Fisheries and Oceans Canada / Pêches et Océans Canada
Science / Sciences

Canadian Science Advisory Secretariat (CSAS)

Research Document 2013/083

Central and Arctic Region

Information in support of a recovery potential assessment of Western Silvery Minnow (*Hybognathus argyritis*) in Canada

D.A. Watkinson

Fisheries and Oceans Canada
Freshwater Institute
501 University Crescent
Winnipeg MB R3T 2N6
Canada

November 2013

Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Research documents are produced in the official language in which they are provided to the Secretariat.

Published by:

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat
200 Kent Street
Ottawa ON K1A 0E6

http://www.dfo-mpo.gc.ca/csas-sccs/
csas-sccs@dfo-mpo.gc.ca

ISSN 1919-5044

Correct citation for this publication:

Watkinson, D.A. 2013. Information in support of a recovery potential assessment of Western Silvery Minnow (*Hybognathus argyritis*) in Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/083. iv + 23 p.

TABLE OF CONTENTS

ABSTRACT

The Western Silvery Minnow (*Hybognathus argyritis*) was listed as Threatened on Schedule 1 of Canada's *Species at Risk Act* (SARA) in 2003. In April 2008, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) re-assessed and designated Western Silvery Minnow as Endangered because this species is restricted to the Milk River in southern Alberta where changes in flow resulting from recurring drought conditions and the St. Mary's diversion have the potential to significantly affect the survival of the species (COSEWIC 2008). Before deciding whether to up-list Western Silvery Minnow to Endangered on Schedule 1, the Science sector in Fisheries and Oceans Canada (DFO) was asked to undertake a Recovery Potential Assessment (RPA); this Research Document supports the RPA. It describes the current state of knowledge of the biology, ecology, distribution, abundance and trends of Western Silvery Minnow in Alberta. Identification of threats to both the minnow and its habitat, and potential measures to mitigate these impacts, are also reported. This information may be used to inform the development of recovery documents, and to support decision-making with regards to up-listing and the issuance of permits, agreements and related conditions under the SARA.

Information à l'appui de l'évaluation du potentiel de rétablissement du méné d'argent de l'Ouest (*Hybognathus argyritis*) au Canada

RÉSUMÉ

Le méné d'argent de l'Ouest (*Hybognathus argyritis*) a été inscrit à la liste des espèces menacées au Canada de l'annexe 1 de la *Loi sur les espèces en péril* (LEP) en 2003. En avril 2008, le Comité sur la situation des espèces en péril au Canada (COSEPAC) a réévalué son statut et a désigné l'espèce comme étant en voie de disparition, car l'espèce n'est présente que dans la rivière Milk, dans le sud de l'Alberta, où les variations du débit résultant des conditions récurrentes de sécheresse ainsi que le canal de dérivation de la rivière St. Mary pourraient avoir une incidence décisive sur la survie de l'espèce (COSEPAC 2008). Avant de décider s'il faut élever le statut du méné d'argent de l'Ouest et l'inscrire à la liste des espèces en voie de disparition de l'annexe 1, on a demandé au Secteur des sciences de Pêches et Océans Canada (MPO) de réaliser une évaluation du potentiel de rétablissement (EPR) de l'espèce; le présent document de recherche a été préparé à l'appui de cette EPR. Il décrit l'état actuel des connaissances sur la biologie, l'écologie, la répartition, l'abondance et les tendances du méné d'argent de l'Ouest en Alberta. L'évaluation fait également état des menaces qui pèsent sur le méné d'argent de l'Ouest et son habitat, et de mesures pouvant atténuer leurs répercussions. Ces renseignements peuvent servir de base à l'élaboration de documents relatifs au rétablissement et éclairer la prise de décisions en ce qui a trait à l'élévation du statut et à l'émission de permis, aux ententes et aux conditions connexes conformément à la LEP.

SPECIES INFORMATION

Scientific Name – *Hybognathus argyritis* (Cope, 1871)
Common Name – Western Silvery Minnow
Range in Canada – Alberta
Current COSEWIC Status and Year of Designation – Endangered, 2008
COSEWIC Reason for Designation – **"**This freshwater fish is restricted to the Milk River in Southern Alberta, a region characterized by drought conditions of increasing frequency and severity. While the future of flow regimes associated with the St. Mary's diversion canal and proposed water storage projects are uncertain, consequences of these activities have the potential to significantly affect the survival of the species. Rescue effect from U.S. populations is not possible." (COSEWIC 2008)

Canada *Species at Risk Act* – Listed, Schedule 1, Threatened, 2003
Alberta *Wildlife Act* – Listed, Threatened, 2003

BACKGROUND

The Western Silvery Minnow is a small minnow of the genus *Hybognathus*. This document evaluates the potential for recovery of this species in Canada.

TAXONOMY

The genus *Hybognathus* contains seven species in North America, of which four are found in Canada: the Western Silvery Minnow (*H. argyritis*), the Plains Minnow (*H. placitus*), the Eastern Silvery Minnow (*H. regius*) and the Brassy Minnow (*H. hankinsoni*) (Schmidt 1994). Originally, *H. placitus* was lumped with Mississippi Silvery Minnow (*H. nuchalis*) but subsequently recognized as a separate species (Niazi and Moore 1962; Bailey and Allum 1962; Al-Rawi and Cross 1964; Pflieger 1971). Following separation of these two species, it was determined that *H. nuchalis* contained three additional species, *H. argyritis*, *H. nuchalis* and *H. regius* (Al-Rawi and Cross 1964; Pflieger 1971). The seventh species in North America is the Rio Grande Silvery Minnow (*H. amarus*).

SPECIES BIOLOGY AND ECOLOGY

The Western Silvery Minnow is an elongated fish and is moderately laterally compressed. The average adult measures 90–130 mm total length, with the deepest body segment in front of the dorsal fin, and a rather stout caudal peduncle. The head is bluntly triangular and short, the eye relatively large in comparison to other *Hybognathus* species in Canada. The mouth is subterminal, slightly overhung by a rounded snout, with a gape extending to below the nostril, not to the anterior margin of the eye. The pharyngeal teeth counts are 0,4–4,0 (Page and Burr 1991); the gill rakers (9–11; Nelson and Paetz 1992) are long. The dorsal fin origin is slightly in advance of the pelvis fin origin, posterior margin somewhat falcate, the caudal fin is distinctly forked; the anal fins origin is behind the posterior margin of depressed dorsal; the pelvic fins originate slightly posterior to dorsal fin origin. Scales are cycloid, with a slightly decurved complete lateral line. The peritoneum is black (very long intestine with numerous coils). The basioccipital process is longer than it is wide with a slightly concave posterior margin. The basioccipital process in Western Silvery Minnow is wider than for the Brassy and Plains minnows.

The overall colouration is silvery, brownish-yellow dorsally. The lateral band is absent but dusky spots may be present. The pelvic and anal fin rays have no melanophores.

Western Silvery Minnow tolerance to high temperatures, high turbidity and low dissolved oxygen levels is unknown. However, based on the rivers they inhabit, they appear to be very tolerant of high turbidity, high water temperatures (as high as 29.1°C have been recorded in the Milk River, AB) and low dissolved oxygen levels. Plains Minnow, a closely related *Hybognathus* species, is tolerant of low dissolved oxygen levels and higher temperatures (40°C) (Matthews and Maness 1979; Ostrand and Wilde 2001).

The Western Silvery Minnow has no direct economic benefit but it is of scientific interest. It does have intrinsic value as a contributor to Canada's biodiversity. As a peripheral population at the northwestern limit of their distribution range, the Western Silvery Minnow in Alberta may be unique and provide evidence of local adaptation to their habitat, and genetic differentiation from other conspecific populations. They may constitute a significant component of the genetic diversity of the species.

Age, Growth and Maturity

Little is known about the spawning biology of Western Silvery Minnow. The sex of Western Silvery Minnow can be differentiated during the breeding season as breeding males have fine nuptial tubercles on the top of the head and nape, as well as on the medial side of the pectoral fin (absent in females). They are suspected pelagic broadcast spawners that produce non-adhesive, semi-buoyant eggs that remain in suspension as long as there is current, similar to the Rio Grande Silvery Minnow and Plains Minnow (Platania and Altenbach 1998; Durum and Wilde 2006; Hoagstrom et al. 2011). Presumably, they also have a protracted spawning period. These species require adequate flow in un-impounded stretches of river to passively disperse eggs to downstream habitats while they develop. Rio Grande Silvery Minnow may need lateral connectivity to floodplain as much as they need longitudinal connectivity for successful recruitment (Porter and Massong 2006). Western Silvery Minnow collected in the Milk River at the end of May with water temperatures as high as 21.2°C had well developed ovaries and had not begun spawning. Fecundities varied in accordance with size with the smallest mature female examined (81 mm fork length (FL)) having 2,924 eggs and a large female (127 mm FL) having 19,573 eggs (DFO, unpubl. data).

