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Pacific Region

Recovery Potential Assessment for the Salish Sucker In Canada

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Canada

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.

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ABSTRACT

Little information is available on the natural history, abundance, population trends, and habitat use of the Salish Sucker. Consequently there are many uncertainties in this paper. The Salish Sucker is documented from 11 watersheds in Canada and six in Washington State. No populations are known to have been extirpated, but significant reductions in area occupied within many of the watersheds are documented. Insufficient information exists to estimate minimum viable population size, but the Salish Sucker's life history traits are associated with rapid population growth, resilience to environmental disturbance, and the ability to rapidly (re)colonize habitat. Seasonal hypoxia is the leading threat, affecting up to two-thirds of the more than 180 km of proposed critical habitat in hot dry summers. Habitat destruction, seasonal dewatering, and toxicity are also considered significant threats. Sediment deposition, habitat fragmentation, and introduced predators may be significant but their impacts are poorly understood. Target population sizes vary from 1500 to 5000 adults in the 11 known populations. Estimates of current abundance exist for all or part of seven populations and are far below target populations in all cases. Achieving targets is feasible if the geographic extent of severe hypoxia in proposed critical habitat is reduced.

Évaluation du potentiel de rétablissement du meunier de Salish au Canada

RÉSUMÉ

Peu de données sont disponibles sur l'histoire naturelle, l'abondance, les tendances de la population et l'utilisation de l'habitat par le meunier de Salish. C'est pourquoi le document présente de nombreuses incertitudes. Les données sur le meunier de Salish proviennent de onze bassins hydrographiques canadiens et de six bassins de l'État de Washington. D'après les connaissances actuelles, aucune population n'aurait disparu, mais des diminutions significatives de l'aire occupée par l'espèce ont été constatées dans de nombreux bassins hydrographiques. Les renseignements actuels étant insuffisants, il est impossible d'estimer la taille minimale nécessaire à la viabilité de la population. Cependant, les caractéristiques du cycle biologique du meunier de Salish sont associées à une croissance de la population rapide, une résilience aux perturbations environnementales et une capacité à rapidement (re)coloniser un habitat. L'hypoxie saisonnière est la principale menace pesant sur l'espèce, touchant jusqu'aux deux tiers de l'habitat essentiel proposé, qui fait plus de 180 km, pendant les étés chauds et secs. La destruction de l'habitat, l'assèchement saisonnier et la toxicité sont également considérés comme des menaces importantes. Le dépôt de sédiments, la fragmentation des habitats et l'introduction de prédateurs pourraient également être des facteurs non négligeables, mais on connaît mal leurs impacts. La taille des groupes cibles varie de 1 500 à 5 000 adultes dans les onze populations connues. L'abondance actuelle a été estimée pour la totalité ou une partie de sept populations de meunier de Salish. Elle est dans tous les cas bien inférieure aux groupes cibles. Il est possible d'atteindre les objectifs des groupes cibles si l'étendue géographique de l'hypoxie sévère est réduite dans l'habitat essentiel proposé.

1 INTRODUCTION

A Recovery Potential Assessment (RPA) is intended to provide the best possible advice on recovery potential, using available data and identifying information gaps. Relatively few data are available on the natural history, abundance, population trends, and habitat use of the Salish Sucker (*Catostomus* sp. cf. *catostomus*) in Canada. Available information is limited to three peer reviewed papers, part of a doctoral thesis (Pearson 2004a), some unpublished reports and the field experience of a handful of biologists. Currently, a MSc thesis (Jill Miners, University of British Columbia [UBC], Vancouver, BC) is in progress, and a very limited amount of mark-recapture work and habitat mapping is being done annually across the range. Given this limited knowledge base, there are many uncertainties in assessments of the elements of the RPA, which are noted throughout. This document conforms to the revised protocol for conducting RPAs (DFO 2009a).

1.1 HISTORY OF STATUS AND RECOVERY PLANNING

The Salish Sucker was listed as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 1986, and added to Schedule 1 of the Species at Risk Act in 2005. An RPA was conducted in 2009 (DFO 2009b) and a proposed Recovery Strategy (Fisheries and Oceans Canada 2012), including proposed Critical Habitat, was posted on the Species at Risk Act Public Registry. Following the most recent status review (COSEWIC 2012), COSEWIC reassessed the Salish Sucker as Threatened, citing "a small increase in the number of known locations (from 9 to 14), including one location thought to have been extirpated, and some improvements in quality of habitat in areas subject to restoration". Consequently, a recommendation was made to the Minister of Environment to reclassify the Salish Sucker as Threatened under Schedule 1 of SARA (COSEWIC 2013). To inform the Minister, it is standard practice to prepare a RPA to update and consolidate information and advice on Salish Sucker acquired since the 2009 RPA. It builds on previous work and updates key information on abundance, distribution and threats.

1.2 BIOLOGY, ABUNDANCE, DISTRIBUTION AND LIFE HISTORY

1.2.1 Summary of Biology of Salish Sucker

The Salish Sucker is a genetically and morphologically distinct taxon within the Longnose Sucker (*Catostomus catostomus*) genome, although the precise taxonomic relationship is uncertain (McPhail & Taylor 1999). The Salish Sucker is short lived (to five years) and typically spawns between early April and early July. It does not construct a nest, but broadcast adhesive eggs which stick to gravel and rocks (McPhail 1987). Adults may spawn in multiple years and females are likely able to spawn more than once in a single year (Pearson and Healey 2003). Adults feed on aquatic insects, but the diet of first-year juveniles is unknown. Adults are active throughout the night, and are most active around dawn and dusk. During the day they rest in heavy cover, often among thick vegetation adjacent to the open channel. They tend to return to the same resting location on successive days (Pearson and Healey 2003). Juvenile activity patterns are unknown. The Salish Sucker is active at temperatures as low as 7 ^{o}C and is commonly found in water exceeding 20 ^{o}C (Pearson and Healey 2003). It can tolerate relatively low dissolved oxygen levels (3.5 mg/l). Within watersheds, populations are aggregated, with a small proportion of habitat supporting the great majority of individuals (Pearson 2004a). Beaver dams, and probably other shallow-water areas, are significant barriers to movement, although fish will cross these areas to access spawning sites (Pearson and Healey 2003). Adults are preyed upon by Mink (*Neovison vison*) and River Otter (*Lontra canadensis*). Juveniles are probably taken by a variety of fish and birds (Pearson 2004; Fisheries and Oceans Canada 2012).

1.3 DISTRIBUTION AND ABUNDANCE

1.3.1 Distribution

The global distribution of the Salish Sucker extends from the Fraser Valley through Washington State on the west side of the North Cascade Mountains to the southern end of Puget Sound (Figure 1).Within Canada, they are known from 11 small watersheds (Figure 2). In Washington State populations are documented in lakes and tributaries of six moderate sized watersheds (Mongillo & Hallock 1997; Wydoski & Whitney 2003), but less search effort has been expended there.

There is no evidence that the number of Canadian watersheds occupied by the Salish Sucker has changed since the taxon was first documented in Canada, more than 50 years ago.

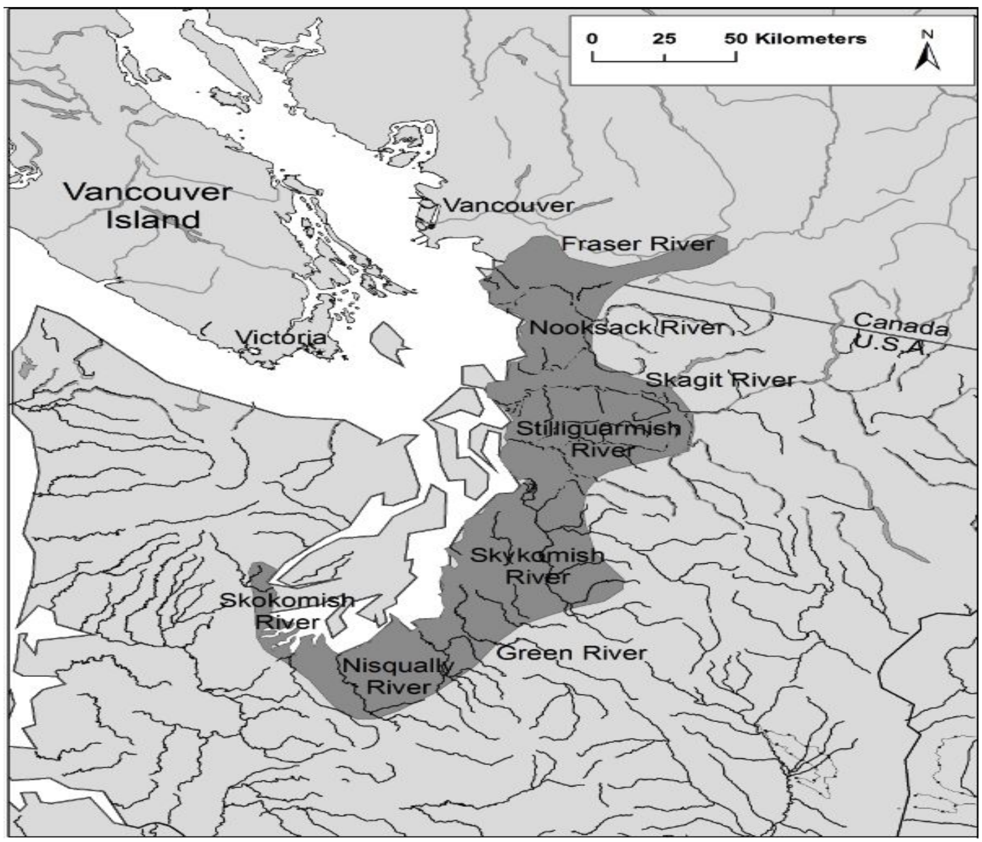

Figure 1. Global Range of the Salish Sucker

For many years it was believed that the Little Campbell River population was extirpated (COSEWIC, 2002; Fisheries and Oceans Canada, 2012; McPhail, 1987; Pearson & Healey, 2003; Pearson, 2004a). This population was 'rediscovered' in October 2011 with the capture of a single individual in a flood plain pond. Since then, 20 individuals encompassing all age classes have been captured at locations scattered across the watershed, confirming the continued existence of a population (Pearson 2014). Similarly, the Salwein Creek population was believed extirpated at one time (Inglis et al. 1992), but was later found to exist (Pearson, 2004a).

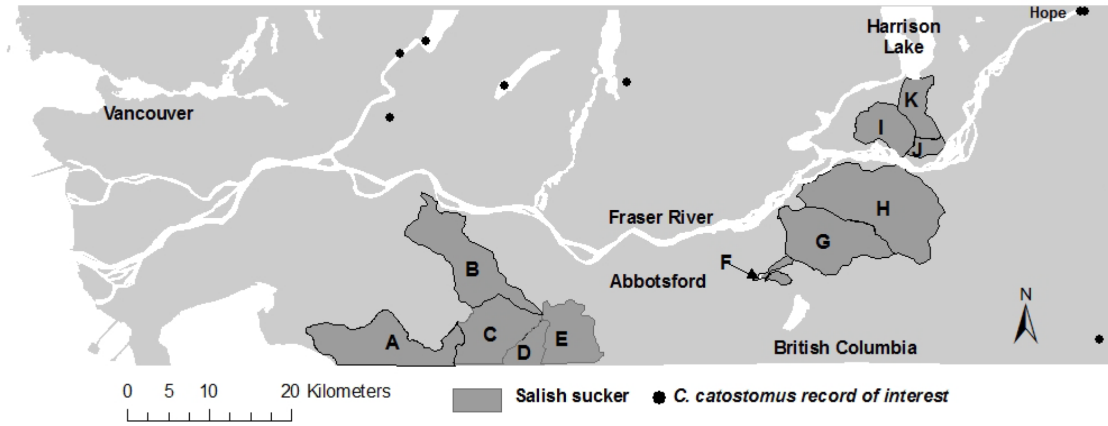

Figure 2. Salish Sucker populations are known from the Little Campbell River (A, 2014), the Salmon River (B, 2013), Bertrand Creek (C, 2013), Pepin Creek (D, 2014), Fishtrap Creek (E, 2012), Salwein Creek and Hopedale Slough (F, 2013), the Chilliwack Delta streams (G, 2014), Elk Creek and Hope Slough (H, 2009), Mountain Slough (I, 2014), Agassiz Slough (J, 2014) and the Miami River (K, 2013). Years refer to the date of most recent capture. Points refer to records of C. catostomus from other watersheds (FISS database and Beatty Museum), some of which may be misidentified Salish Suckers (adapted from COSEWIC 2012).

