Proposed

Species at Risk Act
Recovery Strategy Series

Recovery Strategy for the Nooksack Dace (*Rhinichthys cataractae* ssp.) in Canada

Nooksack Dace

Original publication 2008
1st amendment 2019

Canada

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(changes made to all sections)

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For copies of the recovery strategy, or for additional information on species at risk, including Committee on the Status of Endangered Wildlife in Canada (COSEWIC) Status Reports, residence descriptions, action plans, and other related recovery documents, please visit the SAR Public Registry.

Cover illustration: Adult Nooksack Dace photo by Mike Pearson

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Preface

The federal, provincial, and territorial government signatories under the Accord for the Protection of Species at Risk (1996) agreed to establish complementary legislation and programs that provide for effective protection of species at risk throughout Canada. Under the Species at Risk Act (S.C. 2002, c.29) (SARA), the federal competent ministers are responsible for the preparation of a recovery strategy for species listed as extirpated, endangered, or threatened and are required to report on progress five years after the publication of the final document on the Species at Risk Public Registry.

The Minister of Fisheries and Oceans is the competent minister under SARA for the Nooksack Dace and has prepared this recovery strategy, as per section 37 of SARA. A recovery strategy was completed for Nooksack Dace and posted on the Species at Risk Registry in 2008 (Pearson et al. 2008). This 2018 recovery strategy is the first amendment to the 2008 recovery strategy. It updates the biology, recovery feasibility assessment, threats, population and distribution objectives, residence, and areas identified as critical habitat.

In preparing this recovery strategy, the competent minister has considered, as per section 38 of SARA, the commitment of the Government of Canada to conserving biological diversity and to the principle that, if there are threats of serious or irreversible damage to the listed species, cost-effective measures to prevent the reduction or loss of the species should not be postponed for a lack of full scientific certainty. To the extent possible, this recovery strategy has been prepared in cooperation with the Province of British Columbia as per section 39(1) of SARA.

As stated in the preamble to SARA, success in the recovery of this species depends on the commitment and cooperation of many different constituencies that will be involved in implementing the directions set out in this strategy and will not be achieved by Fisheries and Oceans Canada, or any other jurisdiction alone. The cost of conserving species at risk is shared amongst different constituencies. All Canadians are invited to join in supporting and implementing this strategy for the benefit of the Nooksack Dace and Canadian society as a whole.

The Action Plan for the Nooksack Dace (*Rhinichthys cataractae*) and the Salish Sucker (*Catostomus* sp.) in Canada (DFO 2017a) provides information on recovery measures to be taken by Fisheries and Oceans Canada and other jurisdictions and/or organizations involved in the conservation of the species. Implementation of this recovery strategy is subject to appropriations, priorities, and budgetary constraints of the participating jurisdictions and organizations.

Acknowledgments

Fisheries and Oceans Canada (DFO) developed this amended 2018 recovery strategy for Nooksack Dace. DFO acknowledges the efforts of Mike Pearson (Pearson Ecological), who made the updates to the document with contributions from Erin Gertzen, Sean MacConnachie and Martin Nantel (DFO).

DFO extends their appreciation to the authors of the 2008 recovery strategy including Todd Hatfield (Ecofish Research), Don McPhail, (University of British Columbia (UBC)), Mike Pearson, John Richardson (UBC), Jordan Rosenfeld (B.C. Ministry of Environment (B.C. MOE)), Hans Schreier (UBC), Dolph Schluter (UBC), Dan Sneep (DFO), Marina Stejpovic (Township of Langley), Eric Taylor (UBC), and Paul Wood (UBC).

Executive summary

The Nooksack Dace (*Rhinichthys cataractae* ssp.) was listed as Endangered under the Species at Risk Act (SARA) in 2003. This recovery strategy is considered one in a series of documents for this species that are linked and should be taken into consideration together, including the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) Status Report (COSEWIC 2007), the Science Advisory Report from the Recovery Potential Assessment (RPA) (Harvey 2008), and the joint Nooksack Dace and Salish Sucker action plan (DFO 2017a). Recovery has been determined to be biologically and technically feasible.

A recovery strategy was completed for Nooksack Dace and posted on the Species at Risk Registry in 2008 (Pearson et al. 2008). This 2018 recovery strategy is the first amendment to the 2008 recovery strategy. It updates the biology, recovery feasibility assessment, threats, population and distribution objectives, residence, and areas identified as critical habitat.

The Nooksack Dace is a small (<15 cm) stream dwelling minnow. It is a genetically distinct evolutionary lineage of the widespread and common Longnose Dace (*Rhinichthys cataractae*) that evolved in geographic isolation in Washington State during glaciation. Adults are generalized insectivores while juveniles feed on zooplankton. Within Canada it is known from four lowland streams in British Columbia's (B.C.) Fraser Valley. The global distribution includes approximately twenty additional streams in north-west Washington. The Nooksack Dace is extirpated from some tributaries in Canadian watersheds where it was abundant in the 1960s (McPhail 1997).

Nooksack Dace are strongly associated with riffle habitats and the proportion of riffle in a reach is the strongest predictor of their presence. Young-of-the-year fish require shallow pool and glide habitats in close proximity to the riffles inhabited by adults. Home range size is typically very small (<50 m of channel) although a few individuals venture for at least hundreds of metres. This suggests that clusters of riffles may contain semi-isolated subpopulations and that meta-population dynamics may be important at the watershed scale.

Section 33 of SARA prohibits the damage or destruction of a species' residence. A detailed description of the species' residence is provided in Section 4.

The main threats facing the species are described in Section 5 and include: sediment deposition, seasonal lack of water, physical destruction of habitat, habitat fragmentation, and riffle loss to impoundment. Harmful substances and hypoxia have also been identified as localized threats.

The population and distribution objectives (Section 6) for the Nooksack Dace are:

- population objective: Nooksack Dace are moderately abundant[1] in 60 percent of currently or historically occupied reaches by 2030. Occupied reaches means those reaches that currently contain or historically contained more than 10 percent riffle habitat by length in each of the species' four native watersheds in B.C.
- distribution objective: Nooksack Dace presence is confirmed in 80 percent of currently or historically occupied reaches by 2030. Occupied reaches means those reaches that currently contain or historically contained more than 10 percent riffle habitat by length in each of the species' four native watersheds in B.C.

[1] Moderately abundant is defined in Section 6.

A description of the broad strategies to be taken to address threats to the species' survival and recovery, as well as research and management approaches needed to meet the population and distribution objectives are included in Section 7. These informed the development of specific recovery measures in the Action Plan for the Nooksack Dace (*Rhinichthys cataractae*) and the Salish Sucker (*Catostomus* sp.) in Canada (DFO 2017a).

For the Nooksack Dace, critical habitat is identified to the extent possible, using the best available information, and provides the functions and features necessary to support the species' life-cycle processes and to achieve the species' population and distribution objectives. Section 8 of this recovery strategy identifies critical habitat for Nooksack Dace as those reaches in the four occupied watersheds that consist of or are known to have previously consisted of more than 10 percent riffle by length. It includes all aquatic habitats within those reaches, including features and attributes identified in Section 8, and all riparian areas on both banks for the entire length of the identified aquatic reaches. Riparian critical habitat is continuous and extends laterally (inland) from the top of bank to a width equal to the widest zone of sensitivity calculated for five riparian features and functions. The combined length of aquatic critical habitat for Nooksack Dace is 29.3 km (of 93.9 km of surveyed stream channel) and the area of riparian critical habitat associated with the aquatic critical habitat reaches is 137.6 hectares.

A SARA Critical Habitat Order is currently in place to legally protect from destruction Nooksack Dace critical habitat identified in the 2008 recovery strategy (Pearson et al. 2008). It is anticipated the Order will be amended following the publication of this amended recovery strategy which includes updates to critical habitat identification.

Recovery feasibility summary

The purposes of the Species at Risk Act (SARA) are to prevent wildlife species from being extirpated or becoming extinct, to provide for the recovery of wildlife species that are extirpated, endangered or threatened as a result of human activity and to manage species of special concern to prevent them from becoming endangered or threatened.

DFO determined that the Nooksack Dace is a historically precarious species because it was never widespread or abundant within Canada. The Nooksack Dace has four known populations and a small historic area of occupancy in Canada (<20 km^2; COSEWIC 2007).

For historically precarious species, recovery is considered feasible if the extent of irreversible biological or ecological change is such that it is technically and biologically feasible to improve the condition[2] of the species to approach its historic condition. Using criteria outlined in Table 1 below, DFO determined that the recovery of Nooksack Dace is feasible based on species characteristics and thresholds required to approach the historical condition of the species. While uncertainty[3] remains, Nooksack Dace's current condition can feasibly approach its historic condition with habitat improvements.

Table 1. Recovery feasibility evaluation for the historically precarious Nooksack Dace.

Fundamental species characteristic	Survival or recovery threshold (precarious species)	Technically and biologically feasible to achieve threshold before opportunity is lost? (yes / no / unknown)
Survival threshold		
Species Trend	Stable or increasing over 10 years	Unknown: achievable with improved habitat protection/enhancement
Resilience	Approximating historical condition	Yes: <10,000 mature individuals; high intrinsic rate of population growth due to life history traits (Pearson 2004)
Redundancy	Approximating historical condition	Yes: No populations are extirpated but the species is extirpated from some tributaries (sub-populations) (COSEWIC 2007)
Population Connectivity	Approximating historical condition	Yes: Relies on habitat improvements across the range (COSEWIC 2007)

[2] Condition of the species: combination of the level of redundancy, resilience, representation, population and distribution, trend, threats, ecological role and any other factors that together determine the risk of extinction or extirpation of the species in Canada.
[3] As per the Species at Risk Act's preamble "if there are threats of serious or irreversible damage to a wildlife species, cost-effective measures to prevent the reduction or loss of the species should not be postponed for a lack of full scientific certainty." When the determination of recovery as technically and biologically feasible is uncertain, the recovery strategy required under SARA will be prepared in accordance with requirements for a species for which recovery is feasible and will aim among other things to reduce this uncertainty.

Mitigation of Anthropogenic Threats	Significant threats avoided or mitigated to the extent that they no longer threaten the species	Yes: Reduction of riffle destruction, sedimentation deposition and protection of baseflows will be required (Harvey 2008)
Result	If all above conditions can be met, species is above the survival threshold	☒ **Survival threshold met**[3] ☐ **Survival threshold not met**
Minimum recovery threshold		
Species Condition	Improved over when first assessed as at risk or approximating historical condition	Yes: Distribution and abundance could be increased over first assessment if habitat degradation issues are addressed (Harvey 2008)
Representation (Species presence in appropriate ecological communities)	Approximating historical condition at a coarse scale	Yes: No known extirpations at watershed scale (COSEWIC 2007). Habitat remediation required in Pepin, Fishtrap Creeks and Brunette River (Harvey 2008)
Independent of connectivity with populations outside of Canada	Connectivity okay if necessary	Yes: Connectivity to Washington State exists for 3 populations, but recovered Canadian populations not likely dependent on this connectivity.
Independent of species intervention	Yes	Yes: Some beaver management may be required in Pepin Creek (COSEWIC 2007)
Result	If survival threshold and all above conditions can be met, recovery is feasible	☒ **Recovery feasible**[3] ☐ **Recovery not feasible**

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Background

1. Introduction

The Nooksack Dace (*Rhinichthys cataractae* ssp.) was listed as Endangered under the Species at Risk Act (SARA) in 2003.

This recovery strategy is part of a series of documents regarding Nooksack Dace that should be taken into consideration together, including the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) Status Report (COSEWIC 2007), the Science Advisory Report from the Recovery Potential Assessment (RPA) (Harvey 2008), and the joint Nooksack Dace and Salish Sucker action plan (DFO 2017a). The COSEWIC Status Report contains basic biological information on the species and an assessment classifying the species as data deficient, not at risk, extinct, extirpated, endangered, threatened or special concern. The RPA is a research document undertaken by DFO Science to provide the information and scientific advice required to implement SARA and inform the recovery strategy, relying on the best available scientific information, data analyses and modeling, and expert opinions. A recovery strategy is a planning document that identifies what needs to be done to arrest or reverse the decline of a species. It sets objectives and identifies the main areas of activities to be undertaken. An action plan contains detailed planning aimed to help recover the species.

2. COSEWIC species assessment information

Assessment summary – April 2007

Common name: Nooksack Dace

Scientific name: *Rhinichthys cataractae* ssp.

COSEWIC status: Endangered

Reason for designation: The species is considered a habitat specialist dependent on stream riffles with loose, small grained substrates. This small fish is a representative of the Chehalis fauna, and considered to be a distinct subspecies of the Longnose Dace. It is known in Canada from only four locations in southwestern BC where its area of occupancy is severely limited, and subject to ongoing physical destruction of riffle habitat by urban, industrial and agricultural practices (e.g. dredging, channelization). Streams where the species is found are also impacted by lack of water in late summer due to ground and surface water extraction. Other activities have led to sediment accumulation in riffles caused by bank erosion resulting from gravel mining and/or runoff from urban storm drains, leading to further degradation of water quality and habitat.

Canadian occurrence: British Columbia

Status history: Designated Endangered in April 1996. Status re-examined and confirmed in May 2000 and April 2007.

3. Species status information

The conservation status of the Nooksack Dace within relevant jurisdictions is summarized in Table 2. Based on available information, Canada contains approximately 10 percent of the global range and 20 percent of all populations (COSEWIC 2007).

Table 2. Summary of existing protection or other status designations assigned to Nooksack Dace.

Jurisdiction	Authority/organization	Year	Status/description	Designation level
B.C.	Conservation Data Centre	2010	S1* Red List	Species
Canada	SARA	2003	Schedule 1: Endangered	Species
Canada	COSEWIC	2007	Endangered	Species
Canada	NatureServe	2007	N1*	Species
Washington	NatureServe	1996	S3*	Species
United States	NatureServe	1996	N3*	Species
International	NatureServe	1996	G3*	Species
International	American Fisheries Society	2008	Endangered	Species

*G = Global Status; N = National Status; S = Subnational Status; 1= Critically imperiled, 3 = Vulnerable

Upon listing as an Endangered species under Schedule 1 of SARA, the Nooksack Dace became protected wherever it is found by section 32 of SARA:

> "No person shall kill, harm, harass, capture or take an individual of a wildlife species that is listed as an extirpated species, an endangered species or a threatened species." [s. 32(1)]
>
> "No person shall possess, collect, buy, sell or trade an individual of a wildlife species that is listed as an extirpated species, an endangered species or a threatened species, or any part or derivative of such an individual." [s. 32(2)]

Under section 73 of SARA, the competent minister may enter into an agreement or issue a permit authorizing a person to engage in an activity affecting a listed wildlife species, any part of its critical habitat or its residences.

4. Species information

4.1 Description

The Nooksack Dace is a small (<15 cm) stream dwelling cyprinid (minnow). The body is streamlined, with large pectoral fins and a snout that overhangs the mouth. Body colouration is grey-green above a dull, brassy lateral stripe and dirty white below it. There is often a distinct black stripe on the head in front of the eyes. In juveniles, the stripe continues down the flanks to the tail (McPhail 1997; COSEWIC 2007). The Nooksack Dace is a distinct evolutionary lineage of the widespread and common Longnose Dace[4] (*Rhinichthys cataractae*) found in Washington State and the Fraser Valley of B.C. (Ruskey and Taylor 2016; Taylor et al. 2015). The species evolved through geographic isolation in Washington State's Chehalis River valley during the Pleistocene glaciations (McPhail 1997; Ruskey and Taylor 2016). Adults are generalized insectivores while juveniles feed on zooplankton (McPhail 1997).

4.2 Population abundance and distribution

Populations are documented from lowland streams in four watersheds in B.C.'s Fraser Valley – Brunette River, Bertrand Creek, Pepin Creek (Brook) and Fishtrap Creek (Figure 1). Brunette River is a tributary of the Fraser River and the other three are tributaries of the Nooksack River in Washington State. Each of the four watersheds represents a population. Within each population, there may be several subpopulations at specific locations within the watershed.

For the Canadian range, no reliable estimates of abundance exist; however, abundance is unlikely to exceed 6,800 adults for the Nooksack River tributaries (COSEWIC 2007). Sub-populations of two of the Nooksack Dace populations are extirpated: Howe's Creek (tributary to Bertrand Creek) and the headwaters of Bertrand and Fishtrap creeks where it was abundant in the 1960s (McPhail 1997).

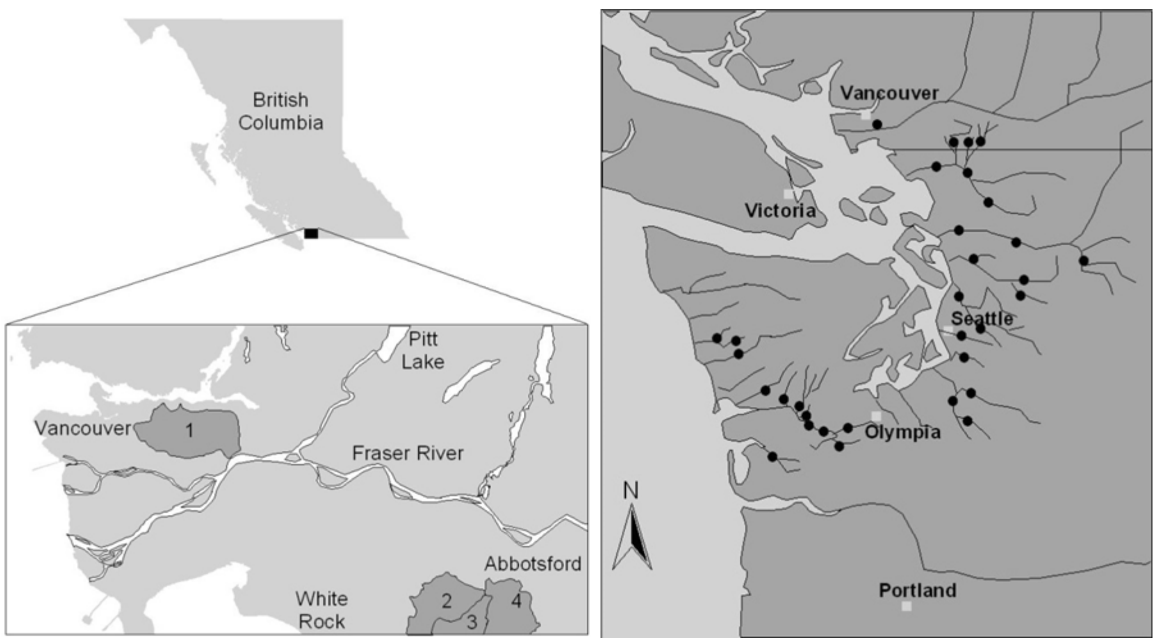

Figure 1. In Canada, Nooksack Dace are known to inhabit four watersheds (left panel; 1: Brunette River, 2: Bertrand Creek, 3: Pepin Creek, 4: Fishtrap Creek). Globally, it is also found in a number of other streams in northwestern Washington (right panel; adapted from COSEWIC 2007).

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[4] Recent morphological and genetic work indicates Nooksack Dace are a distinct evolutionary lineage of *Rhinichthys cataractae* but do not constitute a distinct species (Ruskey and Taylor 2016)

Three additional populations of *R. cataractae* in tributaries to the Lower Fraser River (Coquitlam River, Alouette River and Kanaka Creek) consist of a hybrid population containing genetic markers of both Nooksack Dace and Columbia-Fraser Longnose Dace (Ruskey and Taylor 2016). Another hybrid population exists in the Chilliwack River upstream of Chilliwack Lake, however they exhibit a higher percentage of Nooksack Dace DNA than these three populations (E. Taylor unpubl. data 2018).

Further, it is possible that undocumented populations of Nooksack Dace exist within Canada. The most likely areas are in fast flowing rocky streams on the margins of the Fraser Valley, particularly upstream of lakes, where Nooksack Dace populations may have escaped hybridization with the Columbia form of *R. cataractae*, which recolonized the Fraser Valley long after Nooksack Dace populations were re-established post-glacially. Such areas include the Skagit River (supports Nooksack Dace in the United States), and tributaries to Harrison Lake and Stave Lake.

The global distribution consists of approximately 20 additional streams in northwestern Washington State. The current status of Washington State populations is unknown.

4.3 Needs of the species

Biological needs, ecological role and limiting factors

The major factor limiting population abundance and distribution is the availability of riffle habitat with unembedded[5] substrates that include cobble or boulder elements. Given adequate habitat, Nooksack Dace populations should recover rapidly as their life history characteristics promote rapid population growth. They are small-bodied, mature early (2 years; McPhail 1997), have an extended spawning period (April 15 to July 15) and may spawn more than once each year (Pearson 2004), a trait that increases fecundity in species otherwise limited by small female body size (Blueweiss et al. 1978; Burt et al. 1988). Nooksack Dace fecundity ranges from 200 to 2,000 eggs depending on female body size.

Adult Nooksack Dace forage primarily at night for riffle dwelling insects (McPhail 1997) but have also been observed feeding on plankton and benthos during the day (Pearson 2016). Newly emerged fry feed on zooplankton and small macroinvertebrates (McPhail 1997), and first-summer juveniles drift feed during the day in very shallow pools and glides[6] immediately up or downstream of turbulent flow (Pearson 2016).

Aquatic habitat

Nooksack Dace are riffle specialists. The proportion of riffle habitat in a reach is the strongest predictor of their presence and they are rarely found in reaches with less than 10 percent riffle habitat by length or in reaches where long stretches of deep pool habitat separate riffles (Pearson 2004). Newly emerged fry require shallow, calm pool habitats in close proximity to riffles. In July and August, young-of-the-year move into faster currents (~10 centimetres/second (cm/s)) to drift feed in loose aggregations of 5 to 50 fish (Pearson 2016). After this first summer, Nooksack Dace primarily occupy the boundary layer of low velocity microhabitats at the

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[5] Unembedded: large substrate (boulder, cobble, gravel) free of fine sediment accumulation in the interstitial spaces (holes) between substrate pieces.
[6] Glide: moderately shallow sections of stream with even flow and little turbulence.

substrate surface and interstitial spaces between substrate particles (Champion 2016). This interstitial habitat is larger and more diverse within larger substrates and in the absence of finer sediments that infill interstitial spaces. High surface area and diverse microhabitats in coarse substrate also increase macroinvertebrate production and diversity (Hershey and Lamberti 1998) and provides the low velocity microhabitats where foraging efficiency is highest (Champion 2016). The overwintering habitat requirements of Nooksack Dace are unknown but adults have been observed under cobble in riffles (COSEWIC 2007).

Riffles are among the shallowest of stream habitats and consequently among the first to shrink when flow declines. When riffle habitats lack sufficient water, Nooksack Dace find refuge in pool habitats but both abundance and growth rate decline under these conditions (Avery-Gomm et al. 2014). Predation risk is also likely increased. Unlike riffles, pools in these streams are frequented by many native predators, including Rainbow and Cutthroat Trout (*Oncorhynchus* spp.), Prickly Sculpin (*Cottus asper*), Mink (*Neovison vison*), River Otter (*Lontra canadensis*), Belted Kingfisher (*Megaceryle alcyon*) and Great Blue Heron (*Ardea herodias*), and by introduced predators, including Largemouth Bass (*Micropterus salmoides*) and Brown Bullhead (*Ameiurus nebulosus*) (Pearson 2004).

Most individuals appear to have small home ranges (tens of metres of channel) although a small number of individuals venture hundreds of metres over the course of one year. Clusters of riffles may contain semi-isolated subpopulations. Distances and barriers between clusters may influence long-term population persistence by altering watershed scale meta-population dynamics (Pearson 2004).

Little information exists on tolerances or preferences of Nooksack Dace for dissolved oxygen, pH, temperature, or other water quality parameters. Activity appears minimal at temperatures below 11^{o}C, and fish forage normally at temperatures in excess of 20^{o}C (Pearson 2004). Nooksack Dace are likely poorly adapted to hypoxia, as their riffle habitats are typically well oxygenated. The federal water quality guideline for dissolved oxygen to support aquatic life (5 mg/l; CCREM 2015) is likely an appropriate benchmark for Nooksack Dace.

Riparian habitat

Riparian habitat is important to the Nooksack Dace. Benthic insectivores and riverine specialists like Nooksack Dace are among the most sensitive fish species to loss of wooded riparian areas (Stauffer et al. 2000), probably due to the impacts of riparian loss on siltation and macroinvertebrate community structure (Kiffney et al. 2003; Allan 2004). Riparian habitat helps control sediment entry to streams from overland flow, prevents excessive bank erosion and buffers stream temperatures. Failure to maintain adequate riparian habitats can cause population-level impacts. For example, an absence of shade from overhanging or canopy vegetation may increase water temperatures to harmful levels (>23°C) and result in reduced fitness and mortality of individuals (Lynch et al. 1984; Richardson et al. 2010). Increased erosion due to poorer bank stability can cause sediment deposition in riffles, leading to increased embeddedness, decreased interstitial habitat, impaired spawning and incubation, and decreased invertebrate prey abundance (Richardson et al. 2010).

4.4 Residence of the species

SARA states that “No person shall damage or destroy the residence of one or more individuals of a wildlife species that is listed as an endangered species or a threatened species, or that is listed as an extirpated species if a recovery strategy has recommended the reintroduction of the species into the wild in Canada." [s. 33]

Also, SARA defines "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. 2(1)]

The following is a description of a residence for Nooksack Dace.

4.4.1 Location of the species' residence

Nooksack Dace spawn at night during the spring and usually at the upstream end of riffles (McPhail 1997). They establish small breeding territories (a 10 cm diameter nest) in coarse substrate (Bartnik 1972). A 2015 survey of Bertrand Creek revealed newly emerged fry at virtually all riffles in the watershed (Pearson 2016). All riffles within critical habitat and occupied areas should be regarded as containing residences during spawning and incubation season (April 15 to August 15).

4.4.2 Structure, form and investment

The nest site is a 10 cm diameter depression in the gravel cleaned and formed by probing with the snout by males prior to courtship and by both sexes during courtship. A study of the Nooksack-Columbia Dace hybrids of the Alouette River documented male defence of territories against all fish except receptive female dace. Males entice females to spawn in their territory using complex courtship cues (Bartnik 1972). Females do not deposit all of their eggs in a single spawning event or remain in the nest after spawning; they usually deposit eggs in multiple nests (Bartnik 1973; McPhail 2007).

4.4.3 Occupancy and life-cycle function

Nests are occupied by eggs during incubation and are occupied and defended by males during nest preparation, courtship and egg incubation (Bartnik 1973). Incubation averages one week but varies with water temperature. Hatching is a protracted process, requiring at least 2 days at 18°C (McPhail 2007). At least two pulses of spawning have been detected in populations in the Columbia system and in North Carolina (Roberts and Grossman 2001; McPhail 2007) and female Nooksack Dace in spawning condition have been captured in Canada between the end of April and the beginning of July (M. Pearson pers. comm. 2017). Egg incubation and emergence of fry is likely complete by mid-August.

Typically all riffles in occupied reaches support spawning and incubation (Pearson 2016) and should be assumed to contain residences between April 15 and August 15 (Pearson 2004).

5. Threats

5.1 Threat assessment

An assessment and prioritization of threats to survival and recovery of the Nooksack Dace was undertaken in the RPA (Harvey 2008) and was based on earlier work by Pearson (2004). For more details on the threat assessment process, refer to the Guidance on Assessing Threats, Ecological Risk and Ecological Impacts for Species at Risk (DFO 2014). Assessment category definitions are provided in footnotes to Table 4 and Appendix C.

In this recovery strategy, the threat assessment was updated and revised in accordance with a two-step process, which first characterizes threats at the population (watershed) level and then at the whole Canadian range level. The population level threats analyses for each of the four populations appear in Appendix D. The Canadian range level threat assessment is presented in Table 4.

Eight threats were identified based on knowledge of species biology and habitat conditions across the Canadian range in the RPA (Harvey 2008). Seven of these threats are included in the assessment (Table 3), having removed the threat of increased predation from aquatic invasive species from consideration as there is no evidence it is a significant concern. Introduced predators are widespread in the range (e.g., Largemouth Bass, Brown Bullhead) but probably have minimal impacts on Nooksack Dace because of lack of habitat overlap (Pearson 2004; Harvey 2008).

Table 3. Threats to Nooksack Dace in Canada in descending order of concern.

Threat	Definition
1. Sediment deposition	Deposited sediment degrading habitat.
2. Seasonal lack of water	Low flows in late summer eliminate habitat, reducing fitness or survival.
3. Harmful substances	Harmful discharges from point or non-point sources significantly reducing survival or fitness.
4. Physical destruction of habitat	Drainage, dyking, channelization channel maintenance, and infilling of water bodies destroying habitat.
5. Hypoxia	Episodes of extreme low levels of dissolved oxygen causing acute mortality or reduced fitness.
6. Riffle loss to impoundment	Flooding of riffle habitat by beaver or human activity
7. Habitat fragmentation	Permanent or temporary barriers preventing or inhibiting fish from traversing some stream reaches. This restricts access to usable habitats and/or alters meta-population dynamics to increase extinction risk.

Table 4. Nooksack Dace threat assessment at the Canadian range level, in descending order of severity.[7]

Threat	Canadian range level threat risk[8]	Canadian range level threat occurrence[9]	Canadian range level threat frequency[10]	Canadian range level threat extent[11]
Sediment deposition	High	Historic Current Anticipatory	Recurrent	Extensive
Seasonal lack of water	High	Historic Current Anticipatory	Recurrent	Broad
Harmful substances	High	Historic Current Anticipatory	Recurrent	Extensive
Physical destruction of habitat	High	Historic Current Anticipatory	Recurrent	Extensive
Hypoxia	High	Historic Current Anticipatory	Recurrent	Broad
Riffle loss to impoundment	High	Historical Current Anticipatory	Recurrent	Narrow
Habitat fragmentation	Medium	Historic Current Anticipatory	Continuous	Narrow

[7] The specific assessment categories and associated rankings definitions for population- level threats are provided in Appendix C. Canadian range level threats are a roll-up of population level threats.
[8] Canadian range level threat risk: the highest level of risk for a given population, based on the likelihood and level of impact of a population-level threat
[9] Canadian range level threat occurrence: the timing of occurrence of the threat; may be any combination of historical, current and/or anticipatory representing all categories that have been identified in the population-level assessment
[10] Canadian range level threat frequency: the temporal extent of the threat representing all categories that have been identified in the population-level assessment
[11] Canadian range level threat extent: the proportion of the species affected by the threat

5.2 Description of threats

Across the Canadian range, six of the seven threats are rated as high risk (Table 4). Habitat fragmentation is considered a medium risk threat but is poorly understood (COSEWIC 2007; Harvey 2008). At the population level, the relative seriousness of the threats varies considerably (Appendix D). In the Brunette River, the threats of sedimentation and harmful substances are considered high risk. Seasonal lack of water was rated as a high risk threat to the Bertrand Creek population. In Pepin Creek, riffle loss to impoundment and hypoxia are viewed as high risk. In Fishtrap Creek, harmful substances and physical destruction of habitat (mostly historical) are thought to pose high risks.

Sediment deposition

Sediment deposition is considered a high risk threat to Nooksack Dace in Canada, with significant sediment deposition occurring in portions of all occupied watersheds (Table 4; Pearson 2004; M. Pearson pers. comm. 2017). At the population level, it is a high risk threat in the Brunette River and Fishtrap Creek, and a medium risk threat in Bertrand and Pepin creeks (Appendix D). All Nooksack Dace watersheds except Pepin Creek receive significant amounts of urban stormwater, which can carry sediments into Nooksack Dace habitats. Major sediment deposition events include: a large deposition event in November 2015 caused by slope failure at a construction site in the Brunette River; large slope failure/erosion involving hundreds to thousands of cubic metres of material have also occurred in Pepin Creek (1997, 2009) and Bertrand Creek (2012) (M. Pearson pers. comm. 2017).

Harmful levels of sediment deposition can be caused by direct episodic discharges of sediment from gravel mines, construction sites, landslides, storm drain runoff, or bank erosion. Loss of riparian vegetation and/or increased peak flows increase erosion and sedimentation rates (Waters 1995). Adult Nooksack Dace are sensitive to sediment deposition because they spawn, forage and rest in the interstitial spaces between and under coarse riffle substrate (McPhail 1997). Sedimentation clogs these spaces and inhibits the flow of oxygenated water through the substrate. This has been shown to increase the vulnerability of Nooksack Dace to predation and to reduce the availability of invertebrate food sources (Champion 2016).

Seasonal lack of water

Seasonal lack of water is considered a high risk threat to Nooksack Dace in Canada (Table 4). At the population level, it is a high risk threat in Bertrand Creek, a medium risk threat in Fishtrap Creek, and a low risk threat in the Brunette River and Pepin Creek (Appendix D). During late summer when rainfall is sparse, stream flows in occupied watersheds are maintained almost solely by groundwater. Watersheds with large unconfined aquifers (Pepin Creek, lower Fishtrap Creek) maintain steady flows of cool water throughout this critical period. In contrast, surface flows are much lower in Bertrand and upper Fishtrap creeks, and sometimes cease completely (Pearson 2004). Low surface flows have reduced the availability of suitable Nooksack Dace habitat in Bertrand Creek and portions of Fishtrap and Stoney creeks (a Brunette River tributary) for several weeks in late summer during very dry years (Avery-Gomm et al. 2014; M. Pearson pers. obs.).

Nooksack Dace are highly vulnerable to lack of water. