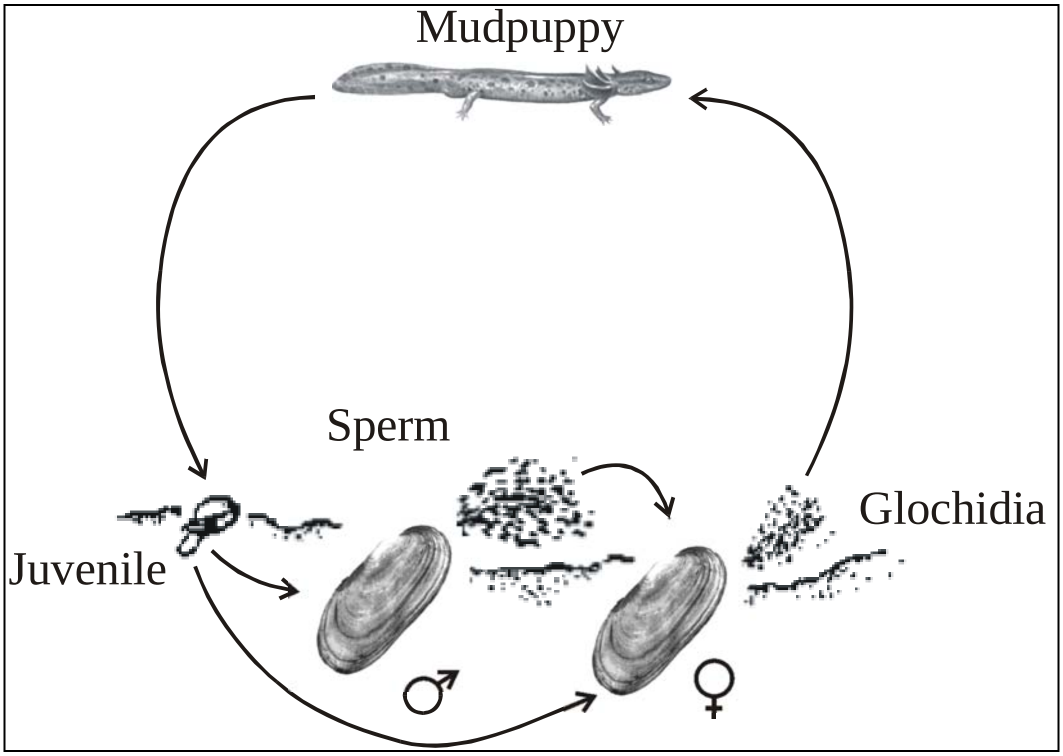

Figure 8. The life cycle of the Mudpuppy Mussel, *Simpsonaias ambigua*. Sperm are taken in by the female and fertilize the eggs in modified portions of the gills. Parasitic larvae (glochidia) attach to the gills of the Mudpuppy *(Necturus maculosus*) and encyst. After about 3 weeks, the glochidia transform into juvenile mussels and detach from the host.

After they have attached to a host, the glochidia of freshwater mussels cause "epithelial proliferation" of host tissue and become completely encysted within two to 36 hours (Lefevre and Curtis 1910). Glochidia are not host-specific in attachment, and when encystment occurs on an unsuitable host, they will be sloughed off within 4-7 days (Kat 1984). Once encystment on a suitable host occurs, it may take from 6 days to over 6 months to complete the transformation from glochidium to juvenile mussel (Kat 1984). During this period, the glochidium is parasitic in that it absorbs organic molecules from the host's tissues and requires plasma for development (Ellis and Ellis 1926, Isom and Hudson 1982). Once metamorphosis is complete, the juvenile mussel ruptures the cyst by extending its foot (Lefevre and Curtis 1910). According to Watters (1994), the odds that a glochidium will reach this stage in its life cycle is 4 in 100,000.

The Mudpuppy, *N. maculosus*, is the only known host for the Mudpuppy Mussel. This mussel did not transform on any of 12 species of fish representing four families (Ictaluridae, Centrarchidae, Percidae, Cottidae) that were tested in laboratory exposures (Barnhart 1998). Howard (1915) collected Mudpuppies on 17 October 1912 that were heavily infested with glochidia he described as "…deeply embedded in the external gills of the waterdog; that is, the tissue of the gill had grown completely over them." The Mudpuppies were held in the laboratory over winter and glochidia were shed the last week of May of the following year, yielding healthy juveniles; thus, Howard (1915) estimated the parasitic period to be over 7 months. Clarke (1985) questioned these findings, suggesting that laboratory conditions may have prolonged the infestation period. In recent work, Barnhart (1998) infested Mudpuppies with glochidia from a gravid female Mudpuppy Mussel on 26 June, and reported that the time from encystment to excystment was 19-28 d (peak at 23 d) at 20°C. Percent transformation was approximately 13%, which Barnhart (1998) described as rather low. These results suggest that *S. ambigua* is indeed bradytictic.

