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# Information in support of a Recovery Potential Assessment of Silver Shiner (*Notropis photogenis*) in Canada

# Information donnée à l'appui d'une évaluation du potentiel de rétablissement du méné-miroir (*Notropis photogenis*) au Canada

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## ABSTRACT

In April 1983, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessed the status of Silver Shiner (*Notropis photogenis*) and determined the designation to be Special Concern. In April 1987, the status was re-examined and confirmed by COSEWIC. This status was re-assessed in May 2011 at which time Silver Shiner was designated as Threatened. The reason given for this designation is that, “This small riverine fish is found at fewer than 10 locations and has a small area of occupancy. The susceptibility of the species to continuing habitat loss and degradation with increasing development pressure resulted in an increase in status.” Silver Shiner is currently listed as Special Concern on Schedule 3 of the *Species at Risk Act* (SARA).

The Recovery Potential Assessment (RPA) provides information and scientific advice needed to fulfill various requirements of SARA, including informing both scientific and socio-economic elements of the listing decision and permitting activities that would otherwise violate SARA prohibitions and the development of recovery strategies. This Research Document describes the current state of knowledge of the biology, ecology, distribution, population trends, habitat requirements, and threats to Silver Shiner. Mitigation measures and alternative activities related to the identified threats, which can be used to protect the species, are also presented. The information contained in the RPA and this document may be used to inform the development of recovery documents and for assessing permits, agreements and related conditions, as per section 73, 74, 75, 77 and 78 of SARA. The scientific information also serves as advice to the Minister of Fisheries and Oceans Canada regarding the listing of the species under SARA and is used when analyzing the socio-economic impacts of adding the species to the list as well as during subsequent consultations, where applicable. This assessment considers the available scientific data with which to assess the recovery potential of Silver Shiner in Canada.

## RÉSUMÉ

En avril 1983, le Comité sur la situation des espèces en péril au Canada (COSEPAC) a évalué la situation du méné miroir (*Notropis photogenis*) et lui a accordé le statut d'espèce préoccupante. En avril 1987, ce statut a été réexaminé et confirmé par le COSEPAC. Son statut a été réexaminé une fois de plus en mai 2011; le méné-miroir a été alors désigné comme menacé. Ce nouveau statut s'expliquerait par le fait que « Ce petit poisson de rivière se trouve dans moins de dix localités et a une petite zone d'occupation. La vulnérabilité de l'espèce à la perte et à la dégradation continues de l'habitat et à des pressions croissantes associées au développement a mené a un statut de risque plus élevé. ». Cette espèce est actuellement inscrite sur la liste d'espèces préoccupantes à l'annexe 3 de la *Loi sur les espèces en péril* (LEP).

L'évaluation du potentiel de rétablissement (EPR) fournit les renseignements et les avis scientifiques nécessaires pour satisfaire à diverses exigences de la LEP; notamment, cette évaluation permet d'éclairer les aspects scientifiques et socioéconomiques de la décision relative à l'inscription à la liste, de réaliser des activités qui autrement enfreindraient les interdictions de la LEP et d'élaborer des stratégies de rétablissement. Le présent document de recherche fournit une description de l'état actuel des connaissances de la biologie, de l'écologie, de larépartition , des tendances démographiques, des besoins en matière d'habitat et des menaces relatives au méné-miroir. On y trouve aussi des mesures d'atténuation et d'autres activités associées aux menaces déterminées qui peuvent être utilisées dans le but de protéger l'espèce. Les renseignements que renferment l'EPR et ce document peuvent servir de base à l'élaboration de documents relatifs au rétablissement et à l'évaluation des permis, les ententes et les conditions s'y rattachant, conformément aux articles 73, 74, 75, 77 et 78 de la LEP. On se sert également de ces renseignements scientifiques pour conseiller le ministre de Pêches et Océans Canada au sujet de l'inscription de l'espèce en vertu de la LEP, analyser les répercussions socioéconomiques de l'inscription de l'espèce sur la liste ainsi que pour les consultations subséquentes, le cas échéant. Cette évaluation tient compte de toutes les données scientifiques existantes pour évaluer le potentiel de rétablissement du méné-miroir au Canada.

# SPECIES INFORMATION

**Scientific Name** – *Notropis photogenis* (Cope, 1865)

**Common Name** – Silver Shiner

**Current COSEWIC Status (Year of Designation)** – Threatened (2011)

**COSEWIC Reason for Designation** – This small riverine fish is found in fewer than 10 locations and demonstrates a small area of occupancy. The susceptibility of the species to continuing habitat loss and degradation with increasing development pressure resulted in an increase in status.

**Current *Species at Risk Act* Status (Schedule)** – Special Concern (Schedule 3)

**Current Ontario *Endangered Species Act* Status (Year of Designation)** – Threatened (2012)

**Range in Canada** – Ontario

# BACKGROUND

In April 1983, COSEWIC recommended that Silver Shiner be designated as Special Concern. This status was reconfirmed in April 1987. In May 2011, Silver Shiner was designated as Threatened due to its small area of occupancy and collection in fewer than 10 locations. Silver Shiner was found to be highly susceptible to ongoing habitat loss and degradation associated with increasing development pressure in watersheds throughout its range in Canada. Subsequent to the original COSEWIC designation, Silver Shiner was listed on Schedule 3 of the federal *Species at Risk Act* (SARA). Silver Shiner is currently assessed as Threatened under the *Endangered Species Act*. A Recovery Potential Assessment (RPA) process has been developed by Fisheries and Oceans Canada (DFO) to provide information and scientific advice needed to fulfill SARA requirements, including the development of recovery strategies and authorizations to carry out activities that would otherwise violate SARA (DFO 2007a, b). This document provides background information on Silver Shiner in Canada to inform the RPA.

## SPECIES DESCRIPTION

Silver Shiner (*Notropis photogenis*) is a small, elongate, silvery fish which reaches a maximum total length (TL) of approximately 144 mm (DFO, unpubl. data; Figure 1). It has: a pointed snout and a large eye with a diameter equal to, or slightly less than, snout length; 36-43 lateral scales; 8-10 (usually 9) pelvic fin rays; and, 15-17 pectoral fin rays (Holm et al. 2010; COSEWIC 2011a). Breeding males of the species are not brightly coloured, however, do express nuptial tubercles on the head, body and fins (Etnier and Starnes 1993; Jenkins and Burkhead 1994).

*Figure 1. Silver Shiner (*Notropis photogenis*). Illustration by Joe Tomelleri, reproduced with permission.*

Silver Shiner is morphologically similar to other shiners, primarily Rosyface Shiner (*N. rubellus*) and Emerald Shiner (*N. atherinoides*), and may be distinguished from congeners by having greater than eight anal fin rays, a pair of crescents between the nostrils, a clearly defined stripe along the back which is anterior to the dorsal fin, as well as a dorsal fin which originates directly opposite the base of the pelvic fins (Holm et al. 2010). Rosyface Shiner has 11-14 pectoral fin rays and reaches a maximum TL of 90 mm (as compared to 144 mm in Silver Shiner) (DFO, unpubl. data); whereas, Emerald Shiner has a shorter, blunter snout (Holm et al. 2010). The frequent confusion amongst congeners may be an impediment towards understanding distribution, abundance, and biology of all three species.

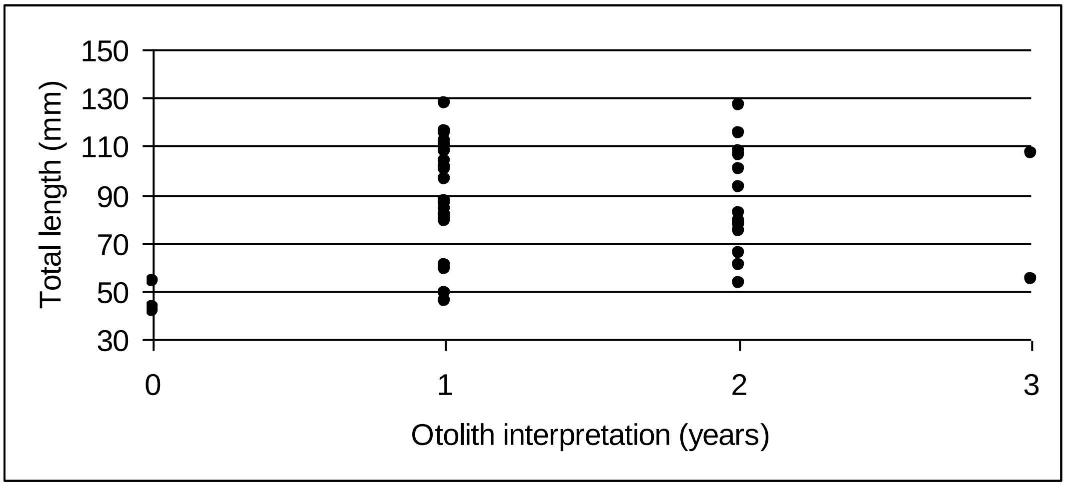
## GROWTH RATE

In Ontario, growth rates are rapid in the first year, with juveniles attaining standard lengths (SL) of 38-71 mm by November and adults ranging from 39-110 mm (Baldwin 1988). In Virginia, slight sexual dimorphism was suggested where adult males fish ranged from 61-117 mm (mean 89 mm) and adult females were 61-109 mm (mean 86 mm) (Jenkins and Burkhead 1994). Individuals are most often mature when reaching 60 mm and will typically spawn in years one or two (COSEWIC 2011a). The maximum documented age is three years; however, recent examination of otoliths from individuals captured in 2011 suggests that they may be much longer lived (DFO, unpubl. data). DFO recently contracted two independent interpreters to age Silver Shiner otoliths. Both interpreters were provided randomly selected specimens of various lengths captured using the same protocol during the same sampling periods. Both interpreters used the right or left lapillus otolith to interpret age. Age analysis results varied greatly between interpreters with one interpreter determining maximum age to be 3 years (107 mm TL; Figure 2a), and the other determining maximum age to be 10+ (122 mm TL; Figure 2b). The age interpretation accuracy of Silver Shiner otoliths has never been validated. Unfortunately, the lack of validated results makes it difficult to estimate the true age of the specimens captured with any certainty.

## DIET

Silver Shiner appears to be an opportunistic feeder, foraging at both surface and mid-water levels (Gruchy 1973; Baldwin 1983; COSEWIC 2011a). Primarily an insectivore, gut content analysis reveals the presence of both adult and larval aquatic insects, worms, crustaceans, water mites, and phytoplankton (COSEWIC 2011a). Silver Shiner has also been observed to leap from the water to prey on flying insects (Gruchy et al. 1973; Parker and McKee 1980; Trautman 1981; Baldwin 1988). Predators of Silver Shiner are not well documented; however, in a single incident, a Smallmouth Bass (*Micropterus dolomieu*) was observed to feed on a large Silver Shiner in the Grand River (Parker and McKee 1980).