The Western Silvery Minnow lives to 5.5 years (Pflieger 1997), with both sexes becoming sexually mature at age 2. Females are a minimum of 81 mm (FL) before becoming sexually mature. The Western Silvery Minnow has a maximum size of approximately 140 mm FL.

Diet

Both the length of the intestine and the elaborate pharyngeal teeth structures, unique to *Hybognathus*, suggest a herbivorous or detritivorous diet (Cross 1967; Hlohowskyj et al. 1989; Robison and Buchanan 1988; Sublette et al. 1990; Winston et al. 1991). Stomach contents of 20 Milk River specimens collected July 15, 2005, contained bacillariophytes (35%), chlorophytes (26%), plant remains (23%) and cyanophytes (10%) along with smaller quantities of carbon, fungi, chrysophytes, pollen, zooplankton remains, heterocysts, rotifers and protozoans.

ASSESSMENT

HISTORIC AND CURRENT DISTRIBUTION AND TRENDS

The Western Silvery Minnow is found throughout the Missouri River basin in the United States and in the Mississippi River only downstream of the confluence of the Missouri River as far south as the confluence with the Ohio River. The distribution of this species has declined extensively in areas of the United States over the past century (Hoagstrom et al. 2011). It is listed as ‘Critically Imperiled’ in Iowa and ‘Imperiled’ in Illinois, Kansas, Missouri and Wyoming (NatureServe 2011).

In Canada, this species is known only from the Milk River, Alberta (Figure 1), a tributary of the Missouri River in Montana. As there are no barriers to movement in the Milk River within Canada, the Milk River Western Silvery Minnow is considered to be one population.

Milk River System

The Milk River is a northern tributary of the Missouri-Mississippi Basin that flows north out of Montana into Alberta, eastward through the southern portion of the province, and then south and east back into Montana. The Town of Milk River is one of the few communities in the Milk River Basin.

In Alberta, the Milk River flows through the Foothills Fescue, Mixed-grass and Dry Mixed-grass subregions of the Grassland Natural Region (Natural Regions Committee 2006). It has a defined valley with limited road access. The short grass prairie that surrounds it is used primarily for cattle grazing. The lower reaches of the Milk River is shallow and turbid, with dynamic hydraulic conditions and poorly developed riparian zone that lacks higher aquatic plants due to the highly mobile stream bed (DFO, unpubl. data). Rainfall in the Milk River basin averages 333 mm annually, with majority fall during the growing season (Natural Regions Committee 2006). Periods of high runoff can occur in late March and April from snowmelt, and June and July from intensive, localized, rain storms (McLean and Beckstead 1985). Above the Town of Milk River, the substrate is dominated by gravel and cobble and the channel has a moderate gradient. The lower 130 river km of the Milk River are low gradient dominated by sand/silt substrate.

The Milk River’s seasonal flow regime has been severely impacted since 1917 by water diverted from the St. Mary River in Montana. Flows are augmented in the North Milk and Milk rivers from late March or early April through late September or mid-October (ISMMRAMTF 2006). Prior to augmentation, summer flows in the North Milk and Milk rivers were typically 1 to 2 $m^3 \cdot s^{-1}$ and 2 to 10 $m^3 \cdot s^{-1}$ respectively (McLean and Beckstead 1985). Flows in the Milk River now typically range from 10 to 20 $m^3 \cdot s^{-1}$ from May to September, and average 15 $m^3 \cdot s^{-1}$ between June and August. As the Milk River flows east through Alberta the concentration of suspended sediment and turbidity increases (Spitzer 1988). Flow augmentation of the Milk River is actively managed at the St. Mary Diversion Dam in Montana in response to major runoff events to prevent or reduce erosion, scouring and risk of canal failure, and to optimize use of the water for irrigation. It is not known whether the flow augmentation has altered Western Silvery Minnow distribution.

The diversion of water from the St. Mary River is terminated in late September to mid-October and the river reverts to natural flows until March or April (ISMMRAMTF 2006). Under severe drought conditions there may be little or no surface flow in the Milk River. At the Town of Milk River, the average flow rate over the period 1912 to 2011 was $<2\ m^3 \cdot s^{-1}$ in November and February, and $\leq 1\ m^3 \cdot s^{-1}$ in December and January (WSC 2011).

Upstream from its confluence with the North Milk River to the Montana Border, surface flow in the Milk River occasionally stops from July or August until March resulting in isolated pools. The Milk River mainstem east of Aden Bridge has zero flows less frequently, most recently in 1989 and 2002 (WSC 2011).

Western Silvery Minnow was first collected in Alberta in 1961 from the eastern portion of the Milk River (Nelson and Paetz 1992). Sampling in the 2000s expanded its known distribution to include the lowermost 220 river km of the Milk River in Canada (Figure 1). Recent range extensions are likely reflective of improved sampling techniques and increased sampling effort rather than a recent change in the species’ distribution.

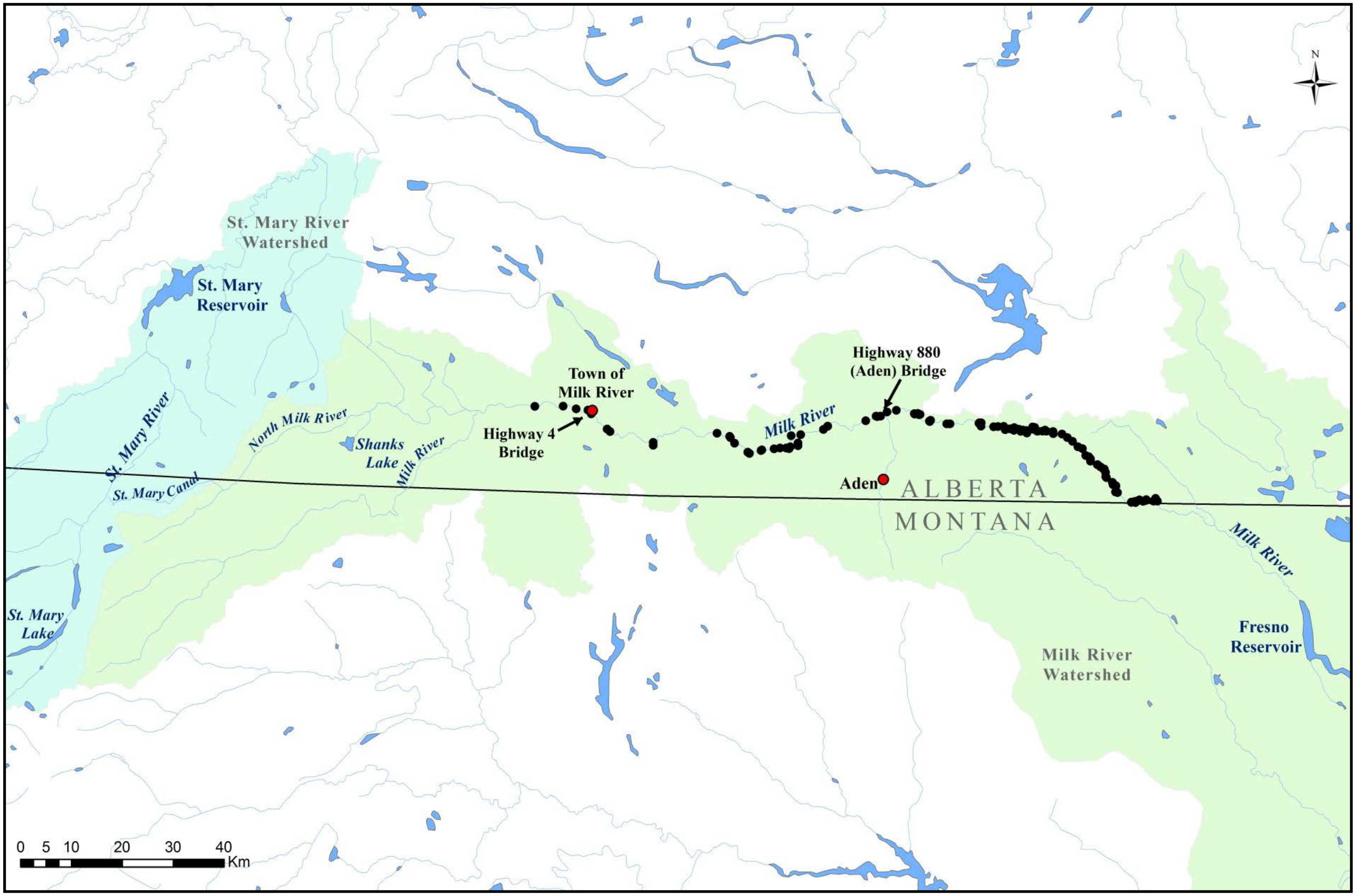

Figure 1. Distribution of Western Silvery Minnow in Canada.