Development from juvenile to adult

A newly metamorphosed juvenile mussel has only rudimentary gills that do not fully develop until the second month of life (Howard 1922). Once it has detached from its host, and if it has been deposited into suitable habitat, the juvenile begins to feed and grow immediately. Juveniles are very active, and may be capable of migrating short distances to find suitable substrate (Howard 1922). At three weeks of age, a gland on the posterior median edge of the foot secretes a sticky thread called a byssus (Fuller 1974). The byssus, which persists until the end of the second growing season, allows purchase on solid objects and prevents the juvenile from being swept away by water currents (Howard 1922). We have observed buried juveniles of the Rayed Bean (*Villosa fabalis*) and Fragile Papershell (*Leptodea fragilis*) in the field with byssal threads attached to one or more small (<0.5 mm diameter) pebbles. Byssal threads have not been described for *S. ambigua*, and may not be needed in their protected habitat.

Growth is most rapid during the first few years of life. Growth rates decline significantly upon maturation, reflecting the allocation of energy to reproduction. Age at sexual maturity is variable among species. Members of the Ambleminae are generally slow growing and long-lived, and tend to mature later in life (generally at 6-8 years of age), while the Anodontinae are fast growing, short-lived, and usually mature within 2 to 5 years (Kat 1984). The Lampsilinae are intermediate in growth rate, longevity and age at maturity. Lifespan and age at sexual maturity are not known for *S. ambigua*. Simpson (1914, cited in Clarke 1985) stated that males are much less common than females. However, Howard (1915) reported that 60% of the 22 specimens he collected from Hickory Creek, Illinois, were males.

Food and feeding

Freshwater mussels feed by passing water (which is propelled by beating cilia on the gills) between the gill filaments to filter out suspended particles (Burky 1983). The filtered particles are passed to two pairs of labial palps that sort food from non-food items (McMahon 1991). Filtered particles that are not consumed are bound in mucus, passed off the edges of the palps, and carried posteriorly by cilia along the edges of the mantle. This "pseudofeces" is then ejected by forceful contractions of the valves (McMahon 1991). Food items are passed to the mouth, which is a simple opening between the two pairs of palps, where they are ingested. Freshwater mussels have been reported to consume all sorts of materials, including algae, plankton, rotifers, diatoms, protozoans, detritus, and sand (Coker *et al*. 1921, Churchill and Lewis 1924). They have been successfully raised on algae and yeast cultures in the laboratory (USFWS 1994). Recently, Nichols and Garling (1999) used a combination of techniques, including identification of gut contents, carbon and nitrogen stable isotope ratios, and tissue biochemical analyses to determine the dietary habits of various species of unionids in a Michigan stream. Results showed that all species were utilizing algae and bacteria as food sources. The specific food habits of *S. ambigua* are unknown.

LIMITING FACTORS

According to the National Native Mussel Conservation Committee (NNMCC 1998), approximately 67% of the nearly 300 species of freshwater mussels in North America are either extinct or vulnerable to extinction. The decline of mussel populations during the 20th century may be largely attributed to impoundments, siltation, channel modification, pollution and, more recently, the introduction of the nonindigenous Zebra Mussel into North American waterways (Williams *et al*. 1993). Metcalfe-Smith *et al*. (1998a) showed that mussels are also declining in the lower Great Lakes drainage basin of central Canada, where three-quarters of Canada's freshwater mussel species were historically found. According to Metcalfe-Smith *et al*. (1998b), as many as 15 of the 40 species native to this region may be at risk. *Simpsonaias ambigua* was among the species identified as being most at risk, mainly because of its very localized distribution.

Simpsonaias ambigua is a very poorly known species of freshwater mussel, and the factors limiting its occurrence in North America are completely unknown. However, it may be surmised that many of the threats jeopardizing the continuing existence of this species are the same as those impacting other mussels.

Zebra mussels

The introduction and spread of the Zebra Mussel throughout the Great Lakes in the late 1980s has decimated native mussel populations in the Lower Great Lakes region of Ontario (Schloesser *et al*. 1996). Zebra Mussels attach to a unionid's shell, interfering with activities such as feeding, respiration, excretion and locomotion — effectively starving it to death (Haag *et al*. 1993, Baker and Hornbach 1997). Ricciardi *et al*. (1998) estimated that the invasion of the Mississippi River basin by Zebra Mussels has increased freshwater mussel extinction rates in that system by 10-fold, from about 1.2% of species per decade to 12% per decade.

Mussel species differ in their sensitivities to Zebra Mussels. Long-term brooders are generally more sensitive than short-term brooders, possibly because they tend to have greater energy requirements for growth and reproduction than short-term brooders and may therefore be more vulnerable to further depletion of their energy reserves by Zebra Mussels (Strayer 1999). According to Mackie *et al*. (2000), species that are more obese in shape, sexually dioecious, and have more glochidial hosts remained relatively stable after Zebra Mussels invaded Lake St. Clair, while species that became more rare were smaller and had specific substrate requirements and fewer known fish hosts.