Given that five of the known populations were found since 2000 and that some areas of the Fraser Valley have not been intensively surveyed using appropriate methods (e.g. Pitt Meadows and Hope areas), it is very possible that one or more Canadian populations remain undiscovered. A number of records of *C. catostomus* from other Fraser Valley watersheds exist (Figure 2). Some of these may be misidentified Salish Suckers, as no records of *C. catostomus* confirmable by voucher specimens exist for locations more than a few kilometres west of Hope.

Some direct and some circumstantial evidence indicates that the distribution of the Salish Sucker within occupied watersheds has been substantially reduced in recent decades.

The Salish Sucker was common in the Lower Salmon River and in parts of the Little Campbell River and Bertrand Creek in the 1950s, but was absent or extremely rare in these areas by the 1980s (McPhail 1987), and remains so today. Only 20 individuals have been caught in over 400 trap sets in the Little Campbell River since 2011 (Pearson, unpub data[1]).

Pearson (2004a) documented the total disappearance of the Salish Sucker from a marshy reach of Pepin Creek in 2003 where they had been extremely abundant from 1999 to 2002. The disappearance was concurrent with a worsening of water quality conditions, specifically low levels of dissolved oxygen (hypoxia). The reach remains hypoxic and no Salish Suckers were found in repeated sampling in 2011 and 2012 (Jill Miners, unpub. data[2]).

The Salish Sucker likely inhabited Sumas Lake, a large (80 – 100 km^2) shallow lake surrounded by extensive wetlands, until it was drained in the 1920s. A small population still inhabits Salwein Creek and Hopedale Slough, both of which were part of this complex.

Anecdotal information suggests that Salish Sucker inhabited the headwaters of Cave Creek, in the Bertrand Creek watershed, prior to the drainage of a wetland in the 1960s (Pearson 1998).

[1] Mike Pearson, Pearson Ecological, Agassiz, BC, unpublished data

[2] Jill Miners, Department of Geography, University of British Columbia, Vancouver, BC, unpublished data

Given the extent of wetland loss in the Fraser Valley over the past century, it seems likely that many similar, but undocumented, losses have also occurred.

Conversely, several reach-scale habitat creation projects have been readily colonized by Salish Sucker and used by hundreds of individuals (Patton 2003; Pearson 2004b; Pearson unpub. data[1]; Jill Miners, unpub. data[2]). The total area of these projects, however, is dwarfed by that of habitats lost historically or currently compromised by poor water quality. Other significant aquatic habitat creation or enhancement projects have been completed on Salwein Creek, and Mountain Slough. Salish Sucker use of these sites has been demonstrated (Pearson unpub. data[1]), but abundance has not been estimated in them.

1.3.2 Abundance

Recent estimates based on mark-recapture studies are available for some, but not all, watersheds or subwatersheds (Table 1).

Range-wide abundance has likely declined considerably over the past century, given the evidence for widespread reductions in distribution within watersheds (see above), however, no quantitative trajectory information exists. The few older estimates of abundance, including those in the proposed Recovery Strategy (Fisheries and Oceans Canada 2012), utilized a catch-per-unit-effort (CPUE) based method now known to be unreliable because CPUE has a weak relationship with density (COSEWIC 2012).

Table 1. Abundance estimates of Salish Sucker populations made using mark-recapture. Bracketed years indicate the year of completed, attempted, or scheduled estimate. 'X' indicates an attempt in which too few fish were captured to make an estimate.

Population	**Subwatershed**	**Mean population estimate (95% CI)**
Agassiz Slough	Agassiz Slough (2012)**	253 (203-354)
Bertrand Creek	Bertrand mainstem (2013)*	735 (638-862)
	Perry Homestead (2016)	
	Howe's Creek (2012)**	329 (206-711)
Chilliwack Delta	Luckakuck Creek (2014)*	378 (345-416)
	Semmihault Creek (2015)	
	Atchelitz Creek (2015)	
	Little Chilliwack Creek (2015)	
Elk/Hope Slough	Elk Creek/Hope Slough (2006)	X
Fishtrap Creek	Fishtrap Creek (2013)	X
Little Campbell River	Little Campbell River (2014)	X
Miami River	Miami River (2012)**	102 (67-193)
Mountain Slough	Mountain Slough (2016)	
Pepin Creek	Pepin Creek (2012)**	1754 (1318-2900)
Salmon River	Upper Salmon River (2013)*	751 (649-915)
	Lower Salmon River (2013)	X
Salwein/Hopedale Slough	Salwein Creek (2012)*	288 (191-635)
	Hopedale Slough (2012)*	469 (346-712)

*Pearson 2013, 2014 **Jill Miners, University of British Columbia, unpub. data

1.3.3 Life History Parameters

The Salish Sucker is characterized by life history traits that are associated with rapid population growth, resilience to environmental disturbance, and the ability to rapidly (re)colonize habitat over short distances. They mature earlier, and at smaller body size than any known population of *Catostomus catostomus.* Sexual maturity is reached at the end of the second year and maximum longevity is five to six years (McPhail 1987).The spawning period is also very protracted (early April to mid-July) relative to other Catostomids (Pearson & Healey 2003), suggesting that females may spawn more than once in a season. This adaptation allows increased fecundity in small bodied species and is common in headwater stream fishes (Blueweiss et al. 1978; Burt et al. 1988).

There are insufficient data to estimate population parameters required for population viability analysis. In particular, no data on fecundity and recruitment rates are available. Relationships between vital rates and habitat quality are not available. Information on the relative quality and substitutability of key habitats for specific populations is also not available (e.g. potential substitutability of spawning habitats in different tributaries).

2 HABITAT REQUIREMENTS

2.1 HABITAT PROPERTIES

Although several lacustrine populations are found in Washington State (Mongillo & Hallock 1997; Wydoski & Whitney 2003), all known Canadian Salish Sucker populations occupy lowland streams and sloughs, particularly headwater marshes and beaver ponds.

The Salish Sucker requires suitable aquatic habitat structure, functional riparian areas and minimum water quality levels. Essential properties of each of these habitat types are listed in Table 2. Detailed rationale for the inclusion of each habitat type and its properties can be found the Proposed Recovery Strategy (Fisheries and Oceans Canada 2012).

Table 2. Habitat properties required for all life history stages of the Salish Sucker.

Habitat Type	Properties	Life History Stage(s)	Comments
Deep Pools	• >70 cm depth • >50 m long • Adequate food supply of insects (food) • Dissolved oxygen >3.5 mg/l • Temperature between 6°C and 23°C • Absence of harmful pollutants	Adults Yearlings	Primary feeding and rearing habitat
Riffles	• Often in small tributary streams • Cobble or gravel substrate • Low proportion of fine sediment • Sufficient flow to maintain riffles • Sufficient intragravel flow to maintain eggs • Adequate food supply of terrestrial and aquatic insects • Temperatures between 6°C and 23°C • Dissolved oxygen >7mg/l (for eggs)	Adults Eggs	Primary spawning habitat

Habitat Type	Properties	Life History Stage(s)	Comments
	• Absence of harmful pollutants		
Shallow Pools and Glides	• < 40 cm depth • Adequate food supply of terrestrial and aquatic insects • Dissolved oxygen >3.5 mg/l • Temperature between 6°C and 23°C • Absence of harmful pollutants	Young of the Year	Nursery Habitat
Riparian	• Native riparian species, typically trees and shrubs • Continuous • Extends inland from top of bank 5 to 30 m depending on stream characteristics • Provides adequate food supply of terrestrial insects • Provides bank stability, shade and woody debris • Provides adequate buffer from impacts of adjacent land uses	All Stages	Maintains the integrity of aquatic habitat and augment food supply

2.2 EXTENT OF AREAS LIKELY TO HAVE REQUIRED HABITAT PROPERTIES

Areas with physically suitable aquatic habitat have been identified and proposed as Critical Habitat in the Proposed Recovery Strategy, and in a more recent report to BC Ministry of Environment and Fisheries and Oceans Canada (Pearson 2014b). The extent of this habitat is summarized in Table 3.

No recent data is available on the integrity or function of riparian habitat. An analysis using high resolution aerial photographs from 2004 (Figure 3) showed that woody riparian vegetation extended less than 5 m inland from the bank on 54% of channel length across all watersheds. This ranged from a low of 12 % in the Little Campbell River watershed to high of 93% in the Agassiz Slough watershed (Pearson 2007).

Large areas of otherwise-suitable habitat do not meet the minimum water quality standards for the protection of aquatic life for dissolved oxygen (CCREM 2015) for all or part of the year. Figure 4 shows the proportions of Proposed Critical Habitat length affected by hypoxia, severe hypoxia, and dewatering. The spatial extent of hypoxia varies annually with temperature and flow rates and other factors (e.g. removal of in-stream vegetation for flood control). The proportions shown in the figure reflect conditions following a prolonged period of hot dry weather and would typically occur in between mid-August and early October. Under these conditions 45% of Proposed Critical Habitat may be severely hypoxic (DO <2.5 mg/l). These areas are largely devoid of native fish during these periods. A few Salish Sucker may survive within localized refugia (e.g. around confluences with oxygenated tributaries). Details on the methods and analyses used in making these estimates are provided in Appendix 1.

Acenaphelene (a polycyclic aromatic hydrocarbon, PAH) originating from creosote-treated wood retaining walls is leaching into two ponds of Salwein Creek (Environment Canada unpub. data, March 2010). Catch per unit effort of Salish Suckers, and other fish is consistently very low in these ponds (Pearson unpub. data[1]). The ponds are on Department of National Defense lands and were constructed originally for engineers to practice temporary bridge construction. The land is currently leased to the City of Chilliwack and used as a nature reserve. Contaminated sediments associated with urban stormwater outfalls are documented in Agassiz Slough and likely occur in parts of other watersheds that receive urban runoff (majority of occupied watersheds). Spills of deleterious substances occur occasionally in all watersheds. Recent examples include a diesel spill in Mountain Slough (2012) and chlorinated runoff from equipment sterilization at a Langley mushroom farm (Bertrand Creek, 2013).

Approximately 4.5 km of Proposed Critical Habitat in Bertrand Creek dewaters annually during summer and early fall (Figure 3), thereby excluding Salish Suckers.

Sedimentation of spawning riffles, particularly in Fishtrap Creek, may impair or preclude successful spawning. It is also possible that introduced predators exclude Salish Suckers from some areas of otherwise suitable habitat, particularly when combined with habitat fragmentation or hypoxia, but insufficient information is available to assess the spatial extent of these threats.

Table 3. Total length of Proposed Critical Habitat reaches in watersheds that support Salish Sucker populations.