(a)




(b)

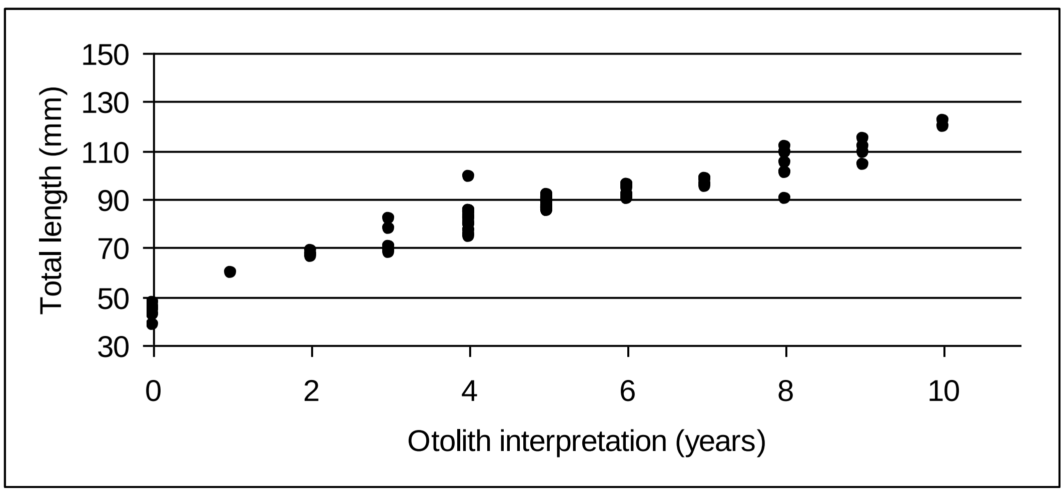



*Figure 2. Results of otolith interpretation by two independent age interpreters (a, b) to determine Silver Shiner age (years). Note that the interpreters did not read the same set of otoliths.*

## GENETICS

Although no research has been conducted to examine the genetic relatedness of populations of Silver Shiner in Canada, some work has been done on the genetic structure of other closely related species. It was originally hypothesized that Silver Shiner was a member of the subgenus *Notropis*, within the species group *photogenis*, which also included the Comely Shiner (*N. amoenus)* and the Silverstripe Shiner (*N. stilbius)* (whereas, Emerald Shiner and Rosyface Shiner were thought to belong to the species group *atherinoides*) (Coburn 1982). This relationship was not supported by the results reported by Bielwaski and Gold (2001); however, no other clear relationship between Silver Shiner and other congeners was identified. Allozymes and mitochondrial DNA (mtDNA) were also used to explore phylogenetic relationships between four species - Common Shiner (*Luxilus cornutus)*, Striped Shiner (*L. chrysocephalus)*, Rosyface Shiner, and Silver Shiner. As was anticipated, allozyme results indicated that Silver and Rosyface shiners clustered together, as did the two *Luxilus* species; however, mtDNA failed to successfully resolve the relationships among the species. Depending on the analysis method used, Silver Shiner would group with either of the *Luxilus* species, as opposed to consistently expressing a phylogenetic affinity for Rosyface Shiner. The inconclusive results of mtDNA to successfully determine intergenic relationships, despite successful resolution using allozyme data, may be attributed to hybridization events which are common among these taxa (COSEWIC 2011a). When variation in the CO1 gene was examined (Barcode of Life initiative), Silver Shiner was determined to differ consistently from other closely related taxa (Hubert et al. 2008).

### DISTRIBUTION

Silver Shiner occurs only in North America where it is widely distributed in the east central United States, primarily in the Ohio and Tennessee river drainages, and less commonly in tributaries of the lower Great Lakes where it has been recorded from Michigan, Ohio, Pennsylvania, and Ontario (COSEWIC 2011a). In Canada, Silver Shiner has a highly restricted distribution that comprises less than 2% of its global range. It is restricted to regions of southwestern Ontario, specifically in tributaries of lakes St. Clair (Thames River), Erie (Grand River), and Ontario (Bronte and Sixteen Mile creeks). It has been identified from museum records as early as 1936 but its presence was only discovered in 1971 in Canadian waters. Recent targeted surveys in the region by DFO in 2011 increased our knowledge of the Canadian range of the Silver Shiner in the Thames and Grand rivers and in Bronte Creek, resulting in a small increase in both extent of occurrence and area of occupancy.

Silver Shiner is found primarily in large streams with widths often greater than 20 m (COSEWIC 2011a). In these streams, the species is most often associated with deep riffles, or in pools immediately adjacent to riffle habitat (Baldwin 1983; COSEWIC 2011a). Juvenile fish may be found in areas with reduced current (Baldwin 1983). Little information is known regarding Silver Shiner spawning habitat; however, it has been suggested that reproductive individuals may migrate upstream to deep riffles and spawn in conjunction with other shiners or chubs (Baldwin 1983). Silver Shiner likely retreat to deeper waters with the onset of cooler fall and winter temperatures as they become scarcer in shallow water locations (Baldwin 1983; COSEWIC 2011a).

Silver Shiner is known to occur in four watersheds in Canada (Scott and Crossman 1973; COSEWIC 2011a). All four watersheds occur in the Great Lakes-Upper St. Lawrence Freshwater Biogeographic Zone (see COSEWIC 2011b for definition). As there are no genetic data for this species in Canada, there is currently no evidence to suggest more than a single designatable unit for the species in Canada.

## CURRENT STATUS

In Canada, Silver Shiner is restricted to southwestern Ontario where it has found in tributaries of Lake Huron, Lake St. Clair, Lake Erie, and Lake Ontario (Figure 3). Although originally reported in 1971, Silver Shiner has been documented from museum collections from as early as 1936 (Baldwin 1988). The Canadian distribution comprises less than 2% of the global distribution based on extent of occurrence. Increased sampling has expanded the known extent of occurrence of Silver Shiner from an estimated 5400 $km^2$ in 1983 to approximately 6996 $km^2$ in 2008 (COSEWIC 2011a). This increase in range is largely the result of targeted sampling in lower sections of Sixteen Mile and Bronte creeks as well as the Thames and Grand rivers rather than an increase in the range of the species.The area of occupancy (AO) based on a 2 x 2 km grid is 896 $km^2$ (419 $km^2$ based on a 1 x 1 km grid; COSEWIC 2011a). The biological AO was estimated to be 19.3 $km^2$ (COSEWIC 2011a).

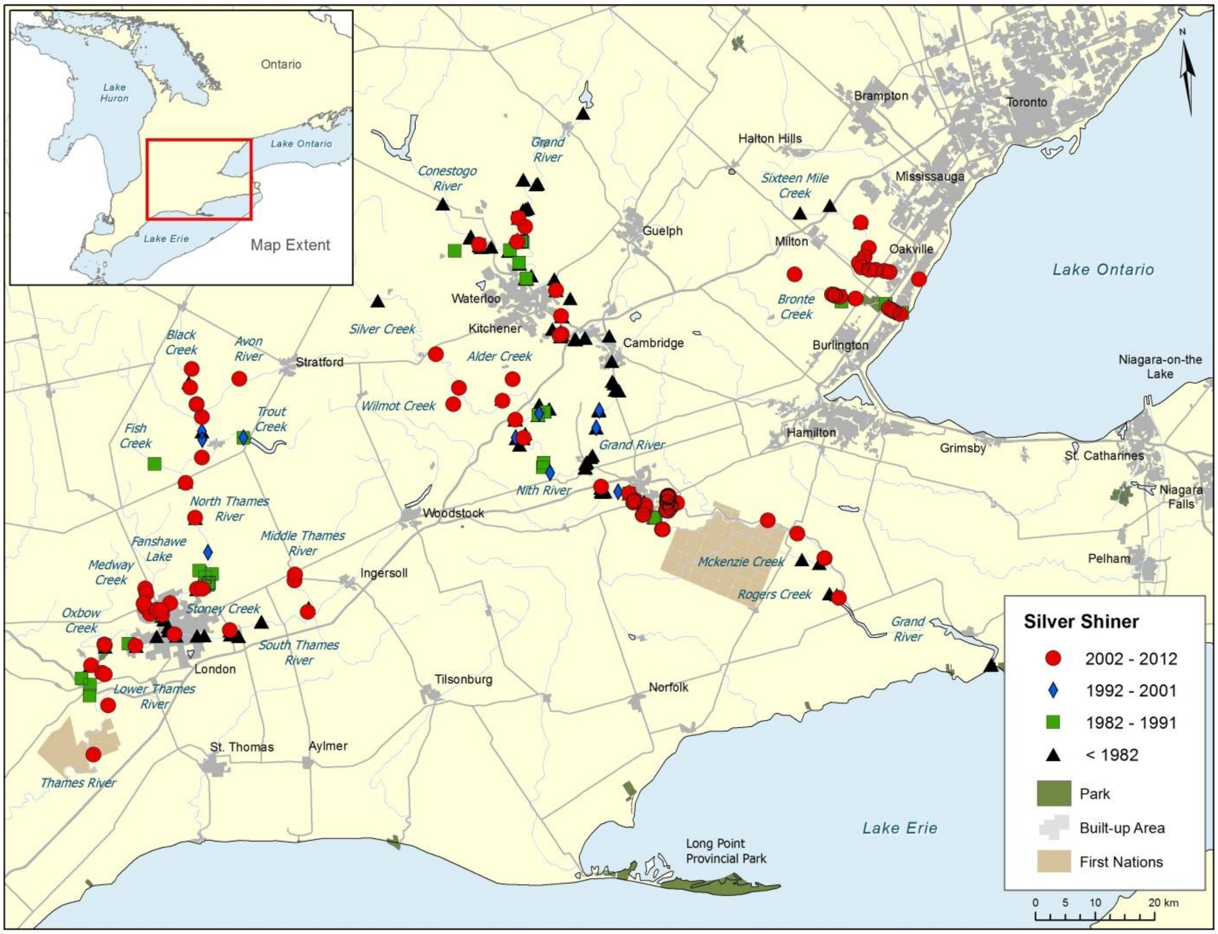



*Figure 3. Current distribution of Silver Shiner (Notropis photogenis) in Canada.*

## GRAND RIVER

Silver Shiner has been found in a 145 km stretch of the Grand River, extending from 7 km below Elora to the mouth of the Grand River. It is also known from the lower reaches of two tributaries, the Nith and Conestogo rivers, as well as in Laurel Creek, Schneider Creek, Speed River, and Whitemans Creek. In the Nith River, it has been found along a stretch of stream extending from the confluence with the Grand River to a location approximately 58 km upstream. In the Conestogo River, Silver Shiner has been recorded along a 25 km stretch, from the mouth of the river extending to Wallenstein. Recent collections using boat seining methods (DFO, unpubl. data) resulted in collections of Silver Shiner from the lower half of the Grand River and extended the known range of the species in the main stem of the river 44 km further downstream than previously reported (Baldwin 1988). Limited collections have been made of the species in the upper half of the Grand River watershed (above Paris, Ontario). Prior to 1982, only four records had been identified, two from the lower Conestogo River [1989, Royal Ontario Museum (ROM) 5592; 1990, Wilfred Laurier University (WLU) 12832]. A third collection was recorded in 2002 near the upstream limit of the species distribution in the Grand River (A. Timmerman, Ontario Ministry of Natural Resources (OMNR), pers. comm. in COSEWIC 2011a) as well as a fourth record in 2007 near Doon (DFO, unpubl. data). Collections made in 2010 and 2011 (DFO, unpubl. data) indicate that Silver Shiner is continually found within the Grand River, as well as in a number of its tributaries; however, samples were captured in smaller numbers than previously observed.