Simpsonaias ambigua has several traits that suggest it may be very sensitive to Zebra Mussels, i.e., it is small, a long-term brooder, and has only one host. However, it may escape serious infestation due to its preferred habitat (burrowed in the mud under flat rocks). The importance of Zebra Mussels as a limiting factor for this and other unionids in Great Lakes waters will depend on the extent and quality of the nearshore refuge areas that have recently been discovered. The Zebra Mussel does not threaten existing populations of *S. ambigua* in the Sydenham River, because the river is not navigable by boats and has no significant impoundments that could support a permanent colony. According to R. Cicerello (Kentucky Nature Preserves Commission, pers. comm., November 1999), the mainstem Kentucky River population of this species is threatened by Zebra Mussels that recently colonized the area.

Siltation

There is a general perception that high loadings of sediment due to poor land-use practices is one of the major causes of unionid declines across the continent (Richter *et al*. 1997; Brim-Box and Mossa 1999). Fine sediments adversely affect mussels in many ways, e.g., they can clog the gills, thereby reducing respiration rates, feeding efficiency, and growth; they can affect the food source by reducing the amount of light available for photosynthesis; and they can affect mussels indirectly by impacting on their host fishes (see Brim-Box and Mossa 1999 for a review). Heavy deposits of silt, such as in riverine impoundments, can bury and smother mussels. Dennis (1984) found that mussels transplanted to heavily silted areas in the Tennessee River system exhibited poor survival and reduced fertilization success after a one-year exposure. Recent investigations have shown that the relationships between sediment and mussels may be weaker than originally thought, and that increased sedimentation may not be detrimental to all species under all circumstances (Strayer and Fetterman 1999; Brim-Box and Mossa 1999). Strayer and Fetterman (1999) suggest that fine sediments may be more harmful to mussels in streams with low gradients than high gradients, as the sediments will settle rather than being flushed out.

It is possible that *S. ambigua* could be smothered if large amounts of silt were to settle around the flat rocks, logs or other debris under which it is usually found. It is more likely to be indirectly impacted by the effects of siltation on its host, the Mudpuppy. There is some evidence that siltation has extirpated the Mudpuppy from certain areas, mainly by reducing its access to nesting sites and hiding places (Gendron 1999). Siltation has undoubtedly increased in most southwestern Ontario rivers as a result of increased agricultural activity (see Habitat Trend).

Pollution

During the early part of the 20th century, chemical pollution from acid mine drainage, agricultural runoff, and untreated domestic and industrial effluents, was responsible for the mass destruction of mussel communities in North American rivers (Baker 1928, Havlik and Marking 1987, Bogan 1993). Mussel populations living immediately downstream of major American cities were extirpated as a result of degraded water quality (Miller and Payne 1998). According to Neves *et al*. (1997), eutrophication was the primary water problem in the 1980s. Sewage treatment has greatly improved over the years, such that the major threats to mussels today are believed to be high loads of sediment (see above), nutrients, and toxic chemicals from non-point sources, especially agriculture (Strayer and Fetterman 1999). Neves *et al*. (1997) reported that levels of nitrates, chloride and metals in North American rivers have increased due to the increased use of fertilizers and road salt. Havlik and Marking (1987) showed that heavy metals, pesticides, ammonia, crude oil, and many other environmental contaminants are toxic to mussels, especially during their early life stage. However, the specific effects of these substances and the levels at which they are detrimental are still not well understood (NNMCC 1998).

According to The Nature Conservancy (TNC 2000b), "Pollution through point and non-point sources is perhaps the greatest on-going threat to…most freshwater mussels." As the range of *S. ambigua* in Ontario is in an area of intensive agricultural activity, exposure to agricultural chemicals may be an important factor limiting its occurrence in Canada.

Dams/Impoundments

Dams and impoundments are a serious threat to most species of freshwater mussels. Dams separate mussels from their fish hosts, alter substrate composition, temperature regimes, water chemistry, and dissolved oxygen concentrations in downstream areas, and cause an accumulation of silt, which smothers mussels, in the impoundments (Bogan 1993). Changes in normal water temperature cycles can suppress reproduction or induce it at the wrong time, cause the abortion of glochidia, and delay mussel maturation and/or development (Fuller 1974; Layzer *et al*. 1993). Although dams may be a limiting factor for *S. ambigua* in other portions of its range, they do not threaten Canadian populations. The Sydenham River has only a few small dams in the headwaters, and these are well upstream of the historical range of the species.

Access to hosts

Due to the parasitic stage in their life cycle, unionids are sensitive not only to environmental factors that limit them directly, but also to factors that affect their hosts (Burky 1983; Bogan 1993). Any factor that changes the distribution or abundance of the host may have detrimental effects on dependent mussel populations. For example, the extirpation of the Dwarf Wedgemussel, *Alasmidonta heterodon*, from Canada was attributed to the disappearance of its host fishes, the Atlantic Salmon (*Salmo salar*) and American Shad (*Alosa sapidissima*), from the Petitcodiac River in New Brunswick after construction of a causeway in the late 1960s (Hrabluk (1999).