Watershed	**Channel Length (km)**	**Reference**
Agassiz Slough	7.69	Fisheries and Oceans Canada 2012
Miami River	7.83	Fisheries and Oceans Canada 2012 Pearson 2014b
Mountain Slough	9.83	Fisheries and Oceans Canada 2012
Chilliwack Delta	34.30	Fisheries and Oceans Canada 2012 Pearson 2014b
Elk Creek / Hope Slough	23.68	Fisheries and Oceans Canada 2012
Salwein Creek / Hopedale Slough	10.73	Fisheries and Oceans Canada 2012 Pearson 2014b
Bertrand Creek	23.11	Fisheries and Oceans Canada 2012 Pearson 2014b
Pepin Creek	11.02	Fisheries and Oceans Canada 2012
Fishtrap Creek	6.52	Fisheries and Oceans Canada 2012
Salmon River	22.60	Fisheries and Oceans Canada 2012 Pearson 2014b
Little Campbell River	22.80	Pearson 2014b
All Watersheds	**180.11**	

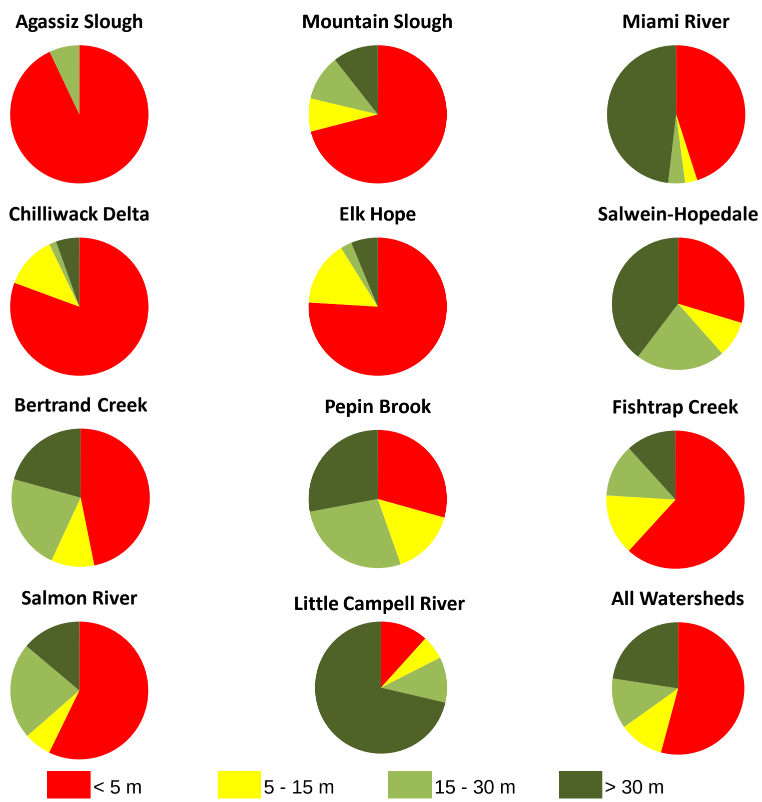

Figure 3. Proportion of Proposed Critical Habitat at risk of seasonal hypoxia or dewatering.

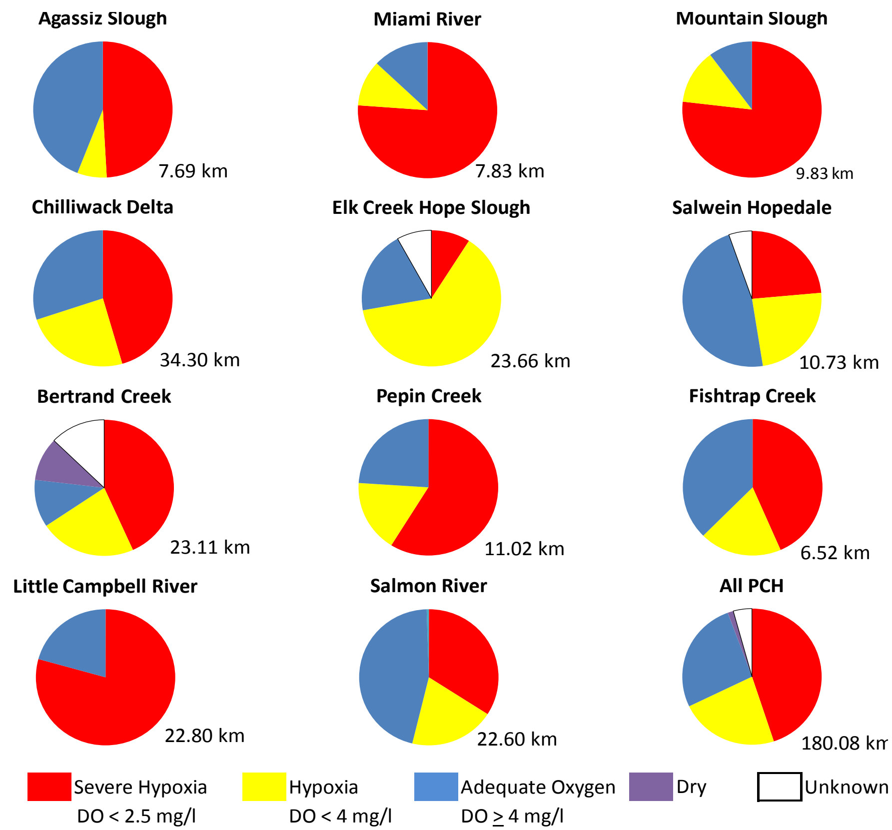

Figure 4. Proportion of proposed critical habitat (by bank length) bordered by native, woody riparian vegetation of differing width categories (from Pearson 2007).

2.3 SPATIAL CONSTRAINTS ON HABITAT ACCESS

Salish Sucker movements within and between watersheds are constrained by natural and human caused barriers. These mapped and described in detail by COSEWIC (2012) and summarized below.

2.3.1 Barriers and Connections Between Watersheds

Seven of the eleven populations are effectively isolated from one another, by dykes, flood-gates, highways, and the historical drainage of Sumas Lake and various wetlands. The only watersheds between which migration is possible are Miami River/Mountain Slough, which are joined in a headwater pond that drains to both, and Salmon River/ Bertrand Creek, which are connected at high water levels through a headwater wetland. In both cases connections are associated with high streamflow conditions or beaver activity. The connections may be sufficient to allow occasional gene flow between populations, but a rescue effect following extirpation of one of the populations is very unlikely.

2.3.2 Barriers within Watersheds

Beaver dams form natural movement barriers to Salish Suckers. They were often approached but almost never crossed by radio-tagged individuals during summer, but significant numbers of elastomer-tagged fish crossed more than one dam during migration to spawning areas in spring (Pearson and Healey 2003). Fish are also commonly trapped behind beaver dams when surface flow ceases, a common occurrence in the at least five of the watersheds. This may be lethal when combined with severe hypoxia, or dewatering, as is common in Howe's Creek (Bertrand Watershed).

Access to parts of smaller tributaries is prevented by perched, or hung, culverts in many locations across their range. These have not been inventoried to date, but may prevent access to suitable spawning and nursery habitats. Salish Sucker movement between habitats is seriously impacted in Bertrand Creek by two water level control structures on Department of National Defense lands. The structures consist of vertical standpipes, separated from the rest of the wetland by chain link fences against which beaver dams have been built. A large portion of the Bertrand Creek population (mark-recapture estimate 240-340 individuals) was isolated above one or both of these structures in severely hypoxic habitat in 2013 (Pearson 2014a).

2.4 RESIDENCE CONCEPT

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" (S.C. 2002, c.29).

The residence must support a life cycle function, there must be an element of investment in the creation or modification of the structure, and it must be occupied by one or more individuals. The Salish Sucker is a broadcast spawner and does not modify its environment for the purpose of "breeding, rearing, staging, wintering, feeding or hibernating". The concept of residence therefore does not apply (Fisheries and Oceans Canada 2012).

3 THREATS AND LIMITING FACTORS

3.1 ASSESSMENT AND PRIORITIZATION

Seven significant threats impact Salish Sucker populations, each caused by a number of contributing factors (Table 4). An eighth threat, *Riffle loss to Beaver Ponds* was included in the proposed Recovery Strategy, but was excluded from this analysis based on the small area of riffle required for spawning, the limited extent of riffle habitat lost to beaver ponds, and evidence that individuals will migrate several kilometres to spawning sites (Pearson 2004, Jill Miners, unpub. data[2]). Thus, it seems unlikely that riffle loss to beaver ponds is a significant threat in any of the surveyed watersheds. The relative importance assigned to threats in Table 4 also differs from that presented in the proposed Recovery Strategy. Seasonal lack of water has been elevated due to recent data on extensive use of seasonally dewatered habitat in Bertrand Creek (Jill Miners, unpub. data[2]). Toxicity has also been elevated in importance due to a significant conversion of pasture to row crops (primarily blueberries) associated with high herbicide/pesticide use in recent years.

3.1.1 Hypoxia

Episodes of extreme hypoxia cause acute mortality or reduce fitness through impairment of key life history functions.

Actual impacts of a given dissolved oxygen concentration vary with water temperature, duration of exposure, body size, health prior to exposure and interactions with other environmental factors. Salish Suckers are regularly captured in waters containing less than 3.5 mg/l dissolved oxygen, suggesting that they may be tolerant of mild hypoxia, but are also occasionally found dead in traps set in near-anoxic water i.e.<1 mg/l (Pearson 2004, Jill Miners, unpub. data[2]). Developing fish eggs have significantly higher dissolved oxygen requirements than free-swimming fish, with sublethal effects occurring at 9 mg/l in some species (Elshout et al. 2013). In the absence of data specific to the Salish Sucker, a threshold for hypoxia of 7mg/l is assumed for eggs.

Risk of hypoxia varies seasonally and annually, but is generally highest in late summer and early fall when temperatures and oxygen demand are highest and water levels are lowest.

For assessment purposes, habitat areas containing less than 2.5 mg/l of dissolved oxygen are considered *severely hypoxic* and likely to be lethal over the short term or to severely impair key life history functions. Areas with levels between 2.5 and 4 mg/l are considered *hypoxic* and likely to cause some impairment of key life history functions. Figure 3 summarizes the extent of hypoxia risk, as assessed from 3082 point measurements across the range, most from 2011 - 2013 (Appendix 1).

Table 4. Threats to the Salish Sucker listed in descending order of importance. The assessment considers present and future impacts only. Darker shading indicates increasing vulnerability or extent of the range affected. This ranking is subjectively based on expert opinion. Bracketed numbers refer to the relevant section in the text.

Threat	**Contributing Factors**	***Extent of Range Affected***	***Vulnerability To Threat***			
			Eggs/ Spawning	***Young of Year***	***Adult/ Yearlings Summer***	***All Ages Winter***
Hypoxia (3.1.1)	Nutrient loading Lack of riparian vegetation (shade) Seasonal lack of water					
Habitat damage or destruction (3.1.2)	Drainage works Infilling channels and floodplains Removal of riparian vegetation					
Seasonal lack of water (3.1.3)	Ground and surface water withdrawals Increased impervious area Wetland loss					
Deleterious Substances (3.1.4)	Agricultural runoff and sprays Urban storm water Creosote structures Spills (road, rail, pipeline) Lack of riparian vegetation (filtration and buffer)					
Habitat Fragmentation (3.1.5)	Dykes, dams, floodgates Perched culverts Poor water quality Seasonal lack of water					
Increased Predation (3.1.6)	Introduced predatory species Increased vulnerability due to hypoxia or seasonal lack of water					
Sediment Deposition (3.1.7)	Urban stormwater Failure of sediment control measures in construction or gravel mining. Lack of riparian vegetation (filtration)					

Figure 5. Eutrophic conditions and severe hypoxia in proposed Critical Habitat in the upper Salmon River (2008, Left) and in Gordon's Brook (2007,Pepin Creek tributary, Right).

3.1.2 Habitat Damage or Destruction

Aquatic or riparian habitat is degraded or destroyed by drainage, diking, channelization, infilling, native vegetation removal, large woody debris removal or other works.

Loss and degradation of habitat continues to occur annually in most watersheds. It includes permitted works such as the dredging of channels for flood control and drainage by local governments in addition to unauthorized/illegal alterations to habitat.