## THAMES RIVER

Within the Thames River watershed, Silver Shiner has been documented from Medway Creek through the Thames, North Thames, and Middle Thames rivers (Baldwin 1988). The known range of the species has increased slightly in recent years, extending a further downstream in the Thames River as well as being found in two additional tributaries of the North Thames River. In summary, Silver Shiner is located in a stretch of the Thames River proper extending from below Delaware to the mouth of the Middle Thames River. It has also been documented from a section of the North Thames River, from the confluence with the main stem to within 1 km above Motherwell. Silver Shiner is also found in the lower Middle Thames River and along Fish Creek, Medway Creek, and Trout Creek, three tributaries of the North Thames River. In addition to the lotic sites along the North Thames River, a single adult Silver Shiner and 95 juveniles were captured from a number of lentic sites in Fanshawe Lake, an artificial reservoir created by a dam 14 km upstream from the mouth of the North Thames River.

## BRONTE CREEK

Silver Shiner was identified from Bronte Creek in 1983 at Zimmerman (Baldwin 1988). In subsequent collections, 130 specimens (1994) and 116 specimens (1998) were captured 14 km further downstream in Oakville, suggesting that the species is widespread in the lower Bronte Creek system (COSEWIC 2011a). Sampling efforts in 2011 were again successful. A total of 57 individuals were captured with a 30 ft bag seine at 8 of 10 sites that were sampled (DFO, unpubl. data). Additional sampling was completed in 2012 at Petro Canada Park and seven individuals were recorded (Halton Conservation Authority, unpubl. data). Length of the occupied area in Bronte Creek is approximately 39 km.

## SIXTEEN MILE CREEK

A single individual was collected in 1998 (ROM 71697) from east Sixteen Mile Creek, located approximately 9 km ESE of Milton. Additional surveys were conducted by DFO in 2011 and multiple, successful collections (N=8, n ≥426) confirm the existence of a persistent population of Silver Shiner in this location. It should be noted that there has been no sampling on Sixteen Mile Creek between the QEW and Dundas Street creating a knowledge gap for this area.

## SAUGEEN RIVER

Records from the WLU collection suggest that Silver Shiner may also occur in the Saugeen River, a tributary of Lake Huron; however, it is plausible that these collections may have been originally misidentified. Subsequent re-examination (E. Holm, ROM) of one specimen has since been identified as a Striped Shiner. The second specimen, previously identified as Silver Shiner, collected from a tributary of the Saugeen River near Port Elgin is missing from the collection (E. Kott, University of Waterloo, 2005 in COSEWIC 2011a) and its identification cannot be confirmed. This record was not included in Baldwin’s (1988) status report. An additional collection, previously identified as Rosyface Shiner collected from the Saugeen River drainage (ROM 24831), was re-examined (K. Stewart, University of Manitoba, 2005) and determined to be Silver Shiner. The collection locality within the watershed is unknown. Additional surveys in the Saugeen River watershed are required to determine if an established population exists in this location. Additional sampling by seining, boat-electrofishing and backpack-electrofishing was completed in the Saugeen River in 2005 and 2006 but no Silver Shiner were captured (Marson et al. 2009).

## HISTORICAL POPULATION STATUS AND SAMPLING EFFORTS

Surveys of the fishes of Ontario were conducted between 1921 and 1928 by Carl Hubbs and others from the University of Michigan Museum of Zoology (UMMZ) (Hubbs and Brown 1929). Of 100 sites sampled in southern Ontario, only two (sampled in 1928 by Hubbs) occur within the current range of Silver Shiner; one in the North Thames River at St. Marys, and the other in the Grand River at Breslau (COSEWIC 2011a). Silver Shiner was not identified in either of these locations at that time (COSEWIC 2011a).

Between 1946 and 1963, the Ontario Department of Planning and Development (ODPD) conducted comprehensive surveys in a selection of river systems from southern Ontario and included the Saugeen River, Ausable River, sections of the North Thames River, tributaries of central Lake Erie, several tributaries of the Grand River (Speed, Eramosa, and Nith rivers) as well as tributaries of the western portion of Lake Ontario. The only sites that occur within the known range of Silver Shiner were in the lower Nith River and a portion of the sites sampled within the North Thames River. Specimens obtained as a result of this extensive survey were deposited in the ROM collection and subsequent analysis by K. Stewart, E. Holm, and M.E. Baldwin discovered the presence of a single Silver Shiner in each of three collections (Saugeen River, ROM 24831; Thames River, ROM 47160; Nith River, ROM 50738).

Numerous stream surveys in southern Ontario were conducted by the OMNR beginning in 1969 and continuing through until the 1980s. Surveys were conducted in the Grand River (437 sites, 1971-1977), Thames River (190 sites, 1974-1976), Saugeen River (306 sites, 1970-1978), Bronte Creek (32 sites, 1971-1977), and Sixteen Mile Creek (65 sites, 1971-1975)(OFDD 2008). Silver Shiner was identified from 14 locations in the Grand River and five locations in the Thames River. It was not identified in any collections from the Saugeen River, Bronte Creek, or Sixteen Mile Creek during this survey period.

In the Grand River drainage, 20 sites were sampled in 1979, along with a further 26 sites in the Thames River drainage (Parker and McKee 1980). Silver Shiner was captured from 11 sites in the Grand River and from three sites in the Thames River drainage (Parker and McKee 1980). Between 1981 and 1982, a comprehensive survey for Silver Shiner was conducted in the Grand and Thames rivers (Baldwin 1983). Sampling occurred at 5 km intervals within the known range at the time with sampling extending 10 km beyond the known boundary. Silver Shiner was identified from 12 of 19 sites within the Thames River drainage, and at 27 of 51 sites in the Grand River watershed (Baldwin 1983).

Since 1983, few surveys have been conducted that have specifically targeted Silver Shiner. Between 1995 and 2006, surveys for several species at risk, including Silver Shiner, were undertaken jointly by the OMNR and ROM in the Thames and Grand watersheds. In the Grand River, four specimens of Silver Shiner were captured at only two of seven previously successful locations, but were also found in two new locations and may be interpreted as a decrease in abundance of Silver Shiner in the Grand River (Holm and Boehm 1998 as cited in COSEWIC 2011). However, these sampling events occurred in October and November during the period when most fishes, including Silver Shiner, migrate to deeper locations and are not present in as many localities (Baldwin 1988). Poor capture results may also be attributed to sampling methods. Bag seines are most effective for capturing Silver Shiner (Baldwin 1983); however, electrofishing was used during these surveys.

The Thames River and its tributaries were sampled between 2001 and 2004 [Upper Thames Region Conservation Authority (UTRCA), unpubl. data]. Sampling occurred at 182 sites within the drainage basin. Silver Shiner was reported at 10 sampling locations, five of which were confirmed by voucher specimens (J. Schwindt, UTRCA, unpubl. data).

DFO conducted several surveys on the Grand River between 2002 and 2005; while Silver Shiner was not specifically targeted, it should have been correctly identified if captured. Using a boat seine, 25 individuals were captured at 6 of 59 locations in 2003. These collections extend the range of Silver Shiner 21 km further downstream than previously known (OMNR/ROM collection in 2000) and 44 km further downstream than previously recorded by Baldwin (1988). Consistent with the results of the OMNR/ROM survey, Silver Shiner were not captured from sites sampled further upstream (COSEWIC 2011a).

Silver Shiner in the Conestogo River was targeted by the OMNR between 2004 and 2008 using extensive electrofishing efforts [both punt and drift boat electrofishing (COSEWIC 2011a)]. No Silver Shiner were captured from the surveyed region between the Conestogo Dam, downstream to the St. Jacob's Dam (A. Timmerman, OMNR in COSEWIC 2011a). As indicated above, electrofishing has not been reliable for detecting Silver Shiner and the unsuccessful collection in this location may not reflect their absence.

During a general survey of the fish community at 25 sites in the Saugeen River watershed, undertaken by DFO in 2005 and 2006, Silver Shiner were not captured (Marson et al. 2009). This survey used seines and electrofishing to collect 1,344 individuals representing 45 species from 25 sites throughout the Saugeen watershed.

Additional targeted surveys conducted by DFO in 2011 captured Silver Shiner from multiple locations in Sixteen Mile and Bronte creeks, Conestogo, Grand, Thames and Nith rivers.

## FLUCTUATIONS AND TRENDS

Knowledge of population-level variation in Silver Shiner in Canada is limited by a lack of regular monitoring, misidentification, selectivity of gear, and sampling time of year. Many successful collections of Silver Shiner were made in Canada between 1974 and 1982. It was suggested that Silver Shiner may have experienced a population increase between 1960 and 1980 (Baldwin 1983). However, new records of Silver Shiner may reflect increased survey efforts at downstream locations rather than range expansions or may also be attributed to downstream migration of populations in response to predatory pressures (COSEWIC 2011a).

Re-examination of museum collection vouchers collected in Ontario between 1921 and 1963 resulted in the identification of Silver Shiner from the Grand (one record, one specimen), Thames (four records, 14 specimens) and Saugeen (one record, one specimen) watersheds (COSEWIC 2011a). Recent collections from the lower reaches of Bronte Creek resulted in 246 individuals captured in 1994 and 1998 (COSEWIC 2011a) and recent collections in similar locations have also yielded successful captures of Silver Shiner (DFO, unpubl. data). Although Silver Shiner is frequently captured in the lower Grand River (below Paris, Ontario), more recent surveys in upstream regions have not been successful.

Should the Silver Shiner become extirpated in Canada, recovery from populations in the United States is unlikely (COSEWIC 2011a). Silver Shiner populations within the Great Lakes watersheds in the United States are located in Michigan (190 km; straight line distance), Ohio (115 km), and Pennsylvania (110 km). To reach suitable habitat in Ontario and rescue extirpated populations, individuals from the American populations would be required to migrate long distances, most of which would be through unsuitable lake habitat. Silver Shiner has never been documented from any of the Great Lakes proper (Baldwin 1983; Cudmore-Vokey and Crossman 2000). Recovery events from more abundant populations of Silver Shiner in the Mississippi River system is prevented by natural watershed division and drainage patterns and, therefore, recovery from populations in the United States is unlikely (COSEWIC 2011a).