As previously noted, the only known host for the Mudpuppy Mussel is the Mudpuppy, *N. maculosus*. A report on the status of the Mudpuppy in Canada was recently prepared for COSEWIC, and the author has recommended the status of "Not At Risk" for this salamander in Canada (Gendron 1999). The Mudpuppy is said to be well established across its Canadian range in southern Quebec, Ontario and Manitoba, particularly along the St. Lawrence and Ottawa river systems and Great Lakes and their major tributaries. Populations appear secure under present conditions. Significant limiting factors for the Mudpuppy include habitat loss as a result of severe siltation and environmental contamination, particularly the use of the lampricide TFM. Indications of extirpations from formerly occupied habitats are relatively few, although Gendron (1999) did report the loss of the species from the highly impacted Hamilton Harbour and low capture rates at several localities in Lakes Ontario, Erie and St. Clair in 1995.

The distribution of the Mudpuppy in southwestern Ontario is shown in Fig. 9, based on records obtained from the Ontario Herpetofaunal Summary Database (courtesy of M.J. Oldham, NHIC, November 1999). There are only five records for the Mudpuppy in the Sydenham River, including two from the Bear Creek drainage in 1980, two near Wallaceburg at the mouth of the river in 1940 and 1988, and one from the East Sydenham River near Alvinston in 1984. The latter site was close to our site SR-3 where we found one fresh shell of *S. ambigua* in 1997 (Table 1). There have been no systematic surveys for the Mudpuppy in the Sydenham River, so we cannot determine if it is rare or common in this system. The Sydenham River has never been treated with TFM (Wayne Westman, Sea Lamprey Control Centre, Sault Ste. Marie, Ontario, pers. comm., January 1999).

Predation

Freshwater mussels are known to serve as food sources for a variety of mammals and fish (Fuller 1974). In particular, foraging by Muskrats (*Ondatra zibethicus*) has been shown to significantly alter the population structure of mussels in lakes and rivers (Convey *et al*. 1989, Hanson *et al*. 1989, Jokela and Mutikainen 1995). Neves and Odom (1989) suggested that Muskrat predation may be causing further declines in populations of endangered mussel species in the North Fork Holston River, VA. It is unlikely that Muskrats pose a threat to *S. ambigua* as they tend to select medium-sized mussels, i.e., those with shell lengths greater than 45 mm (Convey *et al*. 1989, Hanson *et al*. 1989). Also, Mudpuppy Mussels living beneath large rocks would be hidden from view and possibly inaccessible.

As mentioned earlier (see Habitat), Howard (1951) suspected that Mudpuppies prey on Mudpuppy Mussels. According to Gendron (1999), the Mudpuppy is an opportunistic predator that feeds on a variety of benthic organisms including crustaceans, aquatic insects, small fish, frogs, salamanders, oligochaetes, molluscs, etc. Molluscs appear to be a minor food item, normally found in less than 20% of individuals and accounting for less than 5% by weight. However, the Mudpuppy is highly opportunistic, often feeding exclusively on a single prey item that is available in abundance. It is quite possible that Mudpuppies feed on Mudpuppy Mussels when they are present, thus serving as both dispersal mechanism and limiting factor — in a presumably delicate balance.