Figure 6. Partial infilling of channel in proposed Critical Habitat in Bertrand Creek (2013, Left) and riparian clearing on Mountain Slough (2012, Right).

3.1.3 Seasonal Lack of Water

Low flows in late summer eliminate habitat or restrict movements, reducing fitness or survival.

Low flows seriously impact occupied habitat in at least five watersheds (Fisheries and Oceans 2012) either by dewatering habitat completely, or by increasing the risk of hypoxia.

Howe's Creek (Bertrand tributary) has shown impacts of seasonal lack of water most clearly. In May of 2009, 48 Salish Suckers were captured from a deep pool within a riffle-rich reach of Howe's Creek (Bertrand watershed) that dewaters for weeks to months each summer. The majority were in spawning condition. One month later 100 were salvaged and relocated from the isolated remnant of that pool before it dried completely. There are occupied habitats at both ends of the section that dewaters.

Mark-recapture work suggests that over 300 Salish Suckers occupied Howe's Creek in spring of 2012, with most captures occurring within a reach that dewaters completely (Jill Miners, UBC, unpub. data). The risk of entrapment in dewatering areas behind beaver dams or in remnant pools appears to be very high.

Figure 7. Dewatered habitats in Howe's Creek in 2008 (left) and 2010 (Right).

3.1.4 Deleterious Substances

Discharge of deleterious substances to aquatic proposed Critical Habitat from point and non-point sources reduces Salish Sucker survival or fitness.

Deleterious substances enter all streams within the range from road runoff, contaminated groundwater (pesticides, herbicides), direct discharge, aerial deposition, and /or accidental spills. Localized areas of chronic toxicity are documented from Proposed Critical Habitat in Agassiz Slough (stormwater sediment), and Salwein Creek (PAHs from 2 km long creosote retaining wall). The severity of impacts on the Salish Sucker is unknown.

While the risk of a spill at any particular location is low, some significant spills will inevitably impact Salish Sucker habitats over the long term. A large number of road and farm crossings occur within or upstream of occupied habitats. Some are also at risk of spills resulting from train derailment on the CN line. The existing Kinder-Morgan Trans Mountain pipeline and their proposed corridor for a second one cross through or directly upstream of occupied habitat at 12 locations in six watersheds (Trans Mountain 2015). Seasonal channels and ditches add many more points from which spills could enter Salish Sucker habitat.

Figure 8. Creosote treated retaining wall in Salwein Creek (2009, Left) and a diesel spill in Mountain Slough (2012).

3.1.5 Habitat Fragmentation

Permanent or temporary barriers prevent or inhibit fish from accessing usable habitats and/or alter metapopulation dynamics increasing risk of population extirpation.

Salish Sucker movements within and between watersheds are restricted permanently or seasonally in parts of all occupied watersheds, as discussed more fully above (*Spatial Constraints on Habitat Access*).

Figure 9. The single culvert draining Agassiz Slough to the Fraser River (Left, 2012) and a perched (hung) culvert draining an unoccupied tributary into potential Critical Habitat in Fishtrap Creek (Right, 2010).

3.1.6 Increased Predation

Introduced predators consume individuals or reduce their fitness by inducing behavioral changes that increase energy expenditure or reduce food intake.

Introduced species, including Largemouth Bass (*Micropterus salmoides*), Smallmouth Bass (*Micropterus dolomieu*), Pumpkinseed (*Lepomis gibbosus*), Brown Bullhead (*Ameiurus nebulosis*), and Bullfrog (*Lithobates catesbeianus*) co-occur with Salish Sucker populations (COSEWIC 2012). No extirpations have been documented and coexistence with most of these species has lasted more than 20 years, but population level impacts short of extirpation may have occurred. Interactions with other factors (e.g. fish density, habitat structure, hypoxia, temperature, turbidity) are unknown but likely significant.

Animal rights activists have released several thousand farmed Mink (*Neovison vison*), into Salish Sucker watersheds in the past 20 years. Most recently, approximately 300 mink entered the Salmon River watershed in October 2013 (Pynn and Hager 2013). Few of them likely survive for long in the wild, but with the large numbers released, some impact is possible.

Figure 10. Largemouth bass (Micropterus salmoides, Left) and brown bullhead (Ameiurus nebulosi, Right) are found across the Canadian range of Salish Sucker.

3.1.7 Sediment Deposition

Deposited sediment reduces flow of oxygenated water to eggs in riffles, reduces invertebrate (food) availability or, in extreme cases, infills pools.

Chronic sedimentation originating from urban stormwater systems or agricultural ditches affects parts of all watersheds. At least two large scale releases from gravel pits and a debris flow caused by a berm failure and the resulting headwater capture of Howe’s Creek in 2008 have infilled habitat in Pepin Creek. Mining continues in this watershed and has recently expanded into the Fishtrap Creek watershed.

Figure 11. Sediment entering proposed Critical Habitat in Mountain Slough from a recently dredged tributary (Left, 2012) and sediment from an upstream fill site in a tributary immediately upstream of proposed Critical Habitat in the Salmon River (Right, 2007).

3.2 ACTIVITIES LIKELY TO DAMAGE OR DESTROY REQUIRED HABITAT PROPERTIES

There are a wide range of activities with potential to damage or destroy required habitat properties. The nature and extent of the major ones are summarized in Table 5. Note that the assessment assumes that activities occurring upstream of occupied habitat have potential to be as harmful as those that occur within it.

3.3 NATURAL FACTORS LIMITING SURVIVAL AND RECOVERY

Although flooding of spawning riffles by beaver ponds is not considered a significant threat, ponding does sometimes exacerbate the impacts of other human-caused threats. Ponding, and the resulting decrease in water movement, may interact with nutrient loading and riparian vegetation removal to exacerbate hypoxia. Dams may also strand fish, preventing their escape from the impacts of other threats, particularly hypoxia and dewatering.

Loss of riparian vegetation to beaver herbivory or flooding may also impact habitat. For example beaver dams in Pepin Creek within Aldergrove Lake Park caused inundation of the floodplain in the late 1990s and early 2000s. Many trees died, which thinned the canopy. The increased light, combined with nutrient loading from upstream has facilitated invasion and overgrowth of the habitat by reed canary grass and other invasive plants. The overgrowth is likely to inhibit natural succession, preventing the return of native forest even in the absence of the dams.

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Table 5. Summary of nature and extent of activities likely to damage or destroy required habitat features for Salish Sucker.

Activity	**Pathways of Effects**	**Effects**	**Extent of Impacts on Habitat**
Over-application or poor storage of manure.	Nutrients enter aquatic habitat via overland runoff or by groundwater transport, which may be exacerbated by drain tile. Exacerbated by excess production of manure over what is required to fertilize land base	Eutrophication resulting in hypoxia. Overgrowth of habitat with invasive plants, particularly reed canary grass (*Phalarus arunindacea*) Increased need for drainage maintenance.	Occurs in all watersheds and is widespread in PCH of most.
Drainage maintenance works	Physical removal of vegetation, organic debris and/or silt/sediment. Mowing of banks and riparian areas Organic debris and riffles ('high spots') are typically targeted	Destroys habitat features and complexity. Periodic nature of work prevents development of habitat complexity. Temporary increase in dissolved oxygen levels caused by reduced biological oxygen demand and increased flow.	Extensive in Mountain Slough, Chilliwack Delta, Elk Creek/Hope Slough. Occasional in Miami River, Salmon River, Bertrand Creek, Rare in of Agassiz Slough, Pepin Creek, Fishtrap Creek, Little Campbell River, and Salwein Creek/Hopedale Slough
Removal of riparian vegetation	Landowners seeking to increase usable land area. Landowners clearing for aesthetic reasons. Road/utility maintenance work.	Increase in summer water temperature. Increased erosion and reduced bank stability. Increased risk of deleterious substances entering water from adjacent lands. Exacerbated consequences of nutrient loading.	Occurs regularly in all watersheds.
Pesticide/herbicide application near water	Drift from application to adjacent lands into riparian or aquatic habitats. Direct application to riparian or aquatic habitats to kill vegetation for aesthetic or	Potential toxicity to Salish Suckers. Potential reduction in food availability. Potential degradation of habitat from loss of riparian or aquatic plants.	Common in most watersheds.

Activity	Pathways of Effects	Effects	Extent of Impacts on Habitat
	drainage improvement purposes.		
Urban storm drainage	Changes in stream hydrograph and increased pollutant entry to water via storm drains.	Channel incision leading to reduced habitat complexity Impaired water quality including hypoxia. Reduced baseflow, leading to increased water temperature and increased hypoxia risk. Reduced habitat volume and area leading to increased competition and/or predation risk. Increased risk of habitat dewatering	Level of activity varies among watersheds, but is significant in Agassiz Slough, Miami River, Chilliwack Delta, Hope Slough, Fishtrap Creek, and Bertrand Creek
Livestock use of aquatic and riparian areas.	Commercial livestock operations Hobby farms	Increased erosion, bank failure and sediment deposition in aquatic habitats. Nutrient loading from defecation in habitat. Trampling of eggs in riffles.	Still occurs in Fishtrap Creek, Bertrand Creek, Salmon River, Little Campbell River, Salwein Creek/Hopedale Slough.
Water extraction or diversion	Surface withdrawals for irrigation Municipal wells Private wells	Reduced baseflow, leading to increased water temperature and increased hypoxia risk. Reduced habitat volume and area leading to increased competition and/or predation risk. Increased risk of habitat dewatering	Widespread across range. Watersheds range widely in vulnerability.
Spills	Road and rail crossings Pipelines Illegal dumping	Dependent on quantity and properties of substance spilled. Risk of fish kill caused by harmful substances. Risk of persistent toxic effects Risk of habitat damage during cleanup activities	All watersheds are at some risk, but level varies with the nature and number of crossings and access points.
Gravel mining	Failure of water control structures during storm event.	Risk of massive sediment deposition as occurred in Pepin Creek in 1997, 1999, and 2008	Risk in Fishtrap Creek and Pepin Creek.

3.4 BENEFITS OF THREAT ABATEMENT TO SALISH SUCKER AND CO-OCCURRING SPECIES

All identified threats to the Salish Sucker affect the amount or quality of available habitat, and also affect many native species that share that habitat. Species of economic, cultural or conservation concern known or believed to co-occur with the Salish Sucker are listed in Table 6. These include five species that support commercial, recreational or Aboriginal (CRA) fisheries, 13 SARA Schedule 1 species, including 6 at the endangered level, and 11 additional species from the BC Conservation Data Centre's Blue list. A number of plant, lichen, and bryophyte species of conservation concern could be affected by some of the identified threats, but generating a comprehensive list of these taxa is beyond the scope of this work.

Abatement of the extent and severity of hypoxia is likely to benefit all fishes and amphibians, and most other listed taxa. For example, piscivorous and insectivorous birds are likely to benefit from increased food supply. Avoidance or restoration of aquatic habitat damage or destruction will benefit most taxa on the list as well as aquatic plants at risk. Prevention or restoration of riparian clearing is likely benefit the broadest range of species

Table 6. Animals of cultural, economic and conservation concern that occur with Salish Sucker and depend upon similar habitat attributes.

Species	**Scientific Name**	**Status**
Chinook Salmon	*Oncorhynchus tshawytscha*	CRA Fishery
Chum Salmon	*Oncorhynchus keta*	CRA Fishery
Coho Salmon	*Oncorhynchus kisutch*	CRA Fishery
Rainbow Trout/ Steelhead	*Oncorhynchus mykiss*	CRA Fishery
Coastal Cutthroat Trout	*Oncorhynchus clarkii clarkii*	CRA Fishery; BC Blue List
Oregon Spotted Frog	*Rana pretiosa*	SARA Endangered
Yellow-breasted Chat	*Icteria virens*	SARA Endangered
Nooksack Dace	*Rhinichthys cataractae ssp.*	SARA Endangered
Oregon Forestsnail	*Allogona townsendiana*	SARA Endangered
Pacific Water Shrew	*Sorex bendirii*	SARA Endangered
Western Painted Turtle	*Chrysemys picta*	SARA Endangered
Barn Owl	*Tyto alba*	SARA Threatened
Olive-sided Flycatcher	*Contopus cooperi*	SARA Threatened
Red-legged Frog	*Rana aurora*	SARA Spec. Concern
Western Toad	*Anaxyrus boreas*	SARA Spec. Concern
Band Tailed Pigeon	*Patagioenas fasciata*	SARA Spec. Concern
Great Blue Heron (fannini subspecies)	*Ardea herodias fannini*	SARA Spec. Concern
Short-eared Owl	*Asio flammeus*	SARA Spec. Concern
Barn Swallow	*Hirundo rustico*	SARA No Status, COSEWIC Threatened
American Bittern	*Botaurus lentiginosa*	BC Blue List

Species	Scientific Name	Status
Green Heron	*Butorides virescens*	BC Blue List
Purple Martin	*Prognes ubis*	BC Blue List
Brassy Minnow	*Hybognathus hankinsoni*	BC Blue List
Autumn Meadowhawk	*Sympetrum vicinum*	BC Blue List
Beaverpond Baskettail	*Epitheca canis*	BC Blue List
Black Gloss	*Zonitoides nitidus*	BC Blue List
Pacific Sideband	*Monadenia fidelis*	BC Blue List
Olympic Shrew	*Sorex rohweri*	BC Blue List
Trowbridge's Shrew	*Sorex trowbridgii*	BC Blue List
Black-crowned Night Heron	*Nycticora xnycticorax*	BC Red List
Emma's Dancer	*Argia emma*	BC Blue List

3.5 MONITORING OF THREATS

Little monitoring of threats or their indicators is currently underway. Range-wide hypoxia monitoring has been done (Appendix 1), and additional water quality data is undoubtedly available in various government and private sector reports, including fish collection reports to the Province and DFO. The Water Survey of Canada maintains flow gauges on a few of the creeks.

Monitoring of sediment deposition and toxicity is rarely undertaken in these watersheds, generally only in response to investigations of reported incidents. Measures of habitat loss, especially riparian habitat are not routinely made, but considerable data are available in the form of historical aerial and satellite photographs.

4 RECOVERY TARGETS

4.1 PROPOSED ABUNDANCE AND DISTRIBUTION TARGETS

Proposed abundance targets are provided in Table 7.

Minimum viable population (MVP) analysis was not possible due to the lack of known life history parameters. Targets are instead based on mean and median values from a literature review of several large-sample meta-analyses of MVP estimates in vertebrates. These analyses collectively suggest that interim targets in the range of 1375-7000 adults are suitable in the absence of specific data (Reed et al. 2003; Brook et al. 2006; Traill et al. 2007). Targets can be refined based on knowledge of the species' life history and habitat availability (Rosenfeld & Hatfield 2006). It is, however, extremely difficult to develop target abundances in the absence of a credible abundance-area relationship.

The targets proposed (Table 7) are based on channel length. A target of 1375 adults was assigned to the smallest watershed, Agassiz Slough (Length 4.35 km excluding wide slough habitats near the Fraser). Targets for other watersheds were calculated proportionally by length and rounded to the nearest 500 fish. The numbers correspond to mean densities ranging from 0.014 to 0.038 adults per square meter of deep pool, exclusive of wide sloughs near the Fraser River.

The mean and median of candidate abundance targets for Salish Sucker populations are 2864 and 2250 adults respectively (Tale 5). In most cases proposed targets have been reduced from those of the proposed Recovery Strategy, which are based on an assumed density of 0.05 adult/m^2 in all deep pool habitats. The change in method was made because recent studies indicate that Salish Suckers routinely make seasonal movements of several kilometres to access spawning areas or escape severe hypoxia (Jill Miners, unpub. data[2]; Pearson unpub. data[1]) and that they are usually clustered in a few traps when caught. This suggests that they range widely among available habitats over the course of a year and that they either move in groups or congregate in specific areas. Due to the potential aggregating behaviour, the use of simple area/density relationships is inappropriate.

Recent studies also indicate that the Salish Sucker is rarely caught in wide slough channels (i.e. > 20 m) near the Fraser River (Pearson unpub.data[1]). These areas are likely important movement corridors between the smaller tributaries that are the primary habitat, but are unlikely to contribute significantly to productivity. They do, however, have very large surface areas; their inclusion would greatly inflate area-based estimates of carrying capacity. Eliminating them as productive areas results in significant target reductions for Elk Creek/Hope Slough, Chilliwack Delta, and Salmon River compared to those in the proposed Recovery Strategy.

Table 7. Abundance targets in relation to recent abundance estimates for Canadian Salish Sucker populations.

Population	**Mark-Recapture Estimate**	**Proposed 2012 Recovery Strategy Target**	**Proposed 2015 Target**	**Current population Estimate as % of Proposed 2015 Target**
Agassiz Slough	253 (2032-354)	2000	1500	17
Bertrand Creek	1064	7000	4000	27
Mainstem	735 (638-862)			
Howe's Creek	329 (206-711)			
Chilliwack Delta		7000	5500	
Atchelitz Creek				
Little Chilliwack Creek				
Luckakuck Creek	378 (345-416)			
Semmihault Creek				
Elk Creek / Hope Slough		8000	2500	
Fishtrap Creek	X	4700	1500	
Little Campbell River	X	NA	5,000	
Miami River	102 (67-193)	1500	1500	6.8
Mountain Slough		4400	3000	
Pepin Creek	1754 (1318-2900)	1200	2500	70
Salmon River		8200		
Upper River	751 (649-915)		2000	38
Salwein/Hopedale	757	2700	2500	30
Salwein Creek	288 (191-635)			
Hopedale Slough	469 (346-712)			
All Watersheds		46,700	31,500	

4.2 POTENTIAL FOR REACHING RECOVERY TARGETS

Quantitative projections or scenario modelling of Salish Sucker population trajectories are not possible due to the lack of estimates of population dynamic parameters, particularly fecundity and recruitment rates, and the lack of knowledge on impacts of hypoxia on vital rates. It is clear, however, that Salish Sucker populations are limited by the quantity of suitable habitat, particularly by hypoxia during the productive summer season. It is unlikely that any of the watersheds have a sufficient supply of habitat to support potential recovery target abundances during the summer and early fall, when hypoxia is most prevalent.

Recent surveys indicate, however, that small areas of high quality habitat can support relatively large numbers of fish. In Hopedale Slough an estimated 500 fish were found in a pond complex of less than 9000m^2 (Pearson 2013), and in Luckakuck Creek an estimated 378 Salish Suckers of all age class are isolated in a groundwater-fed pond of 4150m^2, except under flood conditions(Pearson, unpub. data[1]). These cases suggest that if the extent and severity of hypoxia is significantly reduced within Proposed Critical Habitat areas, habitat supply will support target abundances.

There is both indirect (Pearson and Healey 2003) and observational evidence that the intrinsic rate of population growth in Salish Sucker is high. Increases in available habitat area and quality through modest reductions in mortality caused by acute hypoxia or in some cases habitat dewatering and increased productivity through improved water quality are likely to be sufficient for most populations to reach candidate target abundances.

5 MITIGATION OF THREATS

Feasible measures for mitigation of the effects of activities that threaten Salish Sucker habitat are provided in Table 8.

Table 8. Potential mitigation measures for activities likely to threaten Salish Sucker populations.

Activity	**Mitigation Options**	**Comments**
Over-application or poor storage of manure.	More stringent guidelines/regulations for application and storage Diversion of manure to composting or energy from waste facilities.	Pilot diversion projects underway in the Fraser Valley
Drainage maintenance works	Limit work to appropriate in-stream work window. Use hand methods where feasible. Plant riparian vegetation to shade channel and reduce in-stream vegetation growth.	Guidelines for work in Salish Sucker habitat are in preparation.
Removal of Riparian Vegetation	Policies/regulations prohibiting removal. Replant with native species, preferably at site of disturbance.	
Pesticide/herbicide application near water	Establish no-spray buffer adjacent to riparian areas	

Activity	Mitigation Options	Comments
Urban storm drainage	Design storm system for full site infiltration/or no change in downstream hydrograph	A few examples of this in BC
Livestock access	Fence out livestock Install off-channel watering facilities or limit access to small area of stream.	Access now rare in large commercial farms, but common on hobby farms.
Water extraction or diversion	Install more efficient irrigation systems. Supplement stream flow from wells in key reaches during critical times. Reduce municipal consumption through water saving incentive programs or pricing.	Lack of metering/monitoring of most water extraction/diversion limits available information.
Spills	Ensure that emergency response measures are well prepared and well known among relevant people and agencies.	
Gravel mining	Properly engineer and maintain facilities.	

Table 9. Activities that could increase Salish Sucker productivity or survivorship.

Activity	Pathway	Effects/Comments
Aquatic habitat creation/ enhancement	Increased quantity of high quality habitat.	Increased productivity
Riparian habitat restoration	Reduced hypoxia, sediment deposition and, peak water temperature. Increased aquatic habitat complexity due to large woody debris influences. Increased allochthanous food availability	Lessens impacts of eutrophication by shading out excessive aquatic plant growth. Reduced mortality and/or increased productivity due to improved water quality, food supply and habitat structure.
Control of introduced predators	Reduced predation, particularly on young-of-the-year fish.	Increased recruitment and survivorship Very unlikely to succeed on large scale, but may be beneficial on small scales, e.g. individual ponds.

5.1 FEASIBILITY OF HABITAT RESTORATION/CREATION

The creation, restoration or enhancement of Salish Sucker habitat is technically and financially feasible as demonstrated by the success of a number of projects (Patton 2003, Pearson 2004b, Jill Miners, UBC. unpub. data[2]). Key habitat features in projects targeting Salish Sucker are sufficient areas of deep pool habitat, abundant cover, typically in the form of large woody debris, and adequate water quality. Spawning riffles have also been constructed successfully. Projects consisting of small ponds, often located on tributaries less prone to hypoxia than the mainstem have worked best. Locations adjacent to occupied habitat are colonized within weeks or months (Patton 2003, Pearson 2004b) and mark recapture work has shown that they can support densities of Salish Sucker comparable to the most productive natural habitats (Pearson unpub. data[1]; Jill Miners, unpub data[2]).

Key attributes of successful riparian restoration projects in Salish Sucker habitat have been robust protection of plants from beaver and vole damage. Challenges have included overgrowth with invasive plant species, vandalism, accidental mowing by municipal maintenance crews, and changing water levels due to beaver activity. All challenges can be met using established mitigation methods.

6 ALLOWABLE HARM ASSESSMENT

6.1 MAXIMUM SUSTAINABLE HUMAN-INDUCED MORTALITY AND HABITAT DESTRUCTION

The aforementioned lack of known life history parameters prevented the calculation of population trajectories. Further, it is believed that persistent hypoxia and range wide habitat degradation are having a negative impact on vital rates. Finally, human population in the Fraser Valley is expected to increase by over 800,000 in the next 20 years (BC Stats 2015). This will apply significant development pressure on already compromised Salish Sucker habitat. As a result, a subjective, conservative approach was used to recommend allowable harm levels. Proposed direct allowable harm to individuals comprises two adult Salish Sucker or two percent of the lower 95% confidence limit of the most recent population estimate, whichever is greater, to a maximum of 10 adults per annum. These values appear in Table 10.

Table 10. Estimates of annual allowable human-induced mortality of the Salish Sucker. In cases where metapopulations are believed to exist, figures are provided for each occupied subwatershed.

Population	**Lower 95% CL of Abundance**	**Allowable Harm Estimate (per annum)**
Agassiz Slough	203	4
Miami River	67	2
Mountain Slough	?	2
Chilliwack Delta		
Luckakuck Creek	345	6
Atchelitz Creek	?	2
Semmihault Creek	?	2
Little Chilliwack Creek	?	2
Elk Creek / Hope Slough	?	2
Salwein Creek	191	4
Hopedale Slough	346	7
Bertrand Creek		
Mainstem	638	10
Howe’s Creek	206	4
Perry Homestead Creek		2
Pepin Creek	1318	10
Fishtrap Creek	?	2

Population	Lower 95% CL of Abundance	Allowable Harm Estimate (per annum)
Salmon River		10
Upper River	649	
Lower River	?	
Little Campbell River	?	2

Approaches to the assessment of allowable harm have varied widely among RPAs conducted for freshwater fishes (Table 11). In cases where insufficient information exists to allow impacts to be quantitatively modelled, several have concluded that ‘there is no scope for allowable harm’ and that ‘when population trajectory is unknown the scope for allowable harm can only be assessed once population data are collected”. Several also recognized the complex and cumulative impacts that occur when vital rates of more than one life history stage are affected. Most analyses explicitly or implicitly included all sources of mortality, including both direct (take) mortality and indirect (habitat mediated) mortality.

Table 11. A comparison of approaches to allowable harm assessment for SARA –listed freshwater fishes.

Species	Approach	Reference
Nooksack dace	Qualitative: “…there is little scope for human-induced mortality. Permitting …should consider the consequence(s) to achieving stated recovery goals.	Harvey 2007
Spotted gar	Cumulative harm to survival of all life stages should not exceed 5%. In the absence of abundance estimates, no harm should be allowed to survival of YOY and juveniles	DFO 2010a
Laurentian black redhorse	Modelling approach: Used published estimates of longevity, and age specific survival, growth and fecundity. Includes mortality from all human sources (take and habitat). Used the lower bound of the 95% confidence intervals as a reference for the determination of maximum allowable harm maximum allowable reductions of 19% for YOY survival, 14% for juvenile survival, or 17% for young adult survival and young adult fertility	Vélez-Espino and Koops 2007
Pugnose Shiner	Modelling approach using published estimates of fecundity, survivorship and other parameters. 6% adult survival or 12% on adult fertility Includes all direct and indirect mortality.	Venturelli et al. 2010
Plains minnow	“Current population trajectory … is unknown. Therefore, allowable chronic harm is not provided…Transient harm (one-time removal of individuals) should not exceed a 12.5% reduction in adult abundance, or a 17% reduction in young-of-the-year abundance, or a 7.5% reduction in total abundance within a seven-year period.”	
Speckled dace	No quantitative advice provided	CSAS 2007/038

Species	Approach	Reference
Umatilla dace	In view of … large uncertainty, allowable harm … should include scientific sampling …but total harm should not increase beyond current levels.	DFO 2013
Lake Chub Sucker	Modelling approach: “If Lake Chub Sucker mature at age 2, harm to annual survival of immature individuals, survival of adults, or fecundity should not exceed 33%, 54%, or 49%, respectively. If age at maturity is 3 years, harms should not exceed 15%, 32%, or 33%, respectively. As harm approaches these levels, recovery times increase exponentially.”	DFO 2011a
Channel Darter	Simultaneous reductions to survival or fertility of all life stages should not exceed 2% or 4%, respectively. If mortality only affects early life stage, then maximum allowable harm to annual survival should be limited to 6, or 10% for 1, 2, 3 year olds, respectively. Maximum allowable harm to the fertility of first- and second-time spawners should be limited to 10 and 15%, respectively	DFO 2010b
Eastern Sand Darter	Populations are particularly susceptible to harm related to the survival of 0+ individuals (S1) and the fertility of first-time spawners (f2) and any harm should be minimized. If population abundance estimates exceed MVP, cumulative allowable harm might be allowed to the level identified in the allowable harm modeling	DFO 2011b
Misty Lake Stickleback	5% of population (halving of estimated 10% rate in turn based on sustainable harvest rate of 14% for (sockeye salmon) adjusted for differences in life history.	DFO 2010c
Northern Madtom	“Allowable harm to the Northern Madtom was not investigated due to data limitations… data should be allowed”	DFO 2012
Vancouver Island Lamprey	“The low and highly uncertain population abundance estimates, the reported recent declines in catch rates and the restricted, endemic population range of Vancouver lamprey indicate that there is no scope for human-induced mortality.”	DFO 2010d

Given currently low abundance across the Canadian range of Salish Sucker, and that habitat integrity is already compromised, habitat destruction should only be allowed under extraordinary circumstances as a last resort. If, following the application of feasible mitigation measures, habitat destruction is unavoidable, then compensatory habitat should be constructed or enhanced and subsequently monitored for effectiveness.

7 INFORMATION GAPS

Table 12. Summary of information gaps identified in this recovery potential assessment. Many were previously identified in the Recovery Strategy (Fisheries and Oceans 2012) and the COSEWIC Status Report (COSWEIC 2013).

Information Gap	Priority	Difficulty/ Expense	Comment
Abundance Estimates	High	High	Easy in watersheds with high abundance, but very difficult to impossible in watersheds with very low abundance.
Distribution	High	Low	Focus on Pitt Meadows, Stave Lake and Hope areas
Perched culvert inventory	Med	Med	Primary difficulty will be access to small tributaries on private land
Projected trends in land use/watershed conditions	High	High	Projected future trends in land use from ongoing and projected development are essential for predicting future habitat impacts that affect recovery, and designing mitigation strategies
Sediment impacts on egg survivorship	Med	High	Experiments likely to conflict with allowable harm limits.
Deleterious substance impacts	Med	High	Experiments likely to conflict with allowable harm limits. Field data likely to be confounded by other factors.
Current riparian status	Low	Low	Requires current high resolution ortho-photos
Historical losses of riparian vegetation	Low	Low	Requires time series of high resolution ortho/aerial photos
Fecundity Measurements	Low	Low	May be possible from existing preserved specimens
Juvenile diet	Low	Unknown	May be relatively simple using stomach flushing, otherwise will entail lethal sampling
Introduced predator impacts	Low	High	Very hard to quantify in the field and both field and lab experiments are likely to conflict with allowable harm limits.
Age Specific Mortality	Low	High	Long-term intensive mark-recapture study required. Most feasible in small system with relatively high density (e.g. Hopedale Slough). There will be issues with suitable marking methods: pit tags cause unacceptable mortality, VIE likely lacks necessary longevity.

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APPENDIX 1: EXTENT OF HYPOXIA IN PROPOSED CRITICAL HABITAT FOR SALISH SUCKER

INTRODUCTION

Hypoxia is considered the leading threat to Salish Sucker survival and recovery in Canada (Fisheries and Oceans Canada 2012). It is a seasonal threat, with maximum severity and spatial extent occurring under drought conditions. In hot, dry summers susceptible habitats may be severely hypoxic for three months or more.

This report uses daytime measurements of dissolved oxygen in all Canadian watersheds that support Salish Sucker populations to assess the risk of hypoxia within Proposed Critical Habitat (PCH).

METHODS

Dissolved oxygen concentration (DO, mg/l) data within Salish Sucker watersheds was gleaned from a number of sources (Table 1). The dataset consists of 3082 records from the 11 occupied watersheds. Of these 2687 records were within Proposed Critical Habitat. The majority of data are from summer (June through September) of 2011 and 2012, but available data for all seasons of the period 2003 to 2014 were included (Tables 2 and 3).

Table A1. Sources of dissolved oxygen concentration data.

Watersheds	**Years**	**Number of Data Points**	**Source**
All Salish Sucker Watersheds	2003-2014	2179	Mike Pearson, Pearson Ecological, Agassiz, BC, unpub. data (from database)
Agassiz Slough Miami River Pepin Creek Howe's Creek	2011-2013	505	Jill Miners, Department of Geography, University of British Columbia, Vancouver, BC, unpub. data (from field work for MSc thesis)
Little Campbell River	2013-2014	398	A Rocha Canada

The minimum recorded DO for each site was overlain with shapefiles of PCH (Fisheries and Oceans Canada 2012) on high resolution ortho photos (2009). PCH reaches or portions of reaches of were classified with respect to risk of seasonal hypoxia according to the following criteria:

- Lowest recorded DO $\geq$4 mg/l : Adequate DO in All Seasons
- Lowest recorded DO 2.5 - 4 mg/l: Risk of Hypoxia
- Lowest recorded DO < 2.5 mg/l: Risk of Severe Hypoxia

Proportions of PCH in each risk category were calculated for each watershed and across the range. Proportions of measurements falling within each measurement range were also calculated for each month to show the seasonal extent of hypoxia within PCH.

Some records are averages of measurements taken at several adjacent fish trap locations within a reach on a particular day, but the great majority are individual point measurements. The inclusion of averages is justified as they are conservative (i.e. by definition they will be higher than the minimum level of measurements included).

Table A2. Number of dissolved oxygen measurements for each month within Proposed Critical Habitat for the Salish Sucker of each watershed.

Watershed	**Month**											
	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Total**
Agassiz Slough	-	-	14	20	26	47	11	26	15	-	-	159
Bertrand Creek	-	-	-	55	39	70	95	40	6	-	-	305
Chilliwack Delta	-	-	-	24	73	96	138	63	20	-	-	414
Elk Creek/Hope Slough	-	-	-	18	17	33	18	15	-	-	-	101
Fishtrap Creek	-	-	-	16	30	35	8	16	-	-	-	105
Hope Slough	1	-	1	9	34	8	19	17	8	-	-	97
Little Campbell River	-	52	28	2	12	46	14	-	41	150	5	350
Miami River	-	-	-	56	27	23	22	22	10	-	-	160
Mountain Slough	-	3	10	9	68	32	26	51	2	-	-	201
Pepin Creek	-	-	16	77	68	44	141	47	4	-	-	397
Salmon River	-	-	-	24	27	37	41	34	22	8	-	193
Salwein Hopedale	-	7	-	-	63	70	44	17	4	-	-	205
Total	**1**	**62**	**69**	**310**	**484**	**541**	**577**	**348**	**132**	**158**	**5**	**2687**

Table A3. Number of dissolved oxygen measurements for each year within Proposed Critical Habitat for Salish Sucker of each watershed.

Watershed	**Year**											
	03	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**	**12**	**13**	**14**
Agassiz Slough	5	10	9	-	-	1	-	-	47	87	-	-
Bertrand Creek	-	-	7	-	-	5	21	29	63	95	85	-
Chilliwack Delta	-	18	-	-	-	-	-	-	104	262	1	29
Elk Creek/Hope Slough	-	-	-	-	-	-	-	-	47	54	-	-
Fishtrap Creek	-	-	9	-	-	-	-	-	24	24	48	-
Hope Slough	-	-	-	2	7	8	80	-	-	-	-	-
Little Campbell River	-	-	-	-	2	2	-	-	7	11	199	127
Miami River	-	4	-	-	-	1	-	-	47	108	-	-
Mountain Slough	5	12	16	1	20	18	13	11	72	33	-	-
Pepin Creek	-	39	19	-	29	7	36	27	81	159	-	-
Salmon River	-	-	14	-	17	7	13	-	44	39	59	-
Salwein Hopedale	-	12	-	-	-	7	-	-	75	111	-	-
Total	10	95	74	3	75	56	163	67	611	983	392	156

RESULTS AND DISCUSSION

Seasonality of Hypoxia

The extent of hypoxia is very seasonal. The proportion of sites recorded as hypoxic or severely hypoxic peaked in September at 43.4 %, and exceeded 25% from July to October (Figure 1). This analysis incudes data from all years, and is consequently conservative. The proportion would be expected to exceed these figures in a year that was hotter and/or dryer than average.

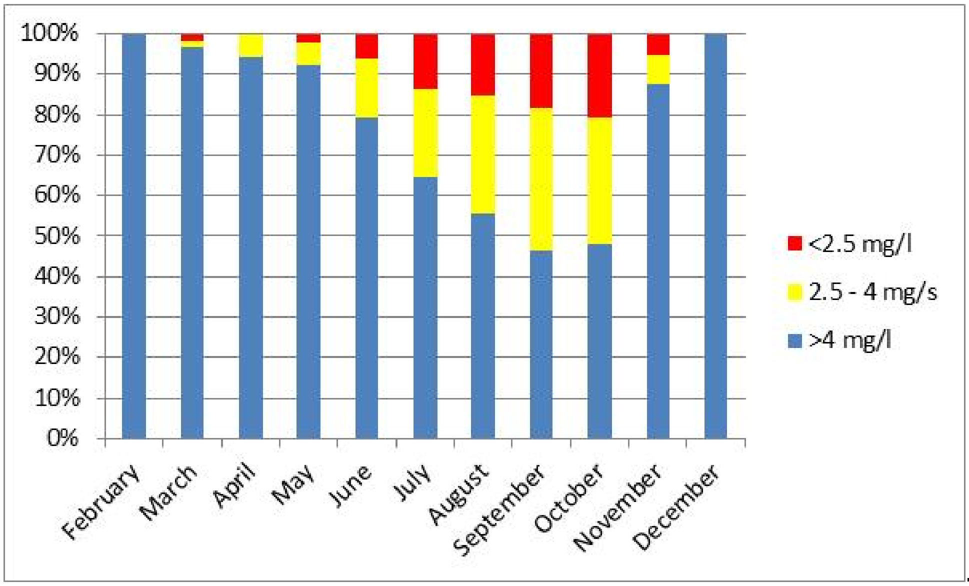

Figure A1. Proportion of sites sampled during each month within Salish Sucker Proposed Critical Habitat classified according to dissolved oxygen concentration. Data from all years are included.

Hypoxia Risk within Potential Critical Habitat

The expected spatial extent of hypoxia during a hot, dry summer is shown in Figures 2, 3 and 4 and the proportions of PCH in each watershed assigned to each risk category is shown in Figure 5.

An estimated 45 % of PCH is at risk of severe hypoxia in a hot dry summer and a further 23 % is at risk of some hypoxia. Levels of DO below 4 mg/l are expected in over half of PCH in all watersheds. The risk of severe hypoxia is most extensive in Mountain Slough, the Miami River, and the Little Campbell River, where more than 75% of PCH is likely to be affected.

Note that these figures are conservative. Undoubtedly some areas are classified at lower risk than they actually because they were not sampled during extreme conditions. Conversely, no exaggeration of risk occurs, as classifications are based on actual measured conditions.

Several watersheds, notably the Chilliwack Delta, Hopedale Slough, Salmon River and Elk Creek/Hope Slough include large areas of wide channel close to the Fraser River that have very low hypoxia risk, or in the case of Hope Slough, the risk of mild hypoxia. The Salish Sucker is seldom encountered in these areas, but they are considered important for migration between tributaries and as refugia during periods of severe hypoxia in habitually occupied habitats. They also inflate the proportion of low risk habitat, relative to habitats habitually occupied by the species.

CONCLUSION

The seasonality and extent of hypoxia risk within Potential Critical Habitat (PCH) for Salish Sucker were estimated from data collected between 2003 and 2014. PCH reaches or portions of reaches were classified according to the minimum recorded dissolved oxygen concentration as at risk of severe hypoxia (< 2.5 mg/l), hypoxia (2.5 – 4 mg/l), or not at risk of hypoxia ($\geq$ 4 mg/l).

The proportion of records classified as hypoxic peaked at over 40% in September samples and exceeded 25 % from July to October. Over two-thirds of PCH, by channel length, is at risk of hypoxia with 45 % being at risk of severe hypoxia. These estimates are considered conservative based on assumptions made during analysis and clearly support the prioritization of hypoxia as the dominant threat to Salish Sucker survival and recovery.

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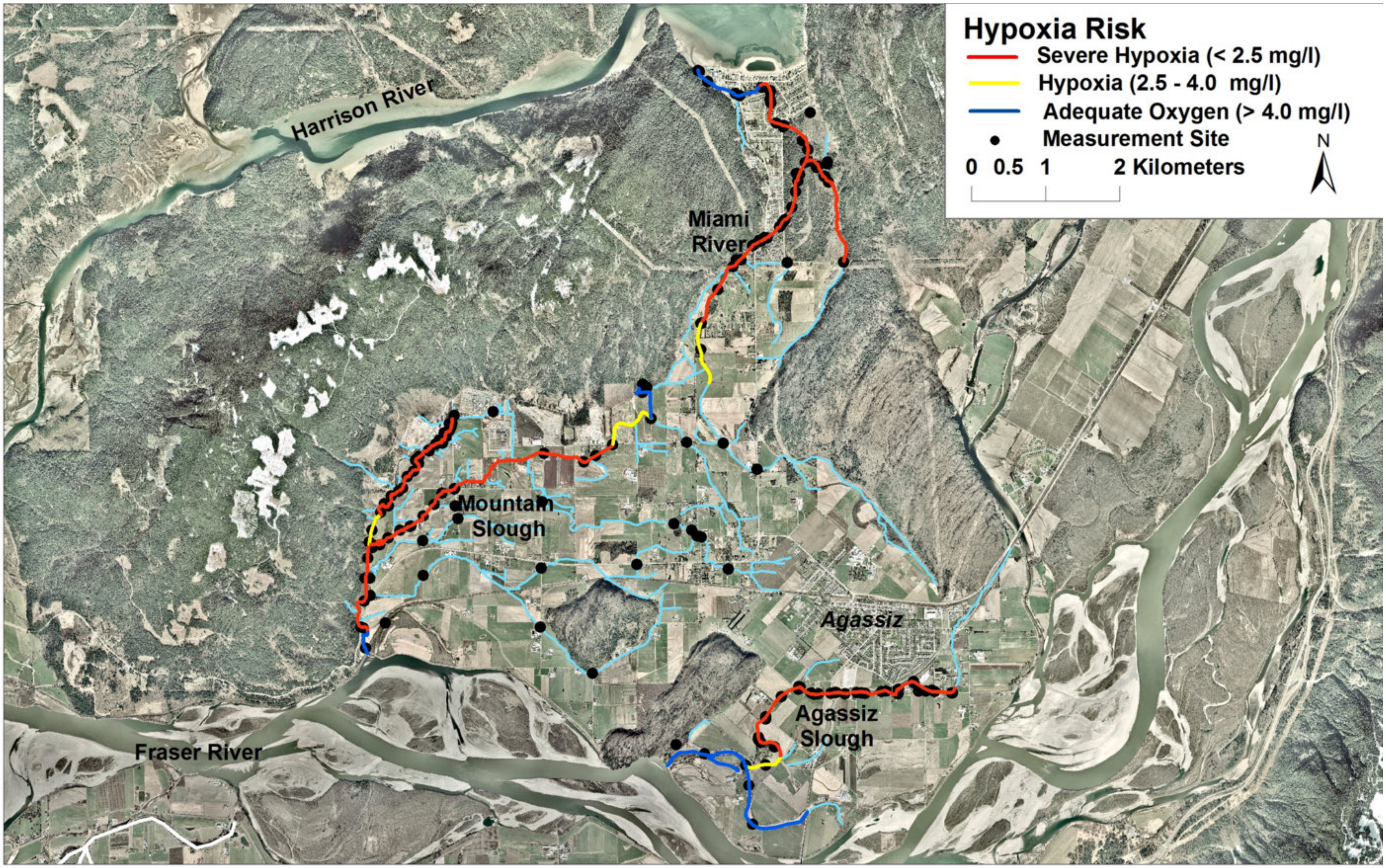

Figure A2. Seasonal hypoxia risk level in Proposed Critical Habitat for Salish Sucker in the eastern portion of the Canadian Range.

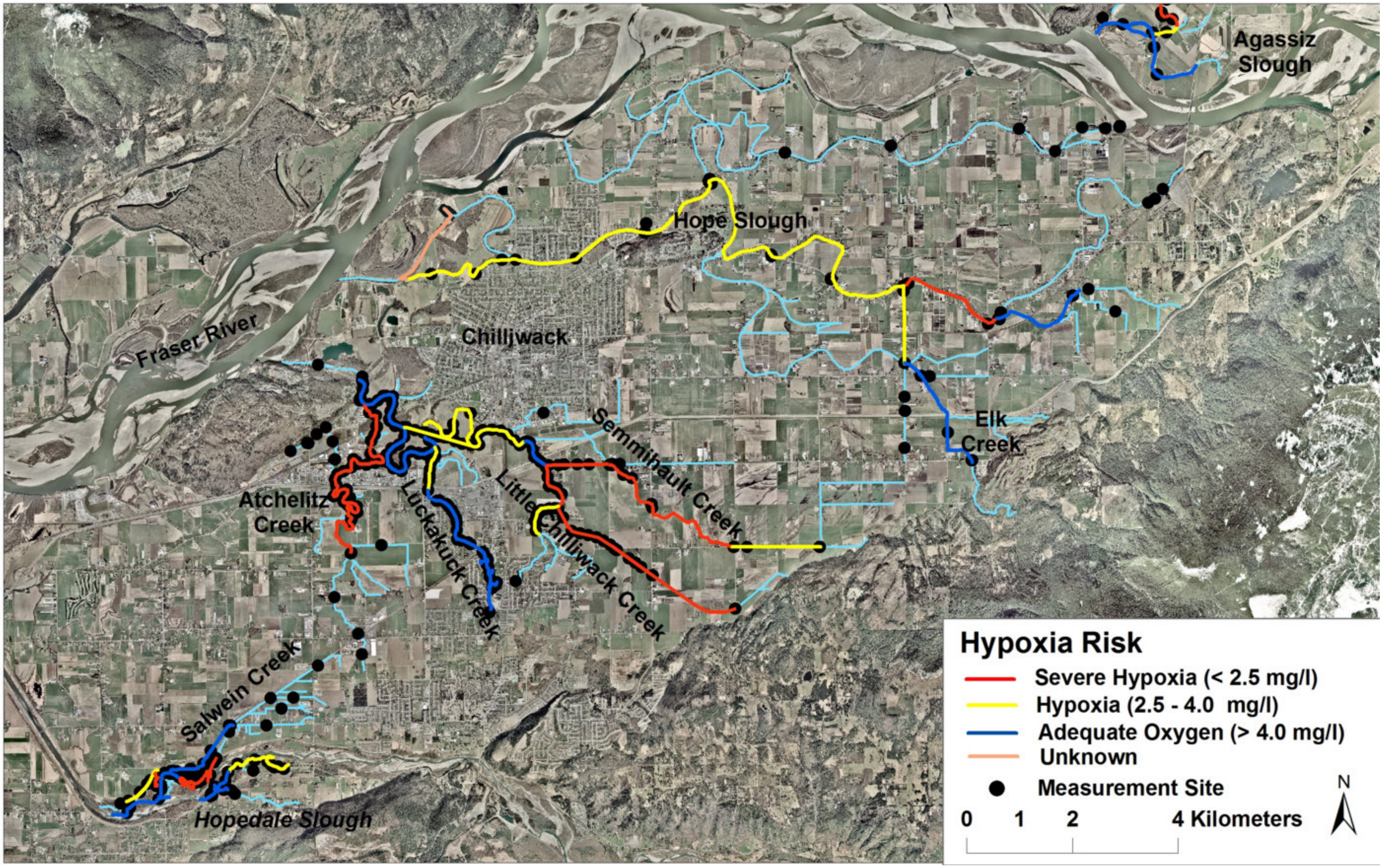

Figure A3. Seasonal hypoxia risk level in Proposed Critical Habitat for Salish Sucker in the central portion of the Canadian Range.

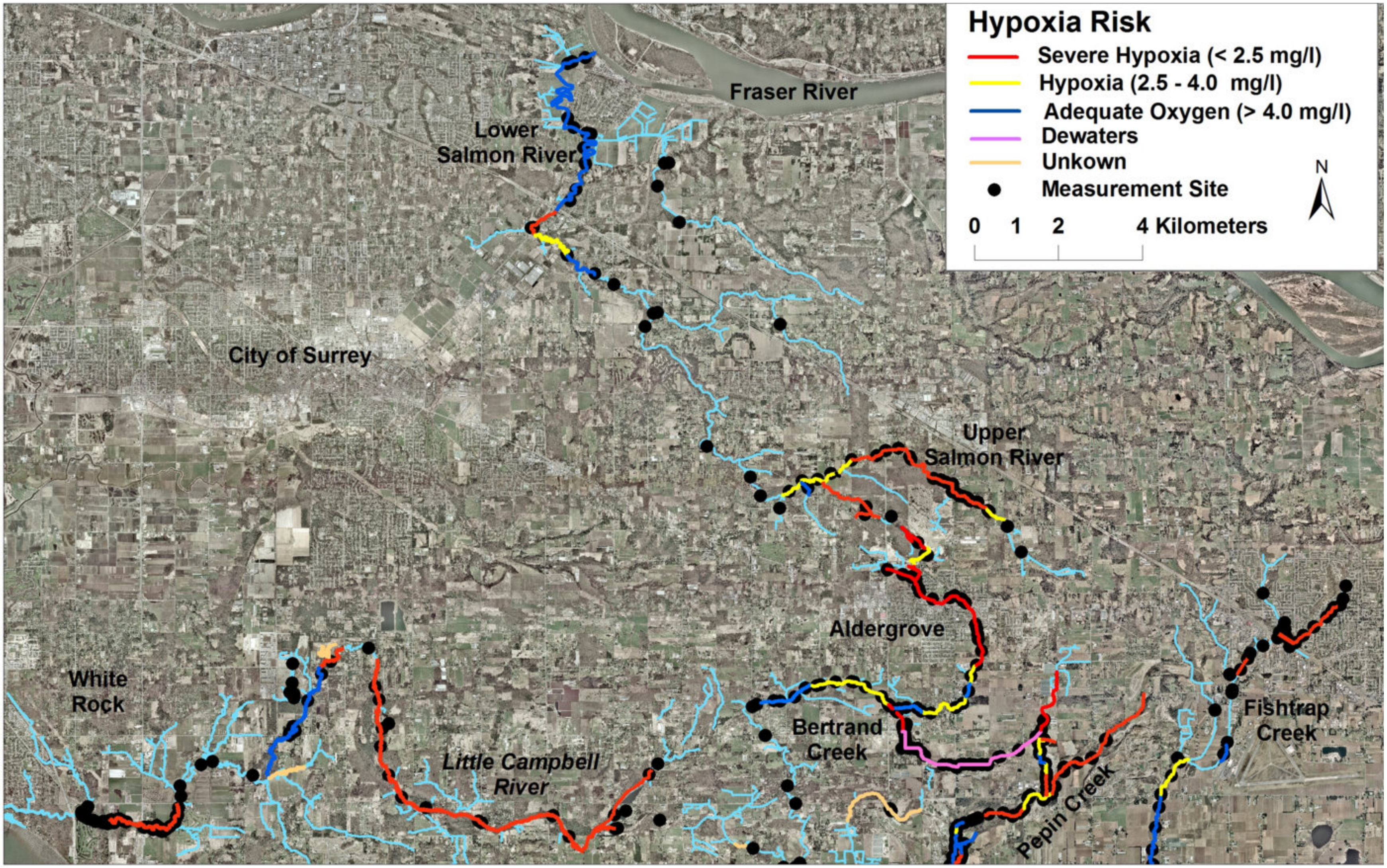

Figure A4. Risk of seasonal hypoxia and dewatering in Proposed Critical Habitat for Salish Sucker in the western portion of the Canadian range.

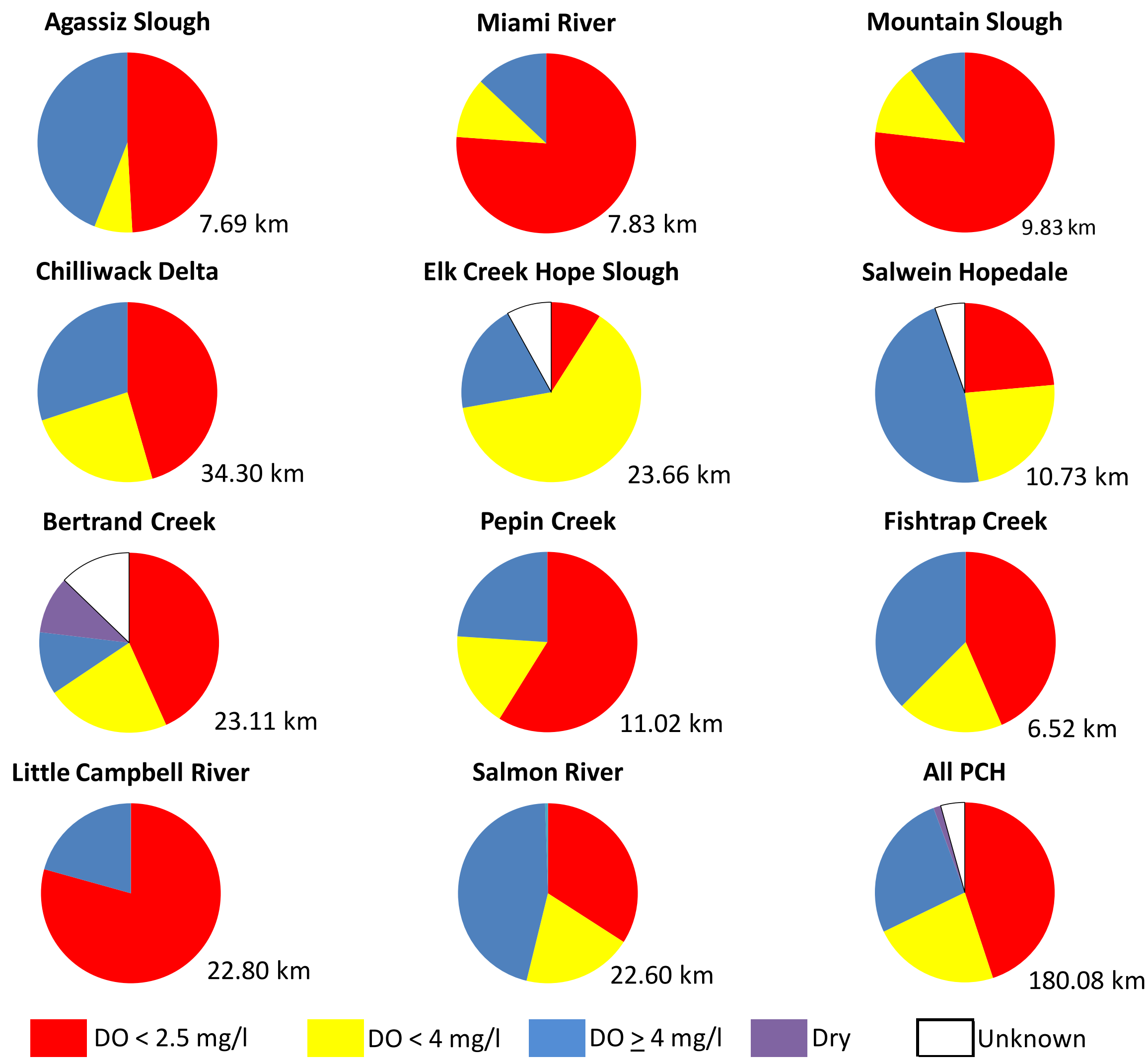

Figure A5. Proportion of Proposed Critical Habitat at risk of seasonal hypoxia or dewatering.

APPENDIX 2: TRACKING OF RECOVERY POTENTIAL ASSESSMENT ELEMENTS IN THE RESEARCH DOCUMENT

Table A4. Recovery potential assessment elements that appear in the research document

Element No.	Description	Section in Research Document
1	Summarize the biology of Salish Sucker	1.2.1
2	Evaluate the recent species trajectory for abundance, distribution and number of populations.	1.3.1 and 1.3.2
3	Estimate the current or recent life-history parameters for Salish Sucker	1.3.2 (insufficient data for quantitative estimates)
4	Describe the habitat properties that Salish Sucker needs for successful completion of all life-history stages. Describe the function(s), feature(s), and attribute(s) of the habitat, and quantify how the biological function(s) that specific habitat feature(s) provides varies with the state or amount of habitat, including carrying capacity limits, if any.	2.1
5	Provide information on the spatial extent of the areas in Salish Sucker distribution that are likely to have these habitat properties.	2.2
6	Quantify the presence and extent of spatial configuration constraints, if any, such as connectivity, barriers to access, etc.	2.3
7	Evaluate to what extent the concept of residence applies to the species, and if so, describe the species' residence.	2.4
8	Assess and prioritize the threats to the survival and recovery of Salish Sucker	3.1
9	Identify the activities most likely to threaten (i.e., damage or destroy) the habitat properties identified in elements 4-5 and provide information on the extent and consequences of these activities.	3.2

Element No.	Description	Section in Research Document
10	Assess any natural factors that will limit the survival and recovery of the Salish Sucker.	3.3
11	Discuss the potential ecological impacts of the threats identified in element 8 to the target species and other co-occurring species. List the possible benefits and disadvantages to the target species and other co-occurring species that may occur if the threats are abated. Identify existing monitoring efforts for the target species and other co-occurring species associated with each of the threats, and identify any knowledge gaps.	3.4 and 3.5
12	Propose candidate abundance and distribution target(s) for recovery.	4.1
13	Project expected population trajectories over a scientifically reasonable time frame (minimum of 10 years), and trajectories over time to the potential recovery target(s), given current Salish Sucker population dynamics parameters.	4.2
14	Provide advice on the degree to which supply of suitable habitat meets the demands of the species both at present and when the species reaches the potential recovery target(s) identified in element 12.	4.2
15	Assess the probability that the potential recovery target(s) can be achieved under current rates of population dynamics parameters, and how that probability would vary with different mortality (especially lower) and productivity (especially higher) parameters.	4.2
16	Develop an inventory of feasible mitigation measures and reasonable alternatives to the activities that are threats to the species and its habitat (as identified in elements 8 and 10).	5; Table 8
17	Develop an inventory of activities that could increase the productivity or survivorship parameters (as identified in elements 3 and 15).	5; Table 9
18	If current habitat supply may be insufficient to achieve recovery targets (see element 14), provide advice on the feasibility of restoring the habitat to higher values. Advice must be provided in the context of all available options for achieving abundance and distribution targets.	5.1

Element No.	Description	Section in Research Document
19	Estimate the reduction in mortality rate expected by each of the mitigation measures or alternatives in element 16 and the increase in productivity or survivorship associated with each measure in element 17.	5.1
20	Project expected population trajectory (and uncertainties) over a scientifically reasonable time frame and to the time of reaching recovery targets, given mortality rates and productivities associated with the specific measures identified for exploration in element 19. Include those that provide as high a probability of survivorship and recovery as possible for biologically realistic parameter values.	4.2 (quantitative projections not possible)
21	Recommend parameter values for population productivity and starting mortality rates and, where necessary, specialized features of population models that would be required to allow exploration of additional scenarios as part of the assessment of economic, social, and cultural impacts in support of the listing process.	4.2 (not possible at present)
22	Evaluate maximum human-induced mortality and habitat destruction that the species can sustain without jeopardizing its survival or recovery.	6.1