## POPULATION STATUS ASSESSMENT

To assess the population status of Silver Shiner in Canada, each population was ranked in terms of its abundance (Relative Abundance Index) and trajectory (Population Trajectory) (Table 1). The Relative Abundance Index was assigned as Extirpated, Low, Medium, High or Unknown. Sampling parameters, such as gear used, area sampled, sampling effort, and whether the study targeted Silver Shiner, were considered. The number of individual Silver Shiner caught during each sampling period was also considered when assigning the Relative Abundance Index. The Relative Abundance Index is a relative parameter in that the values assigned to each population are relative to the most abundant population. In the case of Silver Shiner, all populations were assigned an Abundance Index relative to the Sixteen Mile Creek population. The Population Trajectory was assessed as Decreasing, Stable, Increasing, or Unknown for each population based on the best available information about the current trajectory of the population. The number of individuals caught over time for each population was considered. Trends over time were classified as Increasing (an increase in abundance over time), Decreasing (a decrease in abundance over time), and Stable (no change in abundance over time). If insufficient information was available to identify the trajectory, the Population Trajectory was listed as Unknown. Certainty has been associated with the Relative Abundance Index and Population Trajectory rankings and is listed as: 1=quantitative analysis; 2=CPUE or standardized sampling; 3=expert opinion (Table 1).

*Table 1. Relative Abundance Index and Population Trajectory of each Silver Shiner population in Canada. Certainty has been associated with the Relative Abundance Index, and Population Trajectory rankings and is listed as: 1=quantitative analysis; 2=CPUE or standardized sampling; 3=expert opinion.*

| Population | Relative Abundance Index | Certainty | Population Trajectory | Certainty |
|---|---|---|---|---|
| Grand River | **Medium** | **2** | **Stable** | **3** |
| Thames River | **Medium** | **2** | **Stable** | **3** |
| Bronte Creek | **Medium** | **2** | **Unknown** | **3** |
| Sixteen Mile Creek | **High** | **2** | **Unknown** | **3** |
| Saugeen River | **Unknown** | **3** | **Unknown** | **3** |

The Relative Abundance Index and Population Trajectory values were then combined in the Population Status matrix (Table 2) to determine the Population Status for each population. Each Population Status is subsequently ranked as Poor, Fair, Good, Unknown or Not applicable (Table 3). Certainty assigned to each Population Status is reflective of the lowest level of certainty associated with either initial parameter (Relative Abundance Index, or Population Trajectory).

*Table 2. The Population Status Matrix combines the Relative Abundance Index and Population Trajectory rankings to establish the Population Status for each Silver Shiner population in Canada. The resulting Population Status has been categorized as Extirpated, Poor, Fair, Good, or Unknown.*

| | | Population Trajectory | | | |
|---|---|---|---|---|---|
| | | **Increasing** | **Stable** | **Decreasing** | **Unknown** |
| **Relative Abundance Index** | **Low** | Poor | Poor | Poor | Poor |
| | **Medium** | Fair | Fair | Poor | Poor |
| | **High** | Good | Good | Fair | Fair |
| | **Unknown** | Unknown | Unknown | Unknown | Unknown |
| | **Extirpated** | Extirpated | Extirpated | Extirpated | Extirpated |

*Table 3. Population Status for all Silver Shiner populations in Canada, resulting from an analysis of both the Relative Abundance Index and Population Trajectory. Certainty assigned to each Population Status is reflective of the lowest level of certainty associated with either initial parameter (Relative Abundance Index, or Population Trajectory).*

| Population | Population Status | Certainty |
|---|---|---|
| Grand River | **Fair** | **3** |
| Thames River | **Fair** | **3** |
| Bronte Creek | **Poor** | **3** |
| Sixteen Mile Creek | **Fair** | **3** |
| Saugeen River | **Unknown** | **3** |

## HABITAT REQUIREMENTS

### SPAWNING

Silver Shiner spawning habitat preferences are not well known; however, some evidence suggests that spawning occurs in relatively deep riffles and pools in habitat similar to that used by other shiners (e.g., *Luxilus* spp.) and chubs (*Nocomis* spp.) (Stauffer et al. 1979; Trautman 1981; E. Holm, pers. obs. 2002). It is suggested that spawning occurs at dusk or at night as has been reported for Emerald Shiner (Jenkins and Burkhead 1994). Spawning in Ontario is thought to occur from late May through to mid-June, based on the capture of ripe and then spent individuals by Baldwin (1988), when water temperatures reach 18.1-23.5°C. Spawning appears to vary widely throughout its range, June-early July in Ohio (Trautman 1981), late April-late May in Tennessee (Etnier and Starnes 1993), and early May-mid-June in Virginia (Jenkins and Burkhead 1994).

## LARVAL & JUVENILE

There is very limited information available on habitat preferences of larval and juvenile Silver Shiner. It has been reported that young-of-the-year Silver Shiner are most commonly associated with aquatic habitats of slower water than those preferred by adult fish (Baldwin 1983).

## ADULT

### Stream characteristics

Adult Silver Shiner are found primarily in medium or large streams with moderate gradients (0.5-1.9, mean 1.4 m/km; COSEWIC 2011a). Additional information from Bronte Creek indicates a slightly larger gradient range (0.34-3.02 m/km) but does indicate a similar mean range (1.56 m/km; OMNR, unpubl. data). Most often associated with alternating pools and riffles or more turbulent regions below dams, they are rarely found in small stream habitats (Baldwin 1988; Jenkins and Burkhead 1994). Silver Shiner is noted to be most abundant in deep, swift riffles and in the fast eddies and currents of pools immediately adjacent to them, rather than actually occurring in the area of fast current (Gruchy et al. 1973; Trautman 1981; Baldwin 1988). In smaller systems (e.g., Sixteen Mile Creek), Silver Shiner do occupy, in similar abundances, the riffle, run and pool segments of the river (DFO, unpubl. data). Recent collections from the Grand River have occurred in gradients as low as 0.3 m/km and also from a reservoir; indicating the use of both lentic and lotic habitats (DFO, unpubl. data). Silver Shiner is typically found in mid-upper reaches of the water column in schools or small groups in pools and large backwaters with sufficient current (Baldwin 1983; Baldwin 1988). Sampling completed by DFO between 2003-2010 noted that Silver Shiner were captured in slow to fast current, although flow rate was more commonly classified as ‘medium’ flow (DFO, unpubl. data). Unfortunately, prior to 2011, flow rates were only recorded as qualitative estimates (slow, moderate, fast). In 2011, DFO standardized sampling included recording water velocity, resulting in water velocities between 0.05 and 1.98 m/s (mean=0.45 m/s; DFO, unpubl. data) where Silver Shiner were recorded.

Stream widths where Silver Shiner are found in Ontario varied from 5 to 200 m but tended to be larger than 20-30 m (Gruchy et al. 1973; Parker and McKee 1980; Baldwin 1988; Holm and Boehm 1998 as cited in COSEWIC 2011). In 1997, Silver Shiner was captured in Ontario from streams 24-50 m wide (Holm and Boehm 1998 as cited in COSEWIC 2011). Stream width recorded by DFO during sampling efforts were similar to those previously recorded in the literature, and ranged from 11.5 to 135 m (DFO, unpubl. data).

Following the review of 21 environmental factors influencing Silver Shiner distribution, water depth was found to be the most important variable for supporting a population. Greater stream depth was positively correlated with Silver Shiner presence (Baldwin 1983). It is hypothesized that Silver Shiner migrate to deeper pools or more restricted overwintering habitat in late fall (October-November) as fish are captured less frequently and at fewer sites when sampling later in the season than in the summer (Baldwin 1983). An extensive survey completed in 1997 indicated the capture of Silver Shiner in water up to 1.5 m deep (Holm and Boehm 1998 as cited in COSEWIC 2011). More recently, Silver Shiner were captured in water ranging in depth from 0.24 to 1.24 m (DFO, unpubl. data).

### Water temperature

Water temperature likely limits the northern extent of the range of Silver Shiner; however, actual thermal preferences and tolerances of the species are unknown. In Ontario, Silver Shiner has been captured from streams with summer temperatures ranging from 8.3-27.6°C; however, Baldwin (1983) found no correlation between warmer temperatures and species presence, with the exception that warmer temperatures appeared to be preferred during spring months.

## Water quality

Silver Shiner is most abundant in Ohio in streams with clear water (low turbidity) (Van Meter and Trautman 1970; Trautman 1981); yet is also found in silty waters in New York (Lavett-Smith 1985). It is likely that no relationship exists between water clarity and Silver Shiner occurrence (Baldwin 1983). The species has been captured from sources where the water was identified as “clear”, “muddy” and also “cloudy” (Gruchy et al. 1973; Parker and McKee 1980). Water colour, dissolved oxygen, pH, and conductivity (a measurement of the amount of dissolved solids in water) are also unrelated to the presence of Silver Shiner (Baldwin 1983). Water quality variables measured by Holm and Boehm (1998 as cited in COSEWIC 2011) at Silver Shiner points of capture included visibility (between 0.5-1.2 m), alkalinity (slightly alkaline pH of 8.4-8.6), and conductivity (500-652 µS).

## Vegetation

Silver Shiner may selectively avoid habitat areas with rooted aquatic vegetation, as has been observed among some populations from Ohio (Trautman 1981). In Ontario, it has been noted that aquatic vegetation may be present or absent where Silver Shiner was recorded (Gruchy et al. 1973; Holm and Boehm 1998 as cited in COSEWIC 2011) and is not likely correlated with the presence of the species (Baldwin 1983). This was also observed by Holm and Boehm (1998 as cited in COSEWIC 2011) who noted that Silver Shiner was captured at sites with and without submerged vegetation. More recent studies by DFO indicated that 99% of the sites where Silver Shiner was captured were classified as being open water dominated; a single site was classified as having submergent vegetation as the dominant vegetative type (DFO, unpubl. data).

## Substrate

Descriptions of Silver Shiner substrate preference are quite varied in the literature, including boulder, rubble, gravel, pebble, sand, silt, mud, and clay (Parker and McKee 1980; Trautman 1981; Lavett-Smith 1985). Recent field sampling by DFO supports the literature, in that Silver Shiner were caught over a large range of substrate types (Figure 4). A total of 119 sites were sampled in the four areas where Silver Shiner are known to exist (Bronte Creek, Sixteen Mile Creek, Thames and Grand rivers). At each site the dominant substrate type was recorded. From this information, there does not appear to be a preference for any substrate type. Although Silver Shiner was most often caught over a substrate described as being cobble-dominated, it should be noted that a comparatively similar number of cobble-dominated sites in each system yielded the capture of no Silver Shiner (Figure 4). Silver Shiner were never recorded from sites categorized as silt-, or clay-dominated; however, very few sites with these characteristics were sampled.