In the United States, Western Silvery Minnow is found above and below the Fresno Reservoir and Dam. The Fresno Dam is a barrier to upstream fish movement. However, this species is very abundant upstream of the Fresno reservoir, offering the potential for movements upstream from Montana into Alberta. The Western Silvery Minnow has not been found in the North Milk River or the Milk River upstream of its confluence with the North Milk River, therefore the potential for re-colonization from upstream in the Milk River system is unlikely; however only limited sampling has been conducted to date.

HISTORIC AND CURRENT ABUNDANCE AND TRENDS

No information is available on historic and current trends in abundance of the Western Silvery Minnow in Alberta. Since it was first collected from the Milk River in Alberta, this species was believed to be common downstream of Writing-on-Stone Provincial Park to the Montana border (T. Clayton, pers. comm.). In 2000 and 2001, overall abundance was low in fall surveys of the Milk River (R.L.&.L. 2002). Directed surveys completed by DFO in July 2005, May and August 2006 and July 2007 found Western Silvery Minnow was the second most abundant fish species collected downstream of the confluence of the North Milk and Milk rivers. Electrofishing surveys were conducted in the Milk River downstream of the North Milk confluence to the Montana border using a 16' Jon boat modified as a single boom electrofishing boat, with a Type VI-A electrofisher. In total 295 Western Silvery Minnow were sampled and the mean catch-per-unit-effort (CPUE) for boat electrofishing sampling conducted from 2005 to 2007 was 0.3 fish/min (DFO, unpubl. data). During the same three-year period, a total of 1,279 Western Silvery Minnow were collected in 35 seine hauls in the Canadian portions of the Milk River in using a 9.14 m by 1.82 m seine with 4.76 mm mesh. Twenty six of those hauls had recorded haul lengths with a mean of 25 m. CPUE for all 35 seine hauls was 36.3 fish/haul.

An additional eight seine hauls were completed in the Milk River in Montana within 11.5 river km of Alberta, at what appeared to be excellent Western Silvery Minnow habitat, for the purpose of collecting specimens for a laboratory collection. All eight seine hauls collected Western Silvery Minnow and in total 603 were sampled (CPUE 75 fish/haul); 100 were retained for a laboratory collection.

The status of Western Silvery Minnow in the Canadian portion of the Milk River was assessed in terms of its abundance (Relative Abundance Index) and trajectory (Population Trajectory). The Relative Abundance Index was assigned as Extirpated, Low, Medium, High or Unknown. Sampling parameters considered included equipment used, area sampled, sampling effort, and whether the study was targeting this species. The number of individual Western Silvery Minnow caught during each sampling period was considered. Population Trajectory was based on the best available knowledge about the current trajectory of the population. The number of individuals caught over time was considered. Trajectory was classified as Increasing (an increase in abundance over time), Decreasing (a decrease in abundance over time) or Stable (no change in abundance over time). If insufficient information was available to inform the Population Trajectory, the population was listed as Unknown. The Relative Abundance Index and Population Trajectory values were then combined in a matrix (Table 1) to determine overall Population Status, which was ranked as Poor, Fair, Good, Unknown or Extirpated (Table 2).

The methods used and areas sampled during the DFO surveys did not provide estimates of abundance or trend. Regardless, numbers of Western Silvery Minnow in the Milk River generally increase with distance downstream, likely related at least in part to finer substrates and a lower gradient than farther upstream. Thus the Relative Abundance Index ranges from Low to High (Table 2). As past and recent sampling was not conducted in a manner that allows for comparison, there is no information on trend for the population so Population Trajectory is

Unknown. Using the population status matrix would result in a Population Status of Poor or Fair but a more accurate reflection of current knowledge is Unknown.

Table 1. The Population Status Matrix combines the Relative Abundance Index and Population Trajectory rankings to establish the Population Status for Western Silvery Minnow 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 2. Relative Abundance Index, Population Trajectory and Population Status of Western Silvery Minnow in Canada. The level of Certainty associated with the Relative Abundance Index and Population Trajectory rankings is based on quantitative analysis (1), CPUE or standardized sampling (2) or expert advice (3). Population Status results 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).

Stock	Relative Abundance Index	Certainty	Population Trajectory	Certainty	Population Status	Certainty
Milk River	Low-High	3	Unknown	3	Unknown	3

HABITAT REQUIREMENTS

Milk River

Habitat in the Milk River from the Montana border downstream to the confluence with the North Milk River is dominated by gravel (range: 40-60%) with a moderate gradient (range: 1.49-7.00 m/km) (Clayton and Ash 1980). Surface flow in that portion of the Milk River occasionally drops to 0 $m^3 \cdot s^{-1}$ in July or August until March. This is likely a limiting habitat condition in this reach. In the 100 km of river downstream of its confluence with the North Milk River, the Milk River transitions to a system characterized by silt and sand substrate and a low gradient. Downstream of Writing-on-Stone Provincial Park to the Canada/U.S. border, silt and sand make up 90% of the substrate and the river gradient is 0.65 m/km (Clayton and Ash 1980). The Milk River typically is turbid in spring and summer months, in the reach where Western Silvery Minnow are most abundant, with a mean Secchi disk depth of 20.3 cm.

Spawning

The spawning habitat of Western Silvery Minnow has not been described, however, is thought to be similar to other *Hybognathus* species that are a pelagic broadcast spawners, producing non-adhesive, semi-buoyant eggs that remain in suspension as long as there is current (Perkin and Gido 2011). *H. amarus* and *H. placitus* requires significant stretches of connected habitat with turbid, sediment-laden water of moderate flow velocity for spawning (Platania and Altenbrach 1998; Cowley 2002; Perkin and Gido 2011). The distance that larvae are displaced, the habitat where displaced larvae are deposited, and their ability to move unimpeded to upstream reaches of sustained flow are important determinants of spawning success in these species (Platania and Altenbrach 1998; Perkin and Gido 2011). It has been hypothesized that in the Canadian portion of the Milk River adult Western Silvery Minnow spawn upstream (below the confluence), the eggs drift downstream and hatch. There are insufficient data currently available to test this hypothesis.

Young-of-the-Year (YOY) and Juveniles

Boat electrofishing surveys conducted by DFO in the Milk River collected 107 YOY or juvenile (<81 mm FL) Western Silvery Minnows. Nearly all were collected in the lower 82 river km of the Milk River. This reach is low gradient with backwater areas and is dominated by fine sediments. Fish were collected in 0.08 to 0.8 m of water (mean 0.2 m), water velocities of 0 to 0.93 $m^3 \cdot s^{-1}$ (mean 0.05 $m^3 \cdot s^{-1}$) and sediment was dominated by silt (82%) and some sand (18%). Habitat requirements were similar to adults, but somewhat shallower and slower velocity habitats with fine substrates.

Adults

Adult Western Silvery Minnow inhabit small to large low gradient rivers, with backwater areas, and shallow flat and run habitats. Boat electrofishing surveys conducted by DFO collected 184 adult (≥81 mm FL) Western Silvery Minnow. Fish were collected as far upstream from the eastern border crossing into Montana as river km 223. The majority of fish (75%) were collected downstream of river km 82. Western Silvery Minnow were collected in 0.08 to 1.5 m of water (mean 0.35 m), water velocities of 0 to 1.11 $m^3 \cdot s^{-1}$ (mean 0.20 $m^3 \cdot s^{-1}$) and a substrate dominated by silt (51%) and sand (44%). The occurrence of Western Silvery Minnow in the Missouri River drainage is positively correlated with the percentage of fine substrate, and they favour habitats with increased turbidity and silt deposition (Quist et al. 2004). On the basis of available data, it is likely that Western Silvery Minnow requires highly-connected habitat (i.e., continuous river) more than 100 km in length to complete its life cycle. Impoundments negatively influence distribution and abundance of Western Silvery Minnow, a species adapted to hydrologically dynamic, turbid prairie streams (Platania and Altenbrach 1998; Cowley 2002; Quist et al. 2004; Hoagstrom et al. 2007) and any Critical Habitat designation would need to protect a large flowing section of the Milk River.