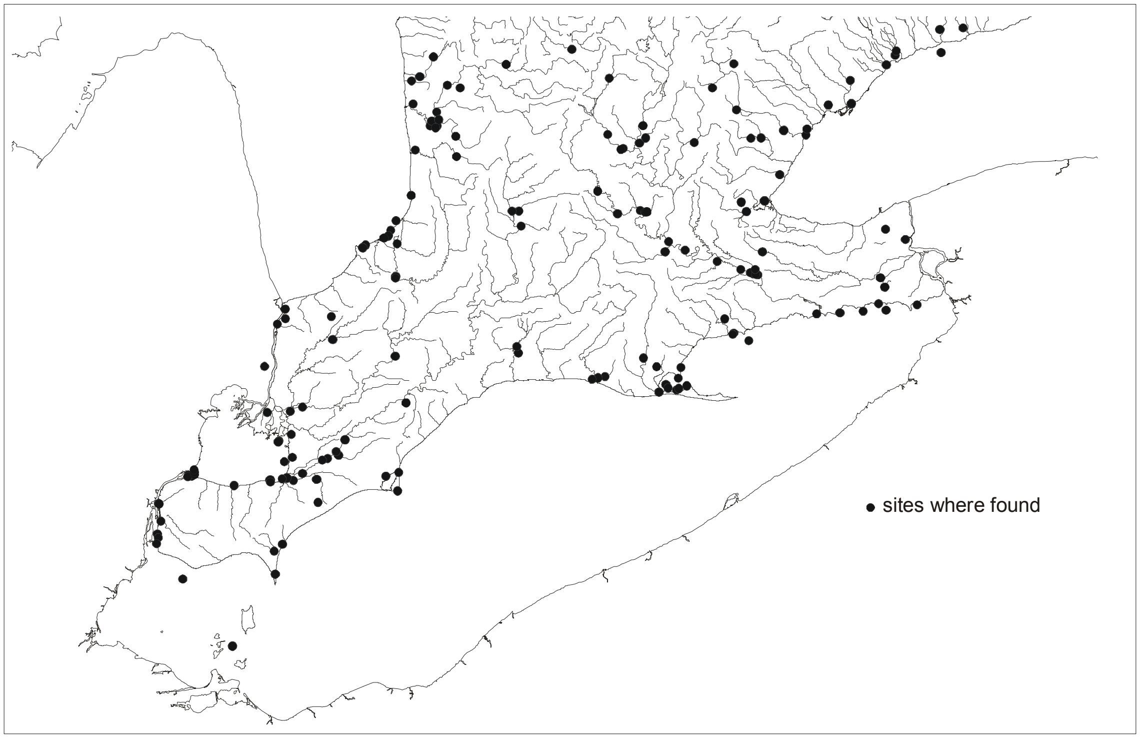

Figure 9.   Distribution of the Mudpuppy in southwestern Ontario, based on records from 1858-1997.

SPECIAL SIGNIFICANCE OF THE SPECIES

Simpsonaias ambigua is phylogenetically unique in that it is the only living member of the genus *Simpsonaias*. It is also is ecologically unique, since it is the only species of freshwater mussel that uses an amphibian host. Although populations are difficult to locate because of the small size and unusual habitat of the animal, it is generally believed that the species is in decline throughout its North American range. The Sydenham River in Ontario supports the only remaining population of this mussel in Canada.

RECOMMENDED MANAGEMENT OPTIONS

The conservation of native freshwater mussels has been an ongoing effort in the United States since the Clean Water Act and Endangered Species Act were passed in 1972 and 1973, respectively. According to Bogan (1998), these efforts have so far had only a localized or limited effect. As of 1998, 12% of the 300 mussel species in North America were presumed extinct, 43% were listed or proposed for listing as endangered or threatened, and an additional 25% were in decline. Thus, less than 25% of mussel taxa are maintaining stable populations. Extinction rates for mussels over the past century were about 1.4% per decade (35 species lost since 1900); however, Ricciardi *et al*. (1998) have shown that the Zebra Mussel invasion has increased this rate of loss by 10-fold.

In 1998, the National Native Mussel Conservation Committee (an ad hoc committee with representatives from US state, tribal, and federal agencies, the mussel industry, conservation groups, and academia) released its "National Strategy for the Conservation of Native Freshwater Mussels" (NNMCC 1998). The National Strategy identifies research, management, and conservation actions necessary to maintain and recover mussel populations, and many of the recommendations can be applied in Canada.

There are two accepted ways to manage declining mussel populations, i.e., to maintain and protect the existing populations, and to expand the current range to historical proportions (TNC 1986). The latter may be accomplished by stocking with laboratory-reared specimens; augmenting marginal populations with specimens from large, stable populations; and translocating mussels from healthy populations into areas from which they were extirpated. Captive breeding programs are in their infancy, and the success of reintroductions has not yet been confirmed (Neves 1997). Before translocations can be considered, it must be determined that the source populations can withstand the reduction in their numbers, and that the animals being moved will survive the stress and thrive in their new environment. Translocation is not an option for *S. ambigua* in Ontario at the present time, since populations in the Sydenham River appear to be too small to serve as a source of specimens, and there would be no point in translocating healthy animals into the Zebra Mussel-infested waters of the Detroit River.

A priority course of action at present would be to protect existing populations of the Mudpuppy Mussel in the Sydenham River from further habitat deterioration. The 50-km reach of the East Sydenham River between Alvinston and Dawn Mills supports a great diversity of mussels, including this and several other rare and endangered species. We need to know why these species are persisting in this reach, and whether populations are declining or stable. According to the NNMCC (1998), further degradation of mussel habitat can be halted and reversed by: (1) enforcing existing government regulations that protect mussels and their habitat; (2) encouraging government agencies to create programs, or modify existing ones, to protect and recover mussel habitat; (3) encouraging local industries and landowners to modify their activities such that mussel habitat can be protected and recovered; and (4) encouraging conservation organizations and agencies to acquire key habitats. Education of the general public, land owners and government agencies about the need for protecting and enhancing natural stream ecosystems for the benefit of mussels and other freshwater organisms is crucial to the success of any rehabilitation program (Bogan 1998, NNMCC 1998).

In order to effectively manage *S. ambigua*, much more must be known about its biology and environmental requirements (NNMCC 1998). Life history studies must be conducted to determine its age and size at sexual maturity, recruitment success, age class structure, and viable population size. Specific effects of various perturbations (e.g., siltation, agricultural chemicals, domestic and industrial effluents, fluctuations in temperature, DO, pH and flow) and the levels at which they are limiting must be determined. The locations and densities of all existing populations must be known, and these populations must be monitored for evidence of change. Since Mudpuppies are widely distributed throughout southwestern Ontario, it is possible that additional populations of Mudpuppy Mussels exist in areas that have not yet been surveyed using appropriate methods. In particular, nearshore areas in Lake Erie and Lake St. Clair that have been shown to be refuges from the Zebra Mussel for other native mussel species, should be surveyed for the presence of *S. ambigua*. The Mudpuppy, is known to occupy such areas (Gendron 1999; Fig. 9). Under the Great Lakes Wetlands Conservation Action Plan, over 4000 hectares of wetlands have been secured, and the rehabilitation of more than 14,000 hectares is underway (Environment Canada 2000b). These wetlands may represent a significant portion of the available habitat for native mussels in Ontario waters. As such, they should be managed with the needs of mussels, in addition to those of other wetland species, in mind.

According to The Nature Conservancy (TNC 1986), the broad distribution of *S. ambigua* in "…streams, smaller rivers, and lakes suggests that its potential for recovery may be greater than that of many other rare naiads." Its host is known, which is not true of all or even most rare species of unionids, and could be monitored at the same time. The recovery plan for the Clubshell (*Pleurobema clava*) and Northern Riffleshell (*E. t. rangiana*) in the United States recommends the development of comprehensive watershed plans for the "…maintenance of the ecosystems on which these mussels and their hosts depend" (USFWS 1994). The U.S. Fish and Wildlife Service is now recommending a basin-wide approach to the conservation of mussels, rather than species-specific recovery plans (Bogan 1998). In keeping with these recommendations, an aquatic ecosystem recovery plan is currently being developed for the Sydenham River.

EVALUATION

Simpsonaias ambigua is the only living member of the genus *Simpsonaias*. It was historically known from 14 states and the province of Ontario. Although it is often overlooked during traditional mussel surveys because of its small size and secretive habitat, there is a general consensus that the species has declined throughout its North American range. In the United States, it is no longer found in 60% of formerly occupied rivers and streams. The species has probably been extirpated from Iowa, New York, Tennessee, and possibly Michigan. Although it is not federally listed in the United States at the present time, is listed as endangered, threatened or of special concern in 8 states. The Nature Conservancy has assigned it a Global Rank of G3 (rare and uncommon globally), and it has an SRANK of S1 (very rare) in 6 states and Ontario.

In Canada, there are only 3 known historical records for *S. ambigua*, and these are from the Detroit and Sydenham rivers. The species is believed to have been lost from the Detroit River, along with most other unionids, due to the impact of the Zebra Mussel. Its host, the Mudpuppy, is still present in the system. Intensive surveys were conducted at 66 sites on tributaries to Lake Erie, Lake St. Clair and lower Lake Huron in 1997-1998 to determine the occurrence of this and other rare species of mussels. Several sites were revisited for additional searches in 1998 and 1999. Both historical sites on the Sydenham River were surveyed. One weathered valve was found at a site on the north branch of the Sydenham River (Bear Creek), and a fresh valve was found at a site on the upper Thames River. A total of 17 live specimens were found at 3 sites on the East Sydenham River and 72 shells, many of them fresh, were found at these and 4 other sites in a 50-km reach of the river between Alvinston and Dawn Mills. The average width of this reach is 25 m (Metcalfe-Smith *et al*. 1998c, unpublished data). If the presence of fresh shells is taken to indicate the presence of living animals, the extent of occurrence for this species in Canada is 50 km $\times$ 25 m = 1.25 km^2. Fifteen of the 17 live specimens were found during searches that specifically targeted *S. ambigua*, i.e., large, flat rocks were overturned and the substrate beneath them was carefully searched. Based on these findings, the Mudpuppy Mussel was recently downlisted from SH (no verified occurrences in the past 20 years) to S1 in Ontario by the NHIC.

The Mudpuppy Mussel is generally believed to be a rare species, although many malacologists would agree with G.T. Watters (Ohio State University, pers. comm., December 1999) that "…its rarity may be a function of us not looking in the right places." It has been described as almost colonial, since hundreds of specimens may be found under a single rock with no other populations apparent for some distance. *Simpsonaias ambigua* was found at more sites on the Sydenham River during recent surveys than in the past, suggesting that its range has not contracted over time. As several year classes were represented among the live specimens and fresh shells collected in 1997-99, it appears that the population is reproducing. The collection of quantitative data to determine the size of the Mudpuppy Mussel population in the East Sydenham River should be a priority.

The Mudpuppy Mussel is a very poorly known species of freshwater mussel, and the factors limiting its occurrence are also unknown. Its host is widely distributed throughout its Canadian range, occupies a variety of freshwater habitats, and is currently stable. However, populations in the Sydenham River have not been assessed. Mudpuppies are known to be intolerant of heavy siltation, probably because it reduces access to nesting sites and hiding places. They are also absent from areas with insufficient cover such as flat rocks, logs and other debris. Studies to evaluate the extent and quality of habitat for the Mudpuppy in the Sydenham River are needed to determine if access to hosts is a limiting factor for the Mudpuppy Mussel. Since the Mudpuppy Mussel is found only in the extreme southern portion of the Mudpuppy's range in Canada, temperature may be a factor limiting its distribution. It is not known if Mudpuppy Mussels serve as a food source for any predators, although it has been suggested that the Mudpuppy itself may be a predator. Because the distribution of the Mudpuppy Mussel in Canada is restricted to a short reach in one river, the Sydenham, a single adverse ecological event in this river could result in the extirpation of the species from this country.

There is no natural immigration of individuals from the United States at the present time, although global warming could result in this and other mussel species extending their ranges further north. Artificial translocations from healthy populations are theoretically possible provided the populations are genetically similar.

Based on the above considerations, the authors recommend a status designation of **Endangered** for the Mudpuppy Mussel in Canada.

TECHNICAL SUMMARY

Mudpuppy Mussel
Simpsonaias ambigua

Distribution
Extent of occurrence: 5 km^2
Area of occupancy: 1.25 km^2

Population Information
Total number of individuals in the Canadian population: Unknown
Number of mature individuals in the Canadian population (effective population size): unknown
Generation time: years
Population trend (check off as appropriate): _x_ declining
Rate of population decline (if appropriate): ? % in 10 years or three generations (whichever is longer).
Number of subpopulations: 3
Is the population fragmented? YES
number of individuals in each subpopulation (give range): 1-3
number of extant sites: 3
number of historic sites from which species has been extirpated: 6-9
Does the species undergo fluctuations? ?

Threats
- Species lives under large rocks but high silt loading from agricultural practices covers/surrounds many rocks
- Dams and impoundments separate species from its host (mudpuppy)
- Pollution from point and non-point sources
- Zebra Mussels, although not contributing to loss of populations to date, are a potential threat, especially if impoundments are built upstream
- Access to hosts; Mudpuppy Mussel is host-specific, using only the Mudpuppy as host. Any threats to Mudpuppy are also threats to mussels.

Rescue Potential
Does species exist outside Canada? YES
Is immigration known or possible? NO, not possible
Would individuals from the nearest foreign population be adapted to survive in Canada? Not applicable
Would sufficient suitable habitat be available for immigrants? Not applicable

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Joanne Di Maio received a B.Sc. (Honours Biology) from the University of Toronto in 1993 and an M.Sc. (Biological Science) from the University of Windsor in 1995. The focus of her master's research was the influence of hydrological variability on the distribution of freshwater mussels in rivers. Part of her thesis research was published in the Canadian Journal of Zoology and the Journal of Molluscan Studies. Joanne studied the macroinvertebrate communities from headwater streams of the Oak Ridges Moraine for the Ontario Ministry of the Environment, and aquatic oligochaetes from Ontario rivers and lakes for the Royal Ontario Museum. Results of these studies were published in the Canadian Field-Naturalist. She is a member of the North American Benthological Society. At the time of writing, Joanne was a research technologist with the National Water Research Institute of Environment Canada.

Appendix 1. Distribution of *Simpsonaias ambigua* in the United States.

State	River/Stream	Occurrence[a]	Reference
Arkansas	Black River	na	C. Osborne (pers. comm.) [b]
	Little Red River	na	"
	Spring River	na	"
	White River	na	Clarke 1985
Illinois	Des Plaines River	H	K.S. Cummings (pers. comm.)
	Embarras River	P	"
	Illinois River	H	"
	Kankakee River	H	"
	Mississippi River	H	"
	Ohio River River	H	"
	Sangamon River	H	"
	Vermillion River	P	"
	Wabash River	H	"
Indiana	Big Creek	P	R. Hellmich (pers. comm.)
	Big Walnut Creek	H	"
	Deer Creek	na	Clarke 1985
	East Fork White River	H	R. Hellmich (pers. comm.)
	Fish Creek	P	"
	Flatrock River	H	"
	Graham Creek	H	"
	Muscatatuck River	P	"
	Otter Creek	P	"
	South Fork Blue River	H	"
	St. Joseph River	H	"
	Sugar Creek	P	"
	Tippecanoe River	P	"
	Wabash River	H	"
	Walnut Creek	na	Clarke 1985
Iowa	West Fork White River	na	"
	Cedar River	na	Clarke 1985
	Des Moines River	na	"
	Iowa River	na	"
	Lizard Creek	na	"
	Mississippi River	na	"
Kentucky	Eagle Creek	na	Clarke 1985
	Green Creek	na	"
	Kentucky River	P	R. Cicerello (pers. comm.)
	Kinniconick Creek	P	"
	Licking River	P	"
	Little Sandy River	H	"
	Ohio River	H	"
	Salt River	P	"
	Slate Creek	na	Clarke 1985
	Troublesome River	na	"
	Tygart's Creek	H	R. Cicerello (pers. comm.)
	Upper Green River	P	"
Michigan	Black River	na	R.R. Goforth (pers. comm.)

State	River/Stream	Occurrence[a]	Reference
	Detroit River	H	T.M. Freitag (pers. comm.)
	Lake Erie	H	R.R. Goforth (pers. comm.)
	Macon Creek	H	"
	Pine River	na	"
	River Rouge	na	Clarke 1985
	Saginaw River	na	R.R. Goforth (pers. comm.)
Minnesota	Tiffin River	H	"
	Minnesota River	H	M. Davis (pers. comm.)
	Mississippi	H	"
	St. Croix River	P	"
Missouri	Bourbeuse River	na	Buchanan 1980
New York	Buffalo Creek	H	Strayer and Jirka 1997
	Cayuga Creek	H	"
	Lake Erie	H	"
Ohio	Alum Creek	H	Clarke 1985
	Big Darby Creek	P	D. Rice (pers. comm.)
	Big Darby Creek	H	Clarke 1985
	Big Walnut Creek	H	"
	Eagle Creek	P	D. Rice (pers. comm.)
	East Fork Little Miami	na	Clarke 1985
	Grand River	H	"
	Lake Erie	H	"
	Little Muskingum River	P	D. Rice (pers. comm.)
	Little Scioto River	H	Clarke 1985
	Maumee River	H	"
	Mohican River	H	"
	Muskingum River	H	"
	North Little Miami River	H	"
	Ohio Bush Creek	H	"
	Olentangy River	H	"
	Salt Creek	H	"
	Scioto River	H	"
	St. Joseph River	H	"
	Tuscarawas River	H	"
	Walhonding River	H	"
	Whiteoak Creek	H	"
Pennsylvania	Allegheny River	na	Clarke 1985
Tennesssee	East Fork Stone's River	H	Parmalee and Bogan 1998
	Stone's River	na	Clarke 1985
West Virginia State	Dunkard Creek	P	J. Clayton (pers. comm.)
	Hurricane Creek	P	"
	Kanawha River	H	"
	Little Kanawha River	P	"
	Middle Island Creek	P	"
	North Fork Hughes River	H	"
	Pocatalico River	H	"
West Virgina	South Fork Hughes River	P	"
	Spring Creek	P	"

State	River/Stream	Occurrence[a]	Reference
	River/Stream		
	Twelvepole Creek	P	J. Clayton (pers. comm.)
	West Fork River	H	"
Wisconsin	Chippewa River	P	Balding 1992
	East Fork Black River	H	J.M. Burnham (pers. comm.)
	Eau Claire River	P	"
	Embarrass River	P	"
	Flambeau River	P	"
	Jump River	H	"
	Kilbourn River	na	Baker 1928
	Lemonweir River	P	J.M. Burnham (pers. comm.)
	Mississippi	na	Clarke 1985
	Namekagon River	H	J.M. Burnham (pers. comm.)
	Oconomowoc Lake	H	"
	South Fork Flambeau River	P	"
	St. Croix River	P	"
	Willow River	H	"
	Wisconsin River	P	"
	Wolf River	P	"

[a]H = believed to be of historical occurrence only, based on a lack of recent records; P = believed to be present, based on recent collections; na = no information available.
[b]See Acknowledgements for affiliations.

Appendix 2. Historical distribution (1934-1967) of *Simpsonaias ambigua* in Canada, based on occurrence records from the Lower Great Lakes Unionid Database. F shells = fresh shells (see text for definition).

Date[a]	Waterbody	Nearest urban centre	Locality description	Latitude	Longitude	Collector(s)	Data source[b]	Database reference number	Museum catalogue number	Live	F shells (whole)	F shells (half)
19340000?	Detroit River		Bois Blanc Island	42.097	-83.125	Walker, Bryant	UMMZ; Clarke (1985)	SMIT1			1	
19650815	Sydenham River	Florence	S edge of town, at Co. Rt. 1 bridge	42.650	-82.010	Stein, C.B., Joanne E. Stillwell	OSUM	1965:0105	19199		1	1
19670813	Sydenham River	Shetland	2.9 km NE of Shetland	42.717	-81.951	Athearn, H.D. & M.A. Athearn	ATH-92	ATH1		1		

[a] Where actual month or day unknown, “00” is used.
[b] OSUM = Ohio State University Museum of Biological Diversity; ATH = H.D. Athearn, Museum of Fluviatile Mollusks, Cleveland, Tennessee (Emeritus, Tennessee Academy of Science), personal records; UMMZ = University of Michigan Museum of Zoology.