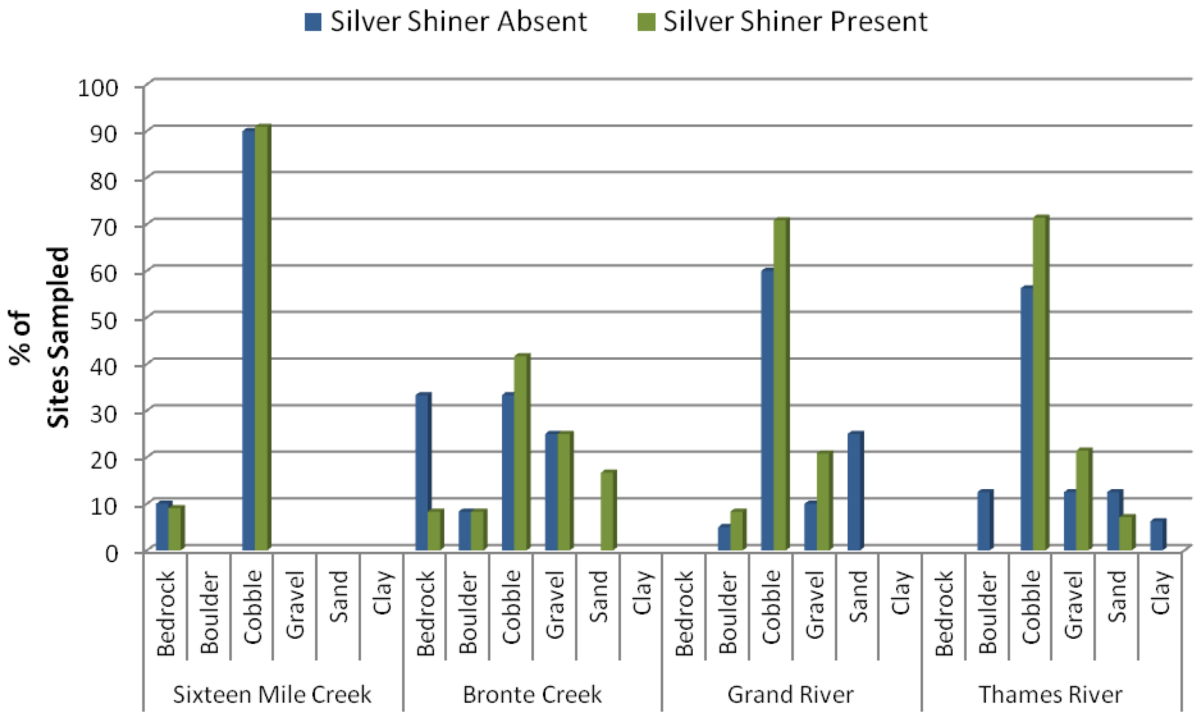



*Figure 4. Comparison of the dominate substrate type recorded at sites were Silver Shiner were both present and absent resulting from sampling of the four waterbodies where Silver Shiner is known to exist (DFO, unpubl. data).*

**FUNCTIONS, FEATURES, AND ATTRIBUTES**

A description of the functions, features, and attributes associated with Silver Shiner habitat can be found in Table 4. The habitat required for each life stage has been assigned a function that corresponds to a biological requirement of Silver Shiner. For example, individuals in the spawn to juvenile life stage require habitat for nursery and spawning purposes. In addition to the habitat function, a feature has been assigned to each life stage. A feature is considered to be the structural component of the habitat necessary for the survival or recovery of the species. Habitat attributes have also been provided, which describe how the features support the function for each life stage. Habitat attributes from the literature for each life stage have been combined with habitat attributes from current records (records from 2001 to present) to show the maximum range in habitat attributes within which Silver Shiner may be found (see Table 4, and references therein). This information is provided to guide any future identification of critical habitat for this species. It should be noted that habitat attributes associated with current records may differ from the habitat attributes described in the literature as Silver Shiner may be occupying sub-optimal habitat in areas where optimal habitat is no longer available.

*Table 4. Summary of the essential functions, features and attributes for each life stage of Silver Shiner. Scientific Literature habitat attributes, borrowed from published literature, and habitat attributes recorded during recent Silver Shiner surveys (captured since 2001) have been combined to derive the habitat attributes required for the delineation of critical habitat (see text for a detailed description of categories).*

| | | | Habitat Attributes | | |
|---|---|---|---|---|---|
| **Life Stage** | **Function** | **Feature(s)** | **Scientific Literature** | **Current Records** | **For Identification of Critical Habitat** |
| Spawning | Reproduction (spawning likely occurs in late May through to late June) | Run, riffle or pool areas of streams. | • Spawning thought to occur when water temperatures are between 18.1-23.5°C (Baldwin 1988) | | • Spawning thought to occur in the spring when water temperatures are between 18.1-23.5°C |
| Egg to juvenile | Nursery<br>Feeding<br>Cover | Run, riffle or pool areas of streams. | | | |
| Juvenile (<60 mm TL) | Feeding<br>Cover | Run, riffle and pool areas of streams with slow to moderate flow and little to no aquatic vegetation. | | • Individuals <60 mm TL have been recently caught in the same habitats as adults (DFO, unpubl. data) | • Same features as adult habitat, with the exception of the flow characteristic, in that juvenile are found in streams with slow to moderate flow |
| Adult (from age 1 [onset of sexual maturity]) | Feeding<br>Cover | Run, riffle and pool areas of streams with moderate to fast flow and little to no aquatic vegetation. | • 0.245-0.405 m - water depth was the most important variable for supporting a population with greater stream depth positively correlated with Silver Shiner presence (Baldwin 1983)<br>• Most often associated with alternating pools and riffles (Baldwin 1988)<br>• Substrate described as varying from boulders, rubble, gravel, pebbles, sand, mud, silt and clay (Parker and McKee 1980; Trautman 1981; Lavett-Smith 1985)<br>• Usually avoided habitats with rooted aquatic vegetation (Trautman 1981) | • 0.24 – 1.24 m depth (DFO unpubl. data)<br>• Water velocity – 0.05 and 1.98 m/s (mean=0.45 m/s; DFO, unpubl. data)<br>• Captured at sites dominated by bedrock, boulder, cobble, gravel and sand (DFO, unpubl. data)<br>• Dominant vegetative classification – Open Water (100% open water at 76% of the sites; DFO unpubl. data) | • 0.245-1.24 m water depth<br>• Moderate to fast flowing riffles, runs, and alternating pools<br>• Most often present in open water-dominated habitats |

## RESIDENCE

Residence is defined in SARA as a, “dwelling-place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating”. Residence is interpreted by DFO as being constructed by the organism. In the context of the above narrative description of habitat requirements during larval, juvenile and adult life stages, Silver Shiner does not construct residences during its life cycle.

# THREATS

A wide variety of threats negatively impact Silver Shiner across its range. Our knowledge of threat impacts on Silver Shiner populations is limited to general documentation, as there is a paucity of threat-specific cause and effect information in the literature. The greatest threats to the survival and persistence of Silver Shiner in Canada are anthropogenic threats such as habitat reduction, fragmentation or degradation attributed to turbidity and sedimentation; contaminant or other toxic substance introductions; dams and other physical barriers which impede movement; aquatic exotic species; as well as incidental harvest, often as a result of the baitfish industry. Silver Shiner in Ontario is found in waterbodies immediately adjacent to agricultural lands with increasing urban populations and development. Poor land use and management practices result in a reduction in water quality, such as sedimentation; increased turbidity; nutrient loading; and introduction of contaminants to the ecosystem, all of which are known to negatively impact fish habitat and population survival. Physical modifications, such as the creation of impoundments and dams, can create barriers to movement, alter flow regimes and contribute to increased sedimentation into aquatic habitats. Habitat reduction or degradation, attributed to river modifications, can result in altered flow regimes which may cause a loss of Silver Shiner habitat. These factors can be detrimental to Silver Shiner populations in Ontario and decrease the likelihood of recovery.

Large areas of the watersheds that support populations of Silver Shiner have undergone extensive alteration over many decades. These modifications resulted in areas of forested land being cleared for intensive agricultural activities and growing urban populations in areas of southern Ontario where Silver Shiner are now known to occur (Taylor 1989; Portt et al. 2007). Two consequences of such modifications are chronic habitat loss and/or habitat degradation as well as an increased likelihood of toxic contamination from agricultural chemicals or other toxic substances. In the Grand River watershed, negative impacts to fish communities have been associated with intensive agricultural practices and increased urbanization (Fitzgerald et al. 1998; Wichert and Rapport 1998). Elevated nutrient concentrations and increased levels of suspended sediment, coupled with a reduction in abundance of specialized insectivorous fishes (including Silver Shiner), have been correlated with high levels of agricultural land cover in regions of the French Broad River basin (North Carolina) (Rasleigh 2004). Silver Shiner has been locally extirpated from the Rocky Fork watershed in Ohio due to degradation of stream habitat and fish communities associated with suburban development in the region (Miltner et al. 2003). It is important to note that most Silver Shiner populations are facing a combination of stressors and the cumulative effects of multiple, potentially interactive, effects may exacerbate the decline of affected populations. It is extremely difficult to quantify these interactions and, therefore, each threat is discussed independently.

## TURBIDITY AND SEDIMENT LOADING

Current monitoring assessments of the Grand and Thames watersheds indicate that poor water quality conditions exist that threaten documented populations of Silver Shiner. Impacts of reduced water quality on Silver Shiner may influence the species in a variety of ways. It has been well documented that increased levels of turbidity and sedimentation degrade fish habitat by reducing primary productivity, abundance, and diversity of macroinvertebrates, decreasing the quality of spawning habitat and survivorship of eggs (Wood and Armitage 1997). Visual cues for prey detection and mate selection may be important for Silver Shiner, as evidenced by their prominent eyes, and a reduction in water clarity may influence predation success, growth rates, and reproduction as have been documented in other fishes (Burkhead and Jelks 2001; Sweka and Hartman 2001, 2003). Silver Shiner declines were documented in the Little Miami River (Ohio) following increased levels of sedimentation associated with the construction of an instream pipeline; however, these declines were only observed in the short term (Schubert et al. 1987 as cited in Reid and Anderson 1999).

### CONTAMINANTS AND TOXIC SUBSTANCES

Southwestern Ontario experiences as many reported toxic spill events (fuel, oils, manure, chemicals) as does the rest of the province combined and represents a significant threat to the persistence of Silver Shiner populations from this region (COSEWIC 2011a). During the period from 1988-1998, 229 manure spills were reported in southwestern Ontario, whereas, 274 were reported from the rest of Ontario (COSEWIC 2011a). Of the manure spills that resulted in large-scale fish die-offs (46 events), 85% occurred in southwestern Ontario (COSEWIC 2011a). The high frequency of manure spills in the southwestern area of the province may be expected, as the watersheds for the Thames and Grand rivers are in the top five regions of Canada that produce manure (>5 000 km/ha; ECO 2002). The COSEWIC assessment of Redside Dace (*Clinostomus elongatus*) in this region identified manure spills that resulted in fish kills over several kilometres of stream (COSEWIC 2007).

Increased salinization of lakes and streams in North America has been attributed to the application of road salt to highways during winter driving conditions (Demers and Sage Jr. 1990). Chloride concentrations measured downstream of urban centers in the Grand River watershed are currently below chronic toxicity threshold levels for Fathead Minnow (*Pimephales promelas*) embryos and Rainbow Trout (*Oncorhynchus mykiss*) embryos and eggs but, at times, have reached toxicity levels (as high as 201 mg/l) that have been shown to negatively affect 5% of aquatic organisms (EC 2001). In addition to chronic toxicity, chemical or agricultural fertilizer spills or other catastrophic events have occurred in watersheds which support Silver Shiner and have resulted in fish kills (COSEWIC 2009).

Additional sources of contaminants and toxic substances for this species include the application of lampricide in Bronte Creek (A. Dunn, Halton Region Conservation Authority (HRCA), pers. comm.) as well as a slow diesel leak from a pipeline that had gone undiscovered until 2010 (S. Mason, HRCA, pers. comm.) Lampricide is currently being applied in Bronte Creek every three years and this lampricide application will occur again at various sites throughout Bronte Creek in 2013 (A. Dunn, HRCA, pers. comm.). A second source of contamination in Bronte Creek is the slow diesel leak that was discovered in February 2010. It was found that corrosion of the Trans Northern Pipeline, which is a pipeline that carries predominantly diesel from Montreal to Nanticoke refinery, lead to a small volume of fuel leaking out of the pipeline for approximately 26 years (S. Mason, HRCA, pers. comm.). A risk assessment is currently ongoing to determine the possible effects of this leak on groundwater and Bronte Creek (S. Mason, HRCA, pers. comm.). The current impact of these two threats is currently unknown for Silver Shiner in this area.

### NUTRIENT LOADING

Agricultural land use is also frequently associated with increased levels of nutrients being deposited into the watershed, often with detrimental effects to water quality and associated aquatic community assemblages. Increased nutrient loading may result from a number of sources including urban and agricultural runoff, tile drains, and sewage treatment plants (COSEWIC 2011a). Although discussed in the Contaminants and Toxic Substances, agricultural inputs in the form of manure entering the waterways should also be considered when discussing the threat of Nutrient Loading. Increased nutrient levels can result in the overgrowth of aquatic plants and algae, including potentially toxic blooms of cyanobacteria. Decomposition of organic matter decreases dissolved oxygen levels and induces metabolic stress for aquatic organisms that may result in a negative impact on population levels (Munn and Hamilton 2003). Reductions in nutrient loading and pollution from agricultural, urban, and industrial sources have produced a slight increase in Silver Shiner abundance and distribution in Ohio since 1990 (Yoder et al. 2005). The Grand River Watershed Report Card (2005) states that 70% of total phosphorus in the Grand River (at the region of Waterloo) comes from farms, while up to 99% of phosphorus in the Nith River comes from farms during low flow seasons (GRCA 2005).

## BARRIERS TO MOVEMENT

Throughout North America, hydrological and ecological changes associated with the presence of barriers have contributed to the loss or reduction of migratory and smaller-bodied riverine fishes (Li et al. 1987; Pringle et al. 2000). Dams create impassable structures, potentially fragmenting upstream and downstream populations. This fragmentation decreases the probability of a rescue effect from neighbouring Silver Shiner populations, increasing the species' vulnerability to extirpation. Concentrations of Silver Shiner have been observed at the downstream end of dams suggesting upstream movement may have been disrupted (Baldwin 1988). Impoundments can also negatively impact Silver Shiner populations by flooding upstream riffles, promoting siltation, and reducing flows downstream (Grandmaison et al. 2004; DFO 2012). Habitat alteration associated with the presence of dams or impoundments, such as altered downstream water temperatures, variable flow regimes, or the creation of reservoir lakes and refuges may also favour the invasion or introduction of non-native species (e.g., Brown Trout, *Salmo trutta*), which may further adversely influence native fish populations (Quinn and Kwak 2003). Silver Shiner has been documented to have undergone local extirpation in the cold tailwaters of the Barren River Lake dam following its construction 13 years prior; whereas, in the Grand River watershed, a decline in populations of fluvial-specialist fishes as well as species dependent upon warmwater temperature cues to elicit spawning activity, has been observed following the construction of dams and impoundments that impede fluvial connectivity and migratory pathways (Spence and Hynes 1971; Fitzgerald et al. 1998; Reid 2004).

Many dams and impoundments are found in the Grand and Thames river watersheds. There are a total of 177 dams and barriers on the Upper Thames River (J. Schwindt, Upper Thames Region Conservation Authority, pers. comm.) and 79 dams in the lower Thames River watershed (J. Wintermute, Lower Thames Valley Conservation Authority, pers. comm.). In the Grand River, a total of 135 dams were reported in 2003, eight of which are used for flood control and low flow augmentation (Reid 2004). In addition to dams, log jams, as a result of land use practices or storm events, may pose act as a barrier to movement.

## FLOW MANAGEMENT

Water quantity and water management issues, independent of climate change, have been highlighted as a potential threat for Silver Shiner. A decrease in water quantity reduces the amount of aquatic habitat, ultimately decreasing the amount of habitat available for Silver Shiner. Water management issues are known for the Grand River where current, and projected, water demands may exceed the amount of water that is available (GRCA 2005). More importantly, water management may also play an important role in the maintenance of sufficient flow rates in areas where Silver Shiner are known to exist. If water taking drawdowns occur rapidly in a system, this may strand individuals, or alter the water flow to the point where the habitat is no longer suitable for Silver Shiner. A summary of water taking permits, as well as an estimate on the yearly consumptive water takings through various activities was completed by HRCA in 2005. A total of 18 permits were allocated for Bronte Creek watershed, while 16 permits were allocated in Sixteen Mile watershed (HRCA, unpubl. data). Water taking permits were sub-divided by specific purpose (Figure 5). From these estimates, water taking for recreational purposes (golf course irrigation) is the greatest use of water in both watersheds. Additional water taking for agricultural, industrial, and dams and reservoirs was recorded but at much lower levels. Water taking may negatively affect water flow, and in turn negatively affect Silver Shiner populations.

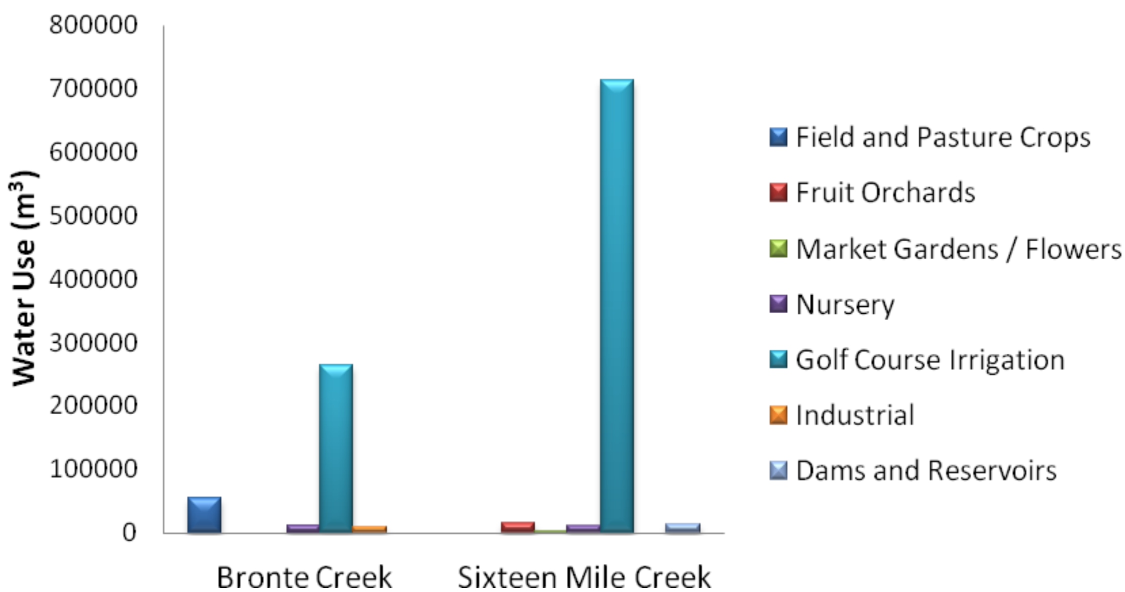



*Figure 5. Summary of consumptive water taking in the Bronte Creek and Sixteen Mile Creek watersheds for 2005 (HRCA, unpubl. data).*

## EXOTIC SPECIES

Sportfishes have been stocked into rivers and lakes within the Grand River watershed since the 1940s, coincidently into the centre of the known range of Silver Shiner in southwestern Ontario. Since 1989, 20,000-25,000 Brown Trout have been stocked into the upper Grand River, from the Shand Dam (above Elora) to West Montrose (approximately 28 km downstream) (A. Timmerman, OMNR in COSEWIC 2011a) and this section of the Grand River is now recognized as a world class Brown Trout fishery (Portt et al. 2007). Brown Trout have also been stocked into the Conestogo River; 209,000 fingerlings and yearlings were introduced to the river between 2003 and 2008 (COSEWIC 2011a). Also, it has been noted that there is a current shift in the Grand River towards an increase in Brown Trout stocking, and a subsequent decrease in Walleye (*Sander vitreus*) stocking. This shift may potentially affect rates of predation on Silver Shiner in this system, but it is currently unknown how this shift will affect Silver Shiner and should be considered as source of uncertainty.

Although no study has yet to examine the effect of introduced Brown Trout on Silver Shiner, it has been hypothesized that predation by stocked sportfishes will compound the negative impacts of habitat degradation on native fishes in the Grand River (Fitzgerald et al. 1998; Reid 2004). Research has identified the vulnerability of native cyprinids to predation by Brown Trout (Penczak 1999; Nannini and Belk 2006) as well as the associated declines in abundance of soft-rayed stream fishes (catostomids and cyprinids) (Garman and Nielsen 1982). The

International Union for the Conservation of Nature (IUCN) included Brown Trout on its list of the world's worst 100 invasive alien species (Lowe et al. 2000). It is expected that, in parts of the Grand River where Brown Trout and Silver Shiner are syntopic (deep, swift riffles and deep pools), Silver Shiner would experience negative impacts and be more vulnerable to predation by Brown Trout (COSEWIC 2011a).

The impact of other non-native species on populations of Silver Shiner in southwestern Ontario is not yet known; however, Canadian freshwater fishes are known to be susceptible to invasive fishes (Dextrase and Mandrak 2006; Mandrak and Cudmore 2010). Introductions of non-native species to areas where Silver Shiner are known to exist include Greenside Darter (*Etheostoma blennioides*), Round Goby (*Neogobius melanostomus*), and Sea Lamprey (*Petromyzon marinus*). These predators may negatively affect Silver Shiner by predating on their eggs, and competing for resources or nest space.

### INCIDENTAL HARVEST

Although favoured by anglers in the Grand River (Parker and McKee 1980), once Silver Shiner was listed as Special Concern, it was no longer concerned to be a legal baitfish (OMNR 2012). As with most fisheries, the potential for bycatch exists during angler and commercial baitfish harvest. Bycatch is dependent on the distribution and intensity of baitfish harvest in relation to the distribution of Silver Shiner. Bycatch of Silver Shiner during angler harvest of bait is currently unknown due to uncertain angler practices, but commercial harvests practices have been estimated (Drake and Mandrak 2012). A substantial portion of Ontario commercial harvest occurs in nearshore areas of lakes Huron, Erie, and Ontario where Silver Shiner does not occur. Commercial harvest also occurs in tributary streams of the Great Lakes, including those where Silver Shiner may be found. Drake and Mandrak (In press) estimated Silver Shiner bycatch potential from Great Lakes tributaries and determined that the probability of randomly selecting a tributary harvest site containing target fishes that also contained Silver Shiner was $p = 0.0160$ (approximately 1 out of 63 sites). Estimates of bycatch-effort relationships indicated that 373 harvest events would be necessary for a single event to have a median 95% chance of capturing Silver Shiner as bycatch during the pursuit of target species. Uncertainty within the models (at $\alpha = 0.05$) indicated that bycatch could be higher (only 163 events for a single event to reach a 95% chance of bycatch) or lower, with the failure of reaching the 95% bycatch threshold, regardless of effort. For comparison, Redside Dace held highest bycatch probabilities for imperiled species, requiring only 358 harvest events to reach a 95% chance of bycatch; whereas, Warmouth (*Lepomis gulosus*) would require 34,246 events to reach the 95% threshold, signifying its extreme rarity within harvest areas. Species predicted to be encountered frequently as bycatch, such as Rock Bass (*Ambloplites rupestris*) and Pumpkinseed (*Lepomis gibbosus*), would require only 17 events for a single event to reach the 95% threshold. Generally, the rarity of Silver Shiner implies that the potential for incidental harvest of Silver Shiner is low.

Should bycatch occur, the ability of harvesters to sort and remove Silver Shiner from target catches is unknown but likely low, particularly if the Emerald Shiner is the target species. However, a study of the Ontario baitfish pathway (Drake 2011) did not document any Silver Shiner during sampling of $n = 68$ baitfish purchases (a cumulative total of 16,886 fishes) in southern Ontario during August-October, 2007 and February 2008 (Drake 2011). The lack of Silver Shiner in baitfish purchases indicated that bycatch did not occur (i.e., sites containing Silver Shiner were avoided during harvest), or that Silver Shiner were captured as bycatch, but extensive sorting at the harvest or retailer sites removed the species from catches prior to sale to the angler. Overall, these results indicate that the probability for incidental harvest and transfer throughout the pathway is low.

An additional source of incidental harvest could include self-harvest by anglers in rural areas. The number of self-harvest events and the likelihood that an angler would successfully capture a Silver Shiner is currently unknown. In addition, the likelihood that an angler will properly identify a Silver Shiner and remove it from their catch is also currently unknown.

### CLIMATE CHANGE

Through discussion of the effects of climate change on Canadian fish populations, impacts such as increases in water and air temperatures, changes (decreases) in water levels, shortening of the duration of ice cover, increases in the frequency of extreme weather events, emergence of diseases, and shifts in predator-prey dynamics have been highlighted, all of which may negatively impact native fishes (Lemmen and Warren 2004). One hypothesis suggests that warmwater species at the northern extent of their range, such as the Silver Shiner, may benefit from increased water temperature allowing them to expand their distribution northwards (Chu et al. 2005). Since the effects of climate change on Silver Shiner are highly speculative, it is difficult to determine the likelihood and impact of this threat on each Silver Shiner population; therefore, this threat is not included in the following population-specific Threat Level analysis.

## THREAT LEVEL ASSESSMENT

To assess the Threat Level of Silver Shiner populations in Ontario, each threat was ranked in terms of the Threat Likelihood and Threat Impact on a population-by-population basis (Table 5-8). The Threat Likelihood was assigned as Known, Likely, Unlikely, or Unknown, and the Threat Impact was assigned as High, Medium, Low, or Unknown (Table 6). Threat Impact categorization is location specific, in that impact categorization was assigned on a location-by-location basis. If no information was available on the Threat Impact at a specific location, a precautionary approach was used - the highest level of impact from all sites was applied. The Threat Likelihood and Threat Impact for each population were subsequently combined in the Threat Level Matrix (Table 7) resulting in the final Threat Level for each population (Table 8). The level of certainty associated with the Threat Impact assignment has been assessed and classified as: 1=causative studies; 2=correlative studies; and, 3=expert opinion.

*Table 5. Definition of terms used to describe Threat Likelihood and Threat Impact.*

| Term | Definition |
|---|---|
| **Threat Likelihood** | |
| Known (K) | This threat has been recorded to occur at site X. |
| Likely (L) | There is a >50% chance of this threat occurring at site X. |
| Unlikely (U) | There is a <50% chance of this threat occurring at site X. |
| Unknown (UK) | There are no data or prior knowledge of this threat occurring at site X. |
| **Threat Impact** | |
| High (H) | If threat was to occur, it would jeopardize the survival or recovery of this population. |
| Medium (M) | If threat was to occur, it would likely jeopardize the survival or recovery of this population. |
| Low (L) | If threat was to occur, it would be unlikely to jeopardize the survival or recovery of this population. |
| Unknown (UK) | There are no prior knowledge, literature or data to guide the assessment of the impact if it were to occur |

*Table 6. Threat Likelihood and Threat Impact of each Silver Shiner population in Canada. Certainty has been associated with the Threat Likelihood (TLH) and Threat Impact (TI) based on the best available data. The Threat Likelihood was assigned as Known (K), Likely (L), Unlikely (U), or Unknown (UK), and the Threat Impact was assigned as High (H), Medium (M), Low (L), or Unknown (UK). Certainty (C) has been classified and is based on: 1=causative studies; 2=correlative studies; and 3=expert opinion. References (Ref) are provided.*

| | Grand River | | | | Thames River | | | | Bronte Creek | | | | Sixteen Mile Creek | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TLH | TI | C | Ref | TLH | TI | C | Ref | TLH | TI | C | Ref | TLH | TI | C | Ref |
| **Turbidity and sediment loading** | K | M | 3 | 1,6,7, 10,11,12 | K | M | 3 | 1,6,7, 10,11,12 | K | H | 3 | 1,6,7, 10,11,12 | K | M | 3 | 1,6,7, 10,11,12 |
| **Contaminants and toxic substances** | K | H | 3 | 1,2,3, 13,14 | K | H | 3 | 1,2,3, 13,14 | K | H | 3 | 1,2,3, 13,14 | K | H | 3 | 1,2,3, 13,14 |
| **Nutrient loading** | K | H | 3 | 1,4,5,6 | K | H | 3 | 1,4,5,6 | K | H | 3 | 1,4,5,6 | K | H | 3 | 1,4,5,6 |
| **Barriers to movement** | K | M | 3 | 15,16, 17 | K | M | 3 | 15,16, 17 | U | M | 3 | 15,16, 17 | U | M | 3 | 15,16, 17 |
| **Flow management** | K | M | 3 | 18 | K | M | 3 | 18 | L | M | 3 | 18 | K | H | 3 | 18 |
| **Exotic species** | K | M | 3 | 1,8 | L | L | 3 | 1,8 | K | M | 3 | 1,8 | K | M | 3 | 1,8 |
| **Incidental harvest** | L | L | 1 | 1,9 | L | L | 1 | 1,9 | L | L | 1 | 1 | L | L | 1 | 1 |

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*Table 7. The Threat Level Matrix combines the Threat Likelihood and Threat Impact rankings to establish the Threat Level for each Silver Shiner population in Canada. The resulting Threat Level has been categorized as Low, Medium, High, or Unknown.*

| | | Threat Impact | | | |
|---|---|---|---|---|---|
| | | **Low (L)** | **Medium (M)** | **High (H)** | **Unknown (UK)** |
| **Threat Likelihood** | **Known (K)** | Low | Medium | High | Unknown |
| | **Likely (L)** | Low | Medium | High | Unknown |
| | **Unlikely (U)** | Low | Low | Medium | Unknown |
| | **Unknown (UK)** | Unknown | Unknown | Unknown | Unknown |

*Table 8. Threat Level for all Silver Shiner populations in Canada, resulting from an analysis of both the Threat Likelihood and Threat Impact. The number in brackets refers to the level of certainty assigned to each Threat Level. The number in brackets represents the level of Certainty associated with the Threat Impact assignment and has classified as: 1=causative studies; 2=correlative studies; and 3=expert opinion.*

| | **Grand River** | **Thames River** | **Bronte Creek** | **Sixteen Mile Creek** |
|---|---|---|---|---|
| **Turbidity and sediment loading** | Medium (3) | Medium (3) | High (3) | Medium (3) |
| **Contaminants and toxic substances** | High (3) | High (3) | High (3) | High (3) |
| **Nutrient loading** | High (3) | High (3) | High (3) | High (3) |
| **Barriers to movement** | Medium (3) | Medium (3) | Low (3) | Low (3) |
| **Flow management** | Medium (3) | Medium (3) | Medium (3) | High (3) |
| **Exotic species** | Medium (3) | Low (3) | Medium (3) | Medium (3) |
| **Incidental harvest** | Low (1) | Low (1) | Low (1) | Low (1) |

The Threat Level results were used to assess the overall effect each threat may have on Silver Shiner in Canada. Each threat was categorized in terms of both Spatial and Temporal Extent (Table 9). Spatial Extent was categorized as Widespread [threat is likely to affect a majority of Canadian Silver Shiner populations (i.e., threat affecting two or more populations)] or Local [threat is likely to not affect the majority of Canadian Silver Shiner populations (i.e., threat affecting less than two populations)]. Temporal Extent was categorized as Chronic (threat that is likely to have a long-lasting, or re-occurring effect on a population) or Ephemeral (threat that is likely to have a short-lived or non-recurring effect on a population).

*Table 9. Overall effect of threats on Silver Shiner populations in Canada. Spatial extent was categorized as Widespread [threat is likely to affect a majority of Silver Shiner populations in Canada (i.e., threat affecting three or more populations)] or Local [threat is likely to not affect the majority of Silver Shiner populations in Canada (i.e., threat affecting less than three populations)]. Temporal Extent was categorized as Chronic (threat that is likely to have a long-lasting, or re-occurring effect on a population) or Ephemeral (threat that is likely to have a short-lived or non-recurring effect on a population).*

| Threat | Spatial Extent | Temporal Extent |
|---|---|---|
| **Turbidity and sediment loading** | Widespread | Chronic |
| **Contaminants and toxic substances** | Widespread | Chronic |
| **Nutrient loading** | Widespread | Chronic |
| **Barriers to movement** | Widespread | Chronic |
| **Flow management** | Widespread | Chronic |
| **Exotic species** | Widespread | Chronic |
| **Incidental harvest** | Widespread | Ephemeral |

## MITIGATIONS AND ALTERNATIVES

Threats to species survival and recovery can be reduced by implementing mitigation measures to reduce or eliminate potential harmful effects that could result from works or undertakings associated with projects, or activities in Silver Shiner habitat. Although currently recognized as a species of Special Concern in Schedule 3 of the SARA, prohibitions do not apply to Silver Shiner. In Ontario, the species is listed as Threatened under the *Endangered Species Act*, which necessitates the preparation of a formal provincial recovery strategy for Silver Shiner to manage the species and prevent further decline. Legislation exists to prevent the intentional harvest of Silver Shiner as bait; however, due to its morphological similarity to other shiners, it may be inadvertently taken. Silver Shiner has previously been identified and included in recovery plans for both the Grand and Thames rivers, both of which recommend initiating a monitoring plan to more accurately determine its distribution and abundance.

Within Silver Shiner habitat, a variety of works, undertakings, and activities have occurred that have directly or indirectly affected Silver Shiner habitat including: water crossings (e.g., bridges, culverts, open cut crossings); shoreline and streambank works (e.g. stabilization, infilling, retaining walls, riparian vegetation management); instream works (e.g., channel maintenance, restoration, modification, realignments, dredging, aquatic vegetation removal); the placement of structures in water (e.g., boat launches, docks, effluent outfalls, water intakes); dams and barriers (maintenance, flow modification, and small hydro facility retrofits); and, water management activities (e.g., stormwater management,  water withdrawals). Research has been completed summarizing the types of work, activity, or project that have been undertaken in habitat known to be occupied by Silver Shiner (Table 10). The DFO Program Activity Tracking for Habitat (PATH) database, as well as summary reports of fish habitat projects reviewed by partner agencies (e.g., conservation authorities), have been reviewed to estimate the number of projects that have occurred during the three-year period, 2009-2011. Approximately 100 projects or activities are indicated but likely do not represent a comprehensive list of all activities that have occurred in these areas (Table 10). Some projects may not have been reported to partner agencies or DFO if they occurred under conditions of an Operational Statement. Of the projects identified, seven were completed under conditions of Operational Statements primarily for bridge maintenance and directional-drilling water crossings. One project for a new bridge on the Thames River was authorized under ss. 35(2) of the *Fisheries Act.*

Following review, the remaining projects were deemed low risk to fishes and fish habitat and were addressed through letters of advice with standard mitigation. Without appropriate mitigation, projects or activities occurring adjacent or close to these areas could have impacted Silver Shiner (e.g., increased turbidity or sedimentation from upstream channel works). Based on the assumption that historic and anticipated development pressures are likely to be similar, it is expected that comparable projects and activities will likely occur in Silver Shiner habitat in the future (i.e. the majority being water crossings, instream works, and the placement of structures in water). Research also indicated that the primary project proponents were municipalities since much of the work occurred in major urban areas or was along roads.

As indicated in the Threat Analysis, numerous threats affecting Silver Shiner populations are related to habitat loss or degradation. Habitat-related threats to Silver Shiner have been linked to the Pathways of Effects developed by DFO Fish Habitat Management (FHM) (Table 10). DFO FHM has developed guidance on mitigation measures for 19 Pathways of Effects for the protection of aquatic species at risk in the Central and Arctic Region (Coker et al. 2010). This guidance should be referred to when considering mitigation and alternative strategies for habitat-related threats. At the present time, we are unaware of mitigation that would apply beyond what is included in the Pathways of Effects.

Additional mitigation and alternative measures, specific to the Silver Shiner, related to exotic species and incidental harvest are listed below.

### EXOTIC SPECIES

As discussed in the **THREATS** section, aquatic invasive species (e.g. non-native Brown Trout) introduction and establishment could have negative effects on Silver Shiner populations.

**<u>Mitigation</u>**

- Physically remove non-native species from areas known to be inhabited by Silver Shiner.
- Monitor watersheds for exotic species that may negatively affect Silver Shiner populations directly, or negatively affect Silver Shiner preferred habitat.
- Develop a plan to address potential risks, impacts, and proposed actions if monitoring detects the arrival or establishment of an exotic species.
- Introduce a public awareness campaign and encourage the use of existing exotic species reporting systems.
- Implement targeted education for resource users (e.g., fisheries management groups) on the potential effects of stocking on Silver Shiner populations.
- Increase the enforcement of existing regulations.

**<u>Alternatives</u>**

- Unauthorized
    - None.
- Authorized
    - Use only native species.
    - Follow the National Code on Introductions and Transfers of Aquatic Organisms for all aquatic organism introductions (DFO 2003).

*Table 10. Summary of works, projects and activities that have occurred during the period of August 2009 to August 2011 in areas known to be occupied by Silver Shiner. Threats known to be associated with these types of works, projects, and activities have been indicated by a checkmark. The number of works, projects, and activities associated with each Silver Shiner population, as determined from the project assessment analysis, has been provided. Applicable Pathways of Effects have been indicated for each threat associated with a work, project or activity (1 - Vegetation clearing; 2 – Grading; 3 –Excavation; 4 – Use of explosives; 5 – Use of industrial equipment; 6 – Cleaning or maintenance of bridges or other structures; 7 – Riparian planting; 8 – Streamside livestock grazing; 9 – Marine seismic surveys; 10 – Placement of material or structures in water; 11 – Dredging; 12 – Water extraction; 13 – Organic debris management; 14 – Wastewater management; 15 – Addition or removal of aquatic vegetation; 16 – Change in timing, duration and frequency of flow; 17 – Fish passage issues; 18 – Structure removal; 19 – Placement of marine finfish aquaculture site).*

| **Work/Project/Activity** | **Threats** (associated with work/project/activity) | | | | | | **Watercourse / Waterbody** (number of works/projects/activities between 2009-2011) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Turbidity and sediment loading** | **Contaminants & toxic substances** | **Nutrient loading** | **Barriers to movement** | **Exotic species** | **Incidental harvest** | **Grand River** | **Thames River** | **Bronte Creek** | **Sixteen Mile Creek** |
| **Applicable pathways of effects for threat mitigation and project alternatives** | 1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 15, 16, 18 | 1, 4, 5 ,6 ,7 ,11 ,12 ,13 ,14, 15, 16 ,18 | 1, 4, 7, 8, 11, 12, 13, 14, 15, 16 | 10, 16, 17 | | | | | | |
| **Water crossings** (e.g., bridges, culverts, open cut crossings) | ✓ | ✓ | | ✓ | | | 23 | 14 | 9 | 4 |
| **Shoreline, streambank work** (e.g., stabilization, infilling, retaining walls, riparian vegetation management) | ✓ | ✓ | | | | | 7 | 3 | 1 | 1 |
| **Dams, barriers** (e.g., maintenance, flow modification, hydro retrofits) | ✓ | | | ✓ | ✓ | | 2 | 2 | | |
| **Instream works** (e.g., channel maintenance, restoration, modifications, realignments, dredging, aquatic vegetation removal) | ✓ | ✓ | ✓ | | | | 3 | 3 | 7 | 1 |

| Work/Project/Activity | Threats (associated with work/project/activity) | | | | | | Watercourse / Waterbody (number of works/projects/activities between 2009-2011) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Turbidity and sediment loading | Contaminants & toxic substances | Nutrient loading | Barriers to movement | Exotic species | Incidental harvest | Grand River | Thames River | Bronte Creek | Sixteen Mile Creek |
| **Applicable pathways of effects for threat mitigation and project alternatives** | 1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 15, 16, 18 | 1, 4, 5 ,6 ,7 ,11 ,12 ,13 ,14, 15, 16 ,18 | 1, 4, 7, 8, 11, 12, 13, 14, 15, 16 | 10, 16, 17 | | | | | | |
| **Water management** (e.g., stormwater management, water withdrawal) | ✓ | ✓ | ✓ | | | | 3 | 5 | 1 | |
| **Structures in water** (e.g., boat launches, docks, effluent outfalls, water intakes) | ✓ | ✓ | ✓ | | | | 9 | 5 | | |
| **Baitfishing** | | | | | | ✓ | | | | |
| **Exotic species introductions (authorized and unauthorized)** (e.g., sportfish stocking, Round Goby) | | | | | ✓ | | | | | |

### INCIDENTAL HARVEST

As discussed in the **THREATS** section, incidental harvest of Silver Shiner through the baitfish industry was recognized as a potentially low risk threat.

**Mitigation**

- Provide information and education to bait harvesters on Silver Shiner to raise awareness, and request the voluntary avoidance of occupied Silver Shiner areas.
- Immediate release of Silver Shiner if incidentally caught, as defined under the Ontario Recreational Fishing Regulations (OMNR 2012).
- Education through mandatory training on species at risk for baitfish harvesters.
- Increase the enforcement of current baitfish regulations.

**Alternatives**

- Prohibit the harvest of baitfish in areas where Silver Shiner is known to exist.

If Silver Shiner is listed under the SARA, it is possible that alternatives in addition to mitigation may be required. However, alternatives, such as redesigning projects, have also been used as mitigation in many of the works that have taken place in the last few years. Offsetting may be required in some instances if future projects are permitted to result in the destruction of critical habitat.

## SOURCES OF UNCERTAINTY

Despite recent sampling efforts for Silver Shiner in Ontario, limited monitoring and research has been conducted on the species (Baldwin 1983, 1988). Accordingly, a number of key sources of uncertainty exist for this species. Resolving these sources of uncertainty would greatly enhance our understanding and detection of Silver Shiner in Ontario.

There is a need for a continuation of quantitative sampling of Silver Shiner in areas where it is known to occur to determine population size, current trajectory, and trends over time. There is also a need for targeted sampling of historic sites throughout southern Ontario to determine the persistence or extirpation of a number of populations [e.g. Fanshawe Lake (2003), Fish Creek (1984), Laurel Creek (1982), Saugeen River (1983); date in brackets represents most recent record]. Targeted sampling at known sites of capture should be completed in these systems to determine population sizes. In terms of distribution, there is a known knowledge gap on Sixteen Mile Creek between the Queen Elizabeth Highway and Dundas Street. This reach of the river should be sampled as it is currently unknown whether Silver Shiner are present. Additional sampling is also necessary for all populations with low certainty identified in the population status analysis. These baseline data are required to monitor Silver Shiner distribution and population trends as well as the success of any recovery measures implemented. There is a need to assess genetic variation across all Silver Shiner populations in Canada to determine population structure. Results of genetic analysis should help to determine the similarity between the north and south Thames populations.

The current distribution and extent of suitable Silver Shiner habitat is unknown and should be investigated and mapped. These areas should be the focus of future targeted sampling efforts for this species. There is also a need to identify habitat requirements for each life stage. There is very little information available for both larval and juvenile habitat requirements, necessitating the inference of these requirements from other life stages. Larval surveys are needed to identify both spawning and nursery grounds. Through qualitative observations, it was determined that flow may play a large role on the presence and abundance of Silver Shiner. Historically, flow was not measured quantitatively but categorized qualitative during site visits. Since this variable can be very subjective, it is suggested that flow be recorded quantitatively in all further studies on Silver Shiner.

Certain life history characteristics, required to inform Silver Shiner population modelling efforts, are currently unknown. Conflicting aging interpretations have resulted in two very different possible life histories. Model results and consequent recommendations based on the two interpretations differ dramatically. Studies to validate the growth, maturity, and longevity of Silver Shiner are needed. Further studies should focus on acquiring additional information on fecundity, population growth rate, and survival of young of the year.

Numerous threats have been identified for Silver Shiner populations in Canada, although the severity of these threats is currently unknown. There is a need for more causative studies to evaluate the impact of each threat on Silver Shiner populations with greater certainty as well as an estimation of the cumulative effects of interactive threats. There is a need to determine threshold levels for water quality parameters (e.g., nutrients, dissolved oxygen, salinity) and to determine physiological parameter limits including temperature, pH, dissolved oxygen, and pollution tolerance. It is also recommended that a study should be completed to look at whether the introduction and stocking of Brown Trout is having a negative impact on Silver Shiner populations, and if so, to what degree.

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