Overwintering

Little is known about the characteristics or availability of overwintering habitat for the Western Silvery Minnow in the Milk River. When diversion from the St. Mary River ceases in the fall, the river reverts back to its natural flow conditions until spring. In normal years, flow is maintained within a reduced channel. Under severe drought conditions the river may be reduced to a series of isolated pools suggesting that these may be important to the species survival. While previous winter sampling efforts have not documented Western Silvery Minnow from such pools (R.L.&.L. 2002), this may be an artifact of limited sampling effort. Alternatively, the species may seek refuge in areas where flowing water is still available.

RESIDENCE

The SARA defines a residence 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 a constructed place (e.g., a spawning redd). The Western Silvery Minnow does not change its physical environment or invest in a structure during any part of its life cycle, therefore no biological feature of this species meets the SARA definition of residence as interpreted by DFO.

THREATS TO SURVIVAL AND RECOVERY

A number of threats to the Western Silvery Minnow have been identified throughout its range, including those believed to be responsible for its extirpation from some systems. The most significant threats may be those that alter the natural flow regime of a river causing habitat loss or impairment. Such threats may include water removal (e.g., for irrigation and domestic use), impoundment, bank stabilization, channelization, changes in geomorphology and flow augmentation. Habitat alterations, particularly the reduction in seasonal fluctuations in discharge and declines in turbidity related to channelization and impoundment, have been correlated with the decline of the Western Silvery Minnow in the lower Missouri River (Pflieger and Grace 1987; Quist et al. 2004; Hoagstrom et al. 2007). Other threats to the species' habitat and survival include species introductions, drought, anoxia, climate change, contaminants and toxic substances and degradation of riparian areas. Some of the above threats may also act indirectly by altering faunal communities (e.g., species introduction), that in turn threaten the minnow's existence.

It is important to note that these threats may not always act independently on Western Silvery Minnow; rather, one threat may directly affect another, or the interaction between two threats may introduce an interaction effect. It is quite difficult to quantify these interactions. Therefore, each threat is discussed independently.

To assess the status of threats with respect to Western Silvery Minnow in Canada, each threat was ranked in terms of its Threat Likelihood, Threat Impact and Threat Level and overall effect on the species in terms of its Spatial Extent and Temporal Extent. Definitions for these terms are presented in Table 3. Threat Likelihood was rated as Known, Likely, Unlikely or Unknown, and the Threat Impact was rated as High, Medium, Low or Unknown (Table 4). The Threat Likelihood and Threat Impact ratings were subsequently combined in the Threat Level Matrix (Table 5) resulting in the final Threat Level for each stock (Table 6). The Spatial Extent of each threat was categorized as Widespread or Local and the Temporal Extent as either Chronic or Ephemeral (Table 7).

Habitat Loss/Degradation

Habitat loss, either through change in access to habitat (flow modification and fragmentation) or change in structure and cover is a significant threat to the survival of Western Silvery Minnow in the Milk River.

Changes in Flow (St. Mary Diversion)

The impact of drought has been reduced by the water diverted from the St. Mary River. The augmentation also may have extended the availability of suitable habitat for the Western Silvery Minnow further upstream than under natural flow conditions (Willock 1969). However, the net effect of changes in substrates, water depths and water velocities on the population is unknown and aspects of the species' life history may be affected negatively. For example, increased water velocities due to flow augmentation might adversely affect the species' reproductive success by increasing larval drift downstream into unsuitable habitats such as the Fresno Reservoir (R. Bramblett, pers. comm.). Fall and winter flows in the Milk River are considered natural and despite frequent low flow conditions there is no evidence of fish becoming stranded

Table 3. Definitions of terms used to describe Threat Likelihood, Threat Impact and Certainty as used in Table 4.

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)	Currently, the threat is jeopardizing the survival or recovery of the population. OR If the threat was to occur, it would jeopardize the survival or recovery of the population.
Medium (M)	Currently, the threat is likely jeopardizing the survival or recovery of the population. OR If threat was to occur, it would likely jeopardize the survival or recovery of the population.
Low (L)	Currently, the threat is unlikely jeopardizing the survival or recovery of the population. OR If threat was to occur, it would be unlikely to jeopardize the survival or recovery of the population.
Unknown (UK)	There is no prior knowledge, literature or data to guide the assessment of the impact if it were to occur.
Certainty (as it relates to Threat Impact)	
1	Causative study
2	Correlative study
3	Expert opinion
Spatial Extent	
Widespread	Threat is likely to affect the population at the medium or high level.
Local	Threat is likely to affect the population at the low level.
Temporal Extent	
Chronic	Threat is likely to have a long-lasting or reoccurring effect on the population.
Ephemeral	Threat is likely to have a short-lived or non-recurring effect on the population.

Table 4. Threat Likelihood (TLH) and Threat Impact (TI) for Western Silvery Minnow in Canada 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). The level of Certainty (C) associated with Threat Impact was based on causative studies (1), correlative studies (2) or expert opinion (3).

Threats	**Milk River below the confluence**		
	TLH	**TI**	**C**
Habitat Loss/Degradation			
Changes in flow (diversion)	K	H	3
Anoxia	K	H	3
Drought	K	H	3
Groundwater extraction	K	L-H	3
Surface water extraction: non-irrigation	K	L-H	3
Changes in habitat quality and availability	L	L-M	3
Changes in geomorphology	K	L-M	2
Livestock use of flood plain	K	L	3
Surface water extraction: irrigation	K	L	3
Dam construction and operation	UK	M-H	3
Species Introductions			
Fish species	K	L-H	3
Contaminants and Toxic Substances			
Point source contamination	K	L-H	3
Non-point source contamination	K	L-H	3
Catch			
Scientific sampling	K	L	3

Table 5. The Threat Level Matrix combines the Threat Likelihood and Threat Impact rankings to establish the Threat Level for the Western Silvery Minnow 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 6. The Threat Level for Western Silvery Minnow in Canada, resulting from an analysis of both the Threat Likelihood and Threat Impact. H=high, M=medium, L=low, UK=unknown.

Threats	Milk River below the confluence		
Changes in flow (diversion)	H		
Anoxia	H		
Drought	H		
Fish species introductions	L	M	H
Groundwater extraction	L	M	H
Surface water extraction: non-irrigation	L	M	H
Point source contamination	L	M	H
Non-point source contamination	L	M	H
Changes in habitat quality and availability	L	M	
Changes in geomorphology	L	M	
Surface water extraction: irrigation	L		
Livestock use of flood plain	L		
Scientific sampling	L		
Dam construction and operation	UK		

Table 7. Overall effect of threats on Western Silvery Minnow in Canada.

Threat	Spatial Extent	Temporal Extent
Changes in flow (diversion)	Widespread	Chronic
Anoxia	Widespread	Chronic
Drought	Widespread	Ephemeral
Fish species introductions	Widespread	Chronic
Groundwater extraction	Widespread	Chronic
Surface water extraction: non-irrigation	Widespread	Chronic
Point source contamination	Widespread	Ephemeral
Non-point source contamination	Widespread	Chronic
Changes in habitat quality and availability	Widespread	Chronic
Changes in geomorphology	Widespread	Chronic
Surface water extraction: irrigation	Local	Chronic
Livestock use of flood plain	Local	Chronic
Scientific sampling	Local	Ephemeral
Dam construction and operation	Unknown[1]	Unknown[2]

[1] Should this threat occur, its spatial extent would likely be widespread.
[2] Should this threat occur, its temporal extent would likely be chronic.

during the fall ramp down (T. Clayton, pers. comm.). The potential for stranding can be related to ramping rate and could increase if the rate increases at which flows are ramped down.

Emergency repairs of the canal have led to temporary or premature closure. Two interruptions to flow during the augmented period have occurred over the past 30 years; both were emergency situations where the integrity of the canal was at stake (K. Miller, pers. comm.). In 2001 the canal was closed in mid-August to allow for emergency repairs. That closure coincided with drought conditions reducing flows for September and October to near zero until the spring freshet.

The St. Mary Canal is in need of maintenance and re-construction, and proposed changes include various options such as abandonment, or significantly increasing its flow capacity (Alberta Environment 2004; U.S. Bureau of Reclamation 2004). Currently the canal is operating at 18.4 $m^3 \cdot s^{-1}$, well short of its design capacity of 24.1 $m^3 \cdot s^{-1}$ due to its poor structural condition. Montana has proposed increasing flow capacity during the irrigation period to 28.3 $m^3 \cdot s^{-1}$, and possibly extending the augmentation period. Increased flows could have major implications for channel morphology, particularly in the lower Milk River where banks are highly susceptible to erosion. Any changes to the flow regime of the Milk River should be preceded by studies to determine how the various options might affect river morphology and Western Silvery Minnow habitat.

The likelihood of this threat for Western Silvery Minnow in the Milk River Known and its impact is likely High (Table 4), resulting in an overall threat level of High (Table 6). The spatial and temporal extent of this threat is Widespread and Chronic, respectively (Table 7).

Anoxia

Low dissolved oxygen levels could seriously impact the survival of Western Silvery Minnow and other fish species in the whole of the Milk River. Noton (1980) concluded that the most important water quality parameter potentially not meeting fish needs in the Milk River was dissolved oxygen. Oxygen concentrations under ice in the lower reach of the river were as low as 1.6 mg/L in January. Possible causes for reduced oxygen concentrations are an accumulation of organic debris, or the inflow of anoxic ground water during low flows (Noton 1980). This threat requires further evaluation to determine extent, timing and duration.

The threat level of anoxia in the Milk River is High (Table 6). The spatial and temporal extent of this threat is Widespread and Chronic, respectively (Table 7).

Drought

Extreme drought conditions can occur in southern Alberta, particularly during the summer and early fall. The impact of this threat will depend on the severity and duration of the drought, with overwintering habitat likely to be the most limiting. In fall 1988/winter 1989 and fall 2001/winter 2002, for example, the surface flow of the Milk River was virtually eliminated due to severe drought conditions (WSC 2011), reducing the Milk River to a series of standing pools. Drought conditions have the potential to seriously stress minnow populations and combined with anthropogenic stresses could compound the severity of drought effects significantly.

The threat level of drought to Western Silvery Minnow in the Milk River is High (Table 6) and its effect is Widespread but Ephemeral (Table 7).

Groundwater Extraction

Groundwater is used for domestic purposes by ranchers along the Milk River. Additionally, loss of surface water flow to groundwater occurs naturally along a section of the Milk River from Black Coulee (MacDonald Creek approx. 8 km upstream of Aden Bridge) to approximately 3 km downstream of the Aden Bridge (Highway 880 crossing) (Grove 1985). If strong linkages exist between groundwater and surface water then excessive diversion of groundwater during low flow conditions could affect Western Silvery Minnow habitat. A better understanding of groundwater use and linkage to surface water is needed to determine the significance of this threat.

The threat level of groundwater extraction to Western Silvery Minnow in the Milk River ranges from Low to High depending on when it occurs and how much it affects river flow (Table 6). This threat is Widespread and Chronic (Table 7).

Surface Water Extraction: Non-irrigation

Temporary Diversion Licences (TDLs) for non-irrigation purposes are issued throughout the year, including during critical low flow periods. Overwintering habitat for Western Silvery Minnow may be particularly vulnerable to this type of extraction for reasons similar to those outlined under “Groundwater Extraction”. If this extraction occurs during the augmented flow period, it may not be an issue unless the St. Mary Canal is prematurely or temporarily closed. TDLs may be revoked, as they were during the drought conditions in 2001 (S. Petry, pers. comm.). The Town of Milk River diverts about 0.3% of the total available flow during the augmentation period for domestic purposes.

Surface water extraction for non-irrigation poses a level of risk to Western Silvery Minnow in the Milk River that ranges from Low to High, depending on when it occurs (Table 6). This threat is Widespread and Chronic (Table 7).

Changes in Habitat Quality and Availability

This threat captures changes to the environment (e.g., substrate and water velocity) at a smaller scale than the Changes in Geomorphology. The likelihood of occurrence of this threat as a result of high volumes of the water in the Milk River drainage during flow augmentation is Likely (Table 4). Further river channel widening in response to an increase in the capacity of the diversion could result in an additional 10% loss in riparian vegetation (AMEC 2008). Increased flows may cause more frequent flooding which would aid in the regeneration of Plains Cottonwood (*Populus deltoides*) (Bradley and Smith 1986).

The overall level of this threat for Western Silvery Minnow is Low to Medium (Table 6) and its effect is Widespread and Chronic (Table 7).

Changes in Geomorphology

This threat captures changes at a larger scale than Changes in Habitat Quality and Availability. Nearly 100 years of flow augmentation from the St. Mary diversion has caused changes in floodplain morphology on the Milk River and the North Milk River in the form of channel widening, increased channel sinuosity and an increase in meander bend cut-offs immediately after the diversion was put into use (McLean and Beckstead 1985). A recent survey of river channel cross sections indicates the channel is still widening (AMEC 2008).

If capacity of the diversion is increased, it is expected that higher flows will transport more sediment and deposit more silt (AMEC 2008). It may result in channel incision deeper than historic conditions which would reduce the frequency of overbank flows thereby decreasing lateral connectivity to secondary channels, oxbows and the floodplain. Lateral habitats are important for reproduction of Rio Grande Silvery Minnow (Porter and Massong 2006) and may also be important for Western Silvery Minnow. Therefore, changes in channel morphology and reduction of lateral habitat connectivity into side channels and backwaters may be important. Loss of this habitat would increase downstream transport which effectively lengthens connectivity requirements.

The overall level of this threat for Western Silvery Minnow ranges from Low to Medium (Table 6) and its effect is Widespread and Chronic (Table 7).

Livestock Use of Flood Plain

Livestock overgrazing of the floodplain is often implicated with destabilization of the stream banks and degradation of the riparian vegetation community. The impact of this on the Western Silvery Minnow is unknown, though likely low.

The Alberta Riparian Habitat Management Society ("Cows and Fish") has undertaken several riparian and grazing management workshops, involving ranchers along the Milk River to increase understanding of the value and vulnerability of the riparian area to degradation and a greater understanding and adoption of management solutions by ranchers, including off-stream water development (Lorne Fitch, pers. comm.). Along the Milk River several riparian benchmark inventories have been completed, but there has not been any follow-up monitoring to date. Demonstration sites have shown riparian vegetation recovery, especially with woody vegetation. In three to five years after the first management changes are made, though it may be ten years before significant physical changes can be measured.

The level of this threat to Western Silvery Minnow is likely Low (Table 6) and its effect is Local but Chronic (Table 7).

Surface Water Extraction: Irrigation

Water extraction for irrigation could seriously reduce habitat available for Western Silvery Minnow, however, the threat in the Milk River is considered low as only a small proportion of the available flow during the augmentation period is withdrawn, and these withdrawals are regulated. Five percent of the total flow is licensed for use in Alberta, most of which (93%) is used for irrigation (T. Clayton, pers. comm.). Temporary diversion licenses (TDLs) are not included in this total. If the diversion is closed for maintenance, or during reduced flow conditions, withdrawals for irrigation are terminated or suspended on a priority use basis. Alberta Environment has initiated installing water meters on all irrigation pumps drawing water from the Milk River to provide an accurate and up-to-date measure of water withdrawals (K. Miller, pers. comm.).

The threat of surface water extraction for irrigation to Western Silvery Minnow in the Milk River is Low (Table 6) and the overall effect is Local but Chronic (Table 7).

Dam Construction and Operation

A dam has been considered for just downstream of the confluence of the North Milk and Milk rivers. While construction of a dam would impose a barrier to fish movements and create a reservoir, resulting in loss of habitat for the dam footprint, it would be located upstream of the Western Silvery Minnow known range. The greatest impact expected is from operation of the dam. Habitats in the lower Milk River have been fragmented by the Fresno Dam in Montana and numerous diversion dams downstream. The Fresno Dam prevents Western Silvery Minnow populations downstream, except those above the reservoir, from re-colonizing habitats in Canada. An additional dam has been proposed on Shanks Lake which drains into the North Milk River via Shanks Creek (Figure 1) (T. Clayton, pers. comm.). Dam operation could impact flows and water temperature in the North Milk and Milk rivers but the dam and reservoir themselves do not pose any threat to Western Silvery Minnow.

The feasibility of developing a dam on the Milk River upstream of the Town of Milk River has been, and continues to be, investigated. The potential impacts on the Western Silvery Minnow will need to be thoroughly considered with any proposal. This species is adapted to hydrologically dynamic, turbid prairie streams (Platania and Altenbrach 1998; Cowley 2002;

Quist et al. 2004; Hoagstrom et al. 2007). Particular attention should be paid to any modification of the flow regime as changes associated with irrigation and impoundment have been identified as a potential limiting factor for the Western Silvery Minnow populations (Pfleiger and Grace 1987; Quist et al. 2004) because they alter habitat types, flow regimes, sediment loads, microbiota and water temperatures and may increase the risk of species introductions (Quist et al. 2004). These changes can result in rivers that are narrower, less turbid, less subject to fluctuations in temperature and flow, cooler water and less productive with less substrate movement (Cross et al. 1986; Pleiger and Grace 1987; Quist et al. 2004). High turbidity has less effect on the prey consumption of Great Plains fish species adapted to turbid conditions than that of species not adapted to turbid conditions (Bonner and Wilde 2002). In North Dakota, significantly more Western Silvery Minnows of a broader size range were observed in natural river segments compared to the moderately altered segments downstream of a large dam (Welker and Scarnecchia 2004).

The loss of connectivity associated with dams may be responsible for the decline or extirpation of several prairie minnow species that follow a similar semi-buoyant, broadcast spawning strategy (Winston et al. 1991; Pringle 1997; Platania and Altenbrach 1998; Cowley 2002; Alò and Turner 2005; Perkin and Gido 2011). Western Silvery Minnow likely requires stretches of river more than 100 km in length to complete its life cycle.

If a dam is constructed and operated sometime in the future its threat impact would range from Medium to High (Table 4). However, it is not currently known whether a dam will be constructed on the Milk River within or upstream of the distribution of Western Silvery Minnow, thus the current threat level is Unknown (Table 6). The overall effect of this threat would be Widespread and Chronic (Table 7).

Species Introductions (Fishes)

Introduced species can impact native fishes through predation, hybridization, competition for resources, the introduction of exotic diseases and parasites and habitat degradation. In the Milk River, Yellow Perch (*Perca flavescens*), Walleye (*Sander vitreus*), Northern Pike (*Esox lucius*), Trout-Perch (*Percopsis omiscomaycus*) are introduced species that have an overlapping distribution with Western Silvery Minnow (T. Clayton and DFO, unpubl. data). The Fresno Reservoir contains two more introduced predatory species, Rainbow Trout (*Oncorhynchus mykiss*) and Black Crappie (*Pomoxis nigromaculatus*), as well as Lake Whitefish (*Coregonus clupeaformis*) and Spottail Shiner (*Notropis hudsonius*) (Montana Fish, Wildlife and Parks). With the exception of Spottail Shiners that have been collected in the Milk River upstream of the Fresno Reservoir in Montana (Stash 2001) the other species are more poorly adapted to the Milk River.

The Alberta Fish and Wildlife Division has no plans to introduce sport fish species into the lower Milk River, and is unlikely to in the future (T. Clayton, pers. comm.). The Milk River and its tributaries in Alberta have not been stocked for at least 10 years. Goldsprings Park Pond, an old oxbow of the river with no connection to the mainstem is stocked annually with Rainbow Trout (T. Clayton, pers. comm.). It is unknown if unauthorized introductions have occurred in the Milk River.

The overall level of this threat for Western Silvery Minnow ranges from Low to High depending on the species introduced (Table 6) and its effect is Widespread and Chronic (Table 7).

There may be other introduced species other than fish that also occur in the Milk River that may impact Western Silvery Minnow, such as Northern Crayfish (*Orconectes virilis*). *Didymosphenia geminata* is not considered a threat because it is eaten by Western Silvery Minnow.

Contaminants and Toxic Substances

Point source and non-point source pollution exists in the Milk River watershed with the extent and severity of any damage to the aquatic community including Western Silvery Minnow depending on the substance released, the location of spill, time of year (flow augmentation or not), and the potential to mitigate the impacts.

Point Source Contamination

Point sources of pollution include any stormwater and sewage releases, contamination of water from seismic or drilling activities, and accidental spills and gas leaks, particularly at river and tributary crossings. The Town of Milk River stopped releasing sewage into the Milk River 20 years ago, and stormwater is surface run-off (K. Miller, pers. comm.) making both of these a minimal risk. The release of a toxic substance at any one of the river crossings including bridges or pipelines could have serious consequences. No such spills have been documented for the Milk River, however the possibility, although quite low, exists as traffic is significant at some crossings. For example, in 2003 there were an average of 2,700 crossings per day on the Highway 4 bridge, 25% by trucks. Gas leaks have also occurred in recent years (S. Petry, pers. comm.).

The threat level of point source contamination to Western Silvery Minnow ranges from Low to High (Table 6) and is Widespread but Ephemeral (Table 7).

Non-point Source Contamination

Non-point sources of pollution in the Milk River watershed would include the runoff of agricultural pesticides and fertilizers. Elevated levels of fecal coliform have also been recorded in the Milk River.[1] The rough terrain near the Milk River channel prevents crops in most areas from being grown adjacent to the river (K. Miller, pers. comm.), reducing the potential for direct contamination of the river. However, nutrient concentrations can become elevated at downstream sites such as the Highway 880 crossing (W. Koning, pers. comm.). Water quality in the Milk River changes in response to flow augmentation, with increases in total dissolved solids, conductivity and salinity when the diversion stops in the winter months (W. Koning, pers. comm.). Thus, the likelihood of occurrence of Non-point Source Contamination is Known although its impact is considered Low to High depending on the substance released, concentration and the time of the year (Table 4).

The overall threat level of non-point source contamination to Western Silvery Minnow ranges from Low to High (Table 6) and is Widespread and Chronic (Table 7).

Other Threats

Scientific Sampling

Scientific sampling may remove individuals from the population or result in delayed mortality. However, the impact of this threat is low as it usually involves live-sampling and has a high potential for mitigation as it is regulated through the issuance of permits under the SARA.

[1] A microbial source tracking study was undertaken along the Milk River, including Writing-on-Stone Provincial Park, between April and August 2012. Preliminary results indicate that a combination of sources may contribute to the recorded high fecal coliform counts including livestock and wildlife, especially birds like geese and cliff swallows, and naturalized *Escherichia coli* (*E. coli*). The latter would have important implications for the interpretation of microbial water quality in the watershed (Tymensen et al. 2013, Microbial source tracking of fecal contamination. *In* Manure Management Update 2013 Conference Proceedings, p. 11).

The threat level and effects of scientific sampling to Western Silvery Minnow in the Milk River are Low, Local and Ephemeral (Tables 6 and 7).

Climate Change

Climate change has the potential to impact water availability, temperature and a broad range of other threats (Schindler 2001). Through discussion on 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). The effects of climate change on Western Silvery Minnow in Alberta are unclear, but as the distribution of this species in Canada is limited, it is particularly susceptible to habitat loss and degradation, which climate change is expected to exacerbate. Climate Change as a threat was not included in the threats analysis.

MITIGATION AND ALTERNATIVES

Habitat Loss/Degradation

Numerous threats affecting Western Silvery Minnow are related to habitat loss or degradation. Habitat-related threats have been linked to the Pathways of Effects developed by DFO Fish Habitat Management (FHM) (Table 8). Guidance on generic mitigation measures have been developed for 19 Pathways of Effects for the protection of aquatic species at risk in DFO's Central and Arctic Region (Coker et al. 2010), some of which are relevant for the Milk River watershed. These mitigation measures should be referred to when considering mitigation and alternative strategies for habitat-related threats. They were developed to mitigate, limit or minimize threats, however, since they were not developed to specifically consider species at risk so they may need to be modified for this purpose. Additionally, site-specific mitigations may be warranted and should be discussed with local conservation managers. Table 8 identifies the relevant Pathways of Effects for Western Silvery Minnow.

Table 8. Threats to Western Silvery Minnow in Canada and the Pathways of Effects associated with each threat as per Coker et al. 2010. 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.

Threats	Pathways of Effects
Changes in flow	10, 16, 17
Surface water extraction: irrigation and non-irrigation	12, 16
Groundwater extraction	12, 16
Livestock use of flood plain	1, 8, 13
Dam construction and operation	1, 2, 3, 4, 5, 6, 7, 10, 11, 13, 14, 15, 16, 17, 18
Non-point source contamination	1, 4, 7, 8, 11, 12, 13, 15, 16, 18
Point source contamination	1, 4, 5, 6, 7, 11, 12, 13, 14, 15, 16, 18

Contaminants and Toxic Substances

The DFO mitigation guide (Coker et al. 2010) also provides guidance on generic mitigation measures for Pathways of Effects related to contaminants and toxic substances from point and non-point sources. Table 8 shows the relevant Pathways of Effects for Western Silvery Minnow. These measures combined with legislative control/licensing at the provincial and federal levels, public education and developing plans to contain and clean up spills and other releases of pollutants have the potential to mitigate this threat. Alternative measures, such as reductions in pesticides, are market driven.

Pathways of Effects were not developed for species introductions or other threats like scientific sampling so the following specific mitigation measures and alternatives are provided for those types of threats.

Fish Species Introductions

Non-native fish species introductions and establishment could have negative effects on Western Silvery Minnow.

Mitigation

- Physically remove non-native species from areas known to be inhabited by Western Silvery Minnow.
- Monitor watersheds for exotic species that may negatively affect Western Silvery Minnow directly, or negatively affect their preferred habitat.
- Coordinate with Montana/U.S. agencies to evaluate all introductions of exotic species in the Milk River systems.
- 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.

Alternatives

Unauthorized

- None

Authorized

- Use only native species of the same genetic stock.
- Follow the National Code on Introductions and Transfers of Aquatic Organisms for all aquatic organism introductions (DFO 2003).

Scientific Sampling

Targeted and incidental harvest of Western Silvery Minnow may occur while undertaking scientific sampling. It was recognized as a low risk threat.

Mitigation

- Non-lethal sampling
- Sampling under a SARA permit

LIMITING FACTORS FOR POPULATION RECOVERY

Western Silvery Minnow is a riverine species that has adapted to survive in warm, turbid, running waters. Changing these conditions will likely have an adverse effect on survival of the species. Flow regulation or decreased sedimentation might, for example, cause them to lose their advantage to competitors or increase their vulnerability to predators such as Sauger (*Sander vitreus*).

SOURCES OF UNCERTAINTY

Very little information is available on some key aspects of the life history and biology of the Western Silvery Minnow. Studies have not, for example, been conducted to describe the species' reproductive strategy or overwintering requirements. Because accurate threats assessments and critical habitat identifications depend upon knowledge of the species' reproductive strategy and its overwintering requirements, such studies should be a priority. There is also little or no information available on population structure, movements or early life stages.

The specific habitat needs of Western Silvery Minnow, particularly for eggs and fry, remain unknown. Spawning has not been documented in the Milk River, nor has the presence of larval and early juvenile stages. Overwintering habitats also have not been documented and the relationship between sediment load, turbidity and the abundance of minnows remains unresolved.

To date, there are no reliable abundance estimates for Western Silvery Minnow within the Milk River. As such, it is not yet possible to set a conservation population target size, or to confirm whether changes in abundance have occurred. The magnitude of natural variability in population size is also unknown, making it difficult to determine if changes in abundance over the short term are related to normal fluctuations or a real change in population status. However, recent studies suggest that abundance of Western Silvery Minnow may be significantly greater than previously assumed (DFO, unpubl. data).

Some potential threats cannot be fully evaluated because detailed information on the stressors and the mechanisms potentially affecting the minnow are not well understood. To accurately predict the effects of impoundment, for example, requires better knowledge of how changes in the physical conditions of the river, such as an altered flow regime, may interact with the species given its life history and habitat requirements. Further study of these relationships is warranted.

Finally, knowledge of the frequency and magnitude of catastrophic events and true extinction thresholds of Western Silvery Minnow in Alberta are needed for population modelling to assess allowable harm, determine population-based recovery targets and conduct long-term projections of population recovery.

OTHER LIMITING FACTORS

The 1909 Boundary Waters Treaty (the Treaty), which is administered by the International Joint Commission (IJC), provides principles for Canada and the United States to follow for the management of shared waters including the St. Mary and Milk rivers (ISMMRAMTF 2006; see also Dolan 2007; Halliday and Faveri 2007a,b; Rood 2007). In 1917, the United States constructed a canal to divert water from the St. Mary River in northwestern Montana through the Milk River system, across southern Alberta, to northeastern Montana for irrigation. An average of about 2.08×10^8 m^3 of water has flowed annually through the St. Mary Canal into the North Milk River over the past two decades (U.S. Bureau of Reclamation 2004). In 2003, Montana requested that the Treaty be re-opened to reconsider how the diverted water is apportioned. However, at the time of writing, this issue had not yet been resolved. At present the operating capacity of the St. Mary Canal is about 18.4 $m^3 \cdot s^{-1}$, significantly less than its original design capacity of 24.1 $m^3 \cdot s^{-1}$. Montana is considering whether to rehabilitate the aging canal infrastructure and return the canal to its original capacity, or whether to increase its capacity to 28.3 $m^3 \cdot s^{-1}$ (Alberta Environment 2004; U.S. Bureau of Reclamation 2004).

Additionally, there may be implications of species introductions by U.S. jurisdictions to Western Silvery Minnow in Canadian waters as there is no joint agreement currently in place between Alberta and Montana regarding species introductions in the Milk River.

PERSONAL COMMUNICATIONS

R. Bramblett, Montana State University, Bozeman, MT.

T. Clayton, Alberta Sustainable Resource Development, Lethbridge, AB.

L. Fitch, Alberta Sustainable Resource Development, Lethbridge, AB.

W. Koning, Alberta Environment, Calgary, AB.

K. Miller, Milk River Watershed Council of Canada, Milk River, AB.

S. Petry, (former employee of Fisheries and Oceans Canada), Alberta Sustainable Resource Development, Medicine Hat, AB.

LITERATURE CITED

Alberta Environment. 2004. Alberta's submission to the International Joint Commission respecting a review of the IJC's 1921 order on the measurement and apportionment of the St. Mary and Milk rivers. Edmonton, AB. i + 33 p.

AMEC. 2008. Study of erosion and sedimentation on the Milk River. Submitted to the Milk River Watershed Council of Canada. AMEC Earth and Environmental Ltd., Calgary, AB. 125 p. + appendices.

Alò, D., and Turner, T.F. 2005. Effects of habitat fragmentation on effective population size in the endangered Rio Grande Silvery Minnow. Conserv. Biol. 19: 1138-1148.

Al-Rawi, A.H., and Cross. F.B. 1964. Variation in the Plains Minnow, *Hybognathus placitus* Girard. Trans. Kans. Acad. Sci. 67: 154-168.

Bailey, R.M., and Allum. M.O. 1962. Fishes of South Dakota. Misc. Publ. Mus. Zool. Univ. Mich. 119. 131 p.

Bonner, T.H., and Wilde, G.R. 2002. Effects of turbidity on prey consumption by prairie stream fishes. Trans. Am. Fish. Soc. 131: 1203-1208.

Bradley, C., and Smith, D.G. 1986. Plains cottonwood recruitment and survival on a prairie meandering river floodplain, Milk River, southern Alberta and northern Montana. Can. J. Bot. 64: 1433-1442.

Clayton, T.B., and Ash, G.R. 1980. A fisheries overview study of the Milk River basin. Rep. by R.L. & L. Environmental Services for Alberta Environment, Edmonton, AB. x + 94 p. [available in the DFO library]

Coker, G.A., Ming, D.L., and Mandrak, N.E. 2010. Mitigation guide for the protection of fishes and fish habitat to accompany the species at risk recovery potential assessments conducted by Fisheries and Oceans Canada (DFO) in Central and Arctic Region. Version 1.0. Can. Manuscr. Rep. Fish. Aquat. Sci. 2904: vi + 40 p.

COSEWIC. 2008. COSEWIC assessment and update status report on the Western Silvery Minnow *Hybognathus argyritis* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa, ON. vii + 38 p.

Cowley, D. 2002. Water requirements for endangered species – Rio Grande Silvery Minnow (*Hybognathus amarus*). New Mexico Water Resources Research Institute (October 2002): 97-107.

Cross, F.B. 1967. Fishes of Kansas. Univ. Kansas Publ. Mus. Nat. Hist. No. 45. University of Kansas, Lawrence, KS. 357 p.

Cross, F.B., Mayden, R.L., and Stewart, J.D. 1986. Fishes in the western Mississippi drainage. *In* The zoogeography of North American freshwater fishes. Edited by C.H. Hocutt and E.O. Wiley. John Wiley & Sons, Toronto, ON. 880 p.

Dolan, L.S. 2007. Comment on "The St. Mary and Milk rivers: the 1921 order revisited" by R. Halliday and G. Faveri, *Canadian Water Resources Journal*, 32(1): 75-92. Can. Wat. Resour. J. 32: 335-338.

Durham, B.W., and Wilde, G.R. 2006. Influence of stream discharge on reproductive success of a prairie stream fish assemblage. Trans. Am. Fish. Soc. 135: 1644–1653.

Grove, G. 1985. An investigation of the streamflow-ground water interactions along a portion of the Milk River, Alberta. National Hydrology Research Institute, Inland Waters Directorate, Environment Canada. 38 p. [available from the Alberta Government Library – Great West Life, Edmonton, AB]

Halliday, R., and Faveri, G. 2007a. The St. Mary and Milk rivers: the 1921 order revisited. Can. Wat. Resour. J. 32: 75-92.

Halliday, R., and Faveri, G. 2007b. Response to comments by S.B. Rood and L.S. Dolan on "The St. Mary and Milk rivers: the 1921 order revisited". Can. Wat. Resour. J. 32: 339-342.

Hlohowskyj, C.P., Coburn, M.M., and Cavender, T.M. 1989. Comparison of a pharyngeal filtering apparatus in several species of the herbivorous cyprinid genus *Hybognathus* (Pisces:Cyprinidae). Copeia 1989: 172-183.

Hoagstrom, C.W., DeWitte, A.C., Gosch, N.J.C., and Berry, C.R., Jr. 2007. Historical fish assemblage flux in the Cheyenne River below Angostura Dam. J. Freshw. Ecol. 22: 219-229.

Hoagstrom, C.W., Brooks, J.E., and Davenport, S.R. 2011. A large-scale conservation perspective considering endemic fishes of the North American plains. Biol. Conserv. 144: 21-34.

ISMMRAMTF (International St. Mary – Milk Rivers Administrative Measures Task Force). 2006. Report to the International Joint Commission. 125 p. [accessed April 10, 2013]

Lemmen, D.S., and Warren, F.J. 2004. Fisheries. *In* Climate change impacts and adaptation: a Canadian perspective. Edited by D.S. Lemmen and F. J. Warren. Natural Resources Canada, Ottawa, ON. xxiv + 174 p. [accessed January 7, 2013]

Matthews, W.J., and Maness, J.D. 1979. Critical thermal maxima, oxygen tolerances and success of cyprinid fishes in a southwestern river. Am. Mid. Nat. 102: 374−377.

McLean, D.G., and Beckstead, G.R. 1985. Long term effects of a river diversion on the regime of the Milk River. Alberta Research Council, Edmonton, AB. Contribution No. 1054. 21 p.

Milk River Fish Species at Risk Recovery Team. 2011. Recovery strategy for the Western Silvery Minnow (*Hybognathus argyritis*) in Canada. *Species at Risk Act* Recovery Strategy Series, Fisheries and Oceans Canada, Ottawa. viii + 39 p. 2008 version of strategy.

Natural Regions Committee. 2006. Natural regions and subregions of Alberta. Compiled by D.J. Downing and W.W. Pettapiece. Government of Alberta Pub. No. T/852. Edmonton, AB. vi + 254 p. [accessed January 7, 2013]

NatureServe. 2011. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, VA.

Nelson, J.S., and Paetz, M.J. 1992. The fishes of Alberta. Second Edition. The University of Alberta Press, Edmonton, AB. 437 p.

Niazi, A.D., and Moore, G.A. 1962. The Weberian apparatus of *Hybognathus placitus* and *H. nuchalis* (Cyprinidae). Southwest. Nat. 7: 41-50.

Noton, L. 1980. Milk River basin environmental overview: surface water quality overview and assessment. Volume 1 (main report). Rep. prep. by Chemical and Geological Laboratories Ltd. for the Alberta Environment Planning Division. vii + 82 p. [available from The Alberta Government Library and the University of Alberta library]

Ostrand, K.G., and Wilde, G.R. 2001. Temperature, dissolved oxygen, and salinity tolerance of five prairie stream fishes and their role in explaining fish assemblage patterns. Trans. Am. Fish. Soc. 130: 742-749.

Page, L.M., and Burr, B.M. 1991. A field guide to the freshwater fishes of North America north of Mexico. Houghton Mifflin Company, Boston and New York. 432 p.

Perkin, J.S., and Gido K.B. 2011. Stream fragmentation thresholds for a reproductive guild of Great Plains fishes. Fisheries 36: 371-383.

Pflieger, W.L. 1971. A distributional study of Missouri fishes. Misc. Publ. Univ. Kans. Mus. Nat. Hist. No. 20: 225-570.

Pflieger, W.L. 1997. The Fishes of Missouri, revised edition. Missouri Department of Conservation, Jefferson City, MO. 372 p.

Pflieger, W.L., and Grace, T.B. 1987. Changes in the fish fauna of the lower Missouri River. 1940-1983. *In* Community and evolutionary ecology of North American stream fishes. Edited by W.J. Matthews and D.C. Heins. University of Oklahoma Press, Norman, OK. 320 p.

Platania, S.P., and Altenbach, C.S. 1998. Reproductive strategies and egg types of seven Rio Grande Basin cyprinids. Copeia 3: 559-569.

Porter M.D, and Massong T.M. 2006. Progress report 2005, contributions to delisting the Rio Grande Silvery Minnow: egg habitat identification. Bureau of Reclamation, Albuquerque, NM.

Pringle, C.M. 1997. Exploring how disturbance is transmitted upstream: going against the flow. J. North Am. Benthol. Soc. 16: 425-438.

Quist, M.C., Hubert, W.A., and Rahel, F.J. 2004. Relations among habitat characteristics, exotic species, and turbid-water Cyprinids in the Missouri River drainage of Wyoming. Trans. Am. Fish. Soc. 133: 727-742.

R.L. & L. Environmental Services Ltd. 2002. Fish species at risk in the Milk and St. Mary Drainages. Prepared for Alberta Sustainable Resource Development, Fish and Wildlife Division, Alberta Species at Risk Report 45. Edmonton, AB. xii + 82 p.

Robison, H.W., and Buchanan T.M. 1988. Fishes of Arkansas. University of Arkansas Press, Fayetteville, AR. 536 p.

Rood, S.B. 2007. Comment on "The St. Mary and Milk rivers: the 1921 order revisited" by R. Halliday and G. Faveri, *Canadian Water Resources Journal*, 32(1): 75-92. Can. Wat. Resour. J. 32: 331-334.

Schindler, D.W. 2001. The cumulative effects of climate warming and other human stresses on Canadian freshwaters in the new millennium. Can. J. Fish. Aquat. Sci. 58: 18-29.

Schmidt, T.R. 1994. Phylogenetic relationships of the genus Hybognathus (Teleosti: Cyprinidae). Copeia 1994: 622-630.

Spitzer, M.O. 1988. Sediment data Milk River basin. Water Survey of Canada IWD-WNR(A)-WRB-SS-87-2. Water Resources Branch Environment Canada, Edmonton, AB.

Stash, S.W. 2001. Distribution, relative abundance, and habitat associations of Milk River fishes related to irrigation diversion dams. Thesis (M.Sc.) Montana State University, Bozeman, MT. 67 p.

Sublette, J.E., Hatch, M.D., Sublette, M. 1990. The fishes of New Mexico. University of New Mexico Press, Albuquerque, NM. 393 p.

U.S. Bureau of Reclamation. 2004. Regional feasibility report – North Central Montana. Montana Area Office, Billings, MT. iii + 115 p. [available in the DFO library]

Welker, T.L., and Scarnecchia, D.L. 2004. Habitat use and population structure for four native minnows (family Cyprinidae) in the upper Missouri and lower Yellowstone rivers, North Dakota (USA). Ecol. Freshw. Fish 13: 8-22.

Willock, T.A. 1969. The ecology and zoogeography of fishes in the Missouri (Milk River) drainage of Alberta. Thesis (M.Sc) Carleton University, Ottawa, ON. xiv + 210 p. [available in the DFO library]

Winston, M.R., Taylor, C.M., and Pigg, J. 1991. Upstream extirpation of four minnow species due to damming of a prairie stream. Trans. Am. Fish. Soc. 120: 98-105.

WSC (Water Survey of Canada). 2011. Archived hydrometric data, Milk River at Milk River (11AA005), monthly mean discharge, June 1909 to December 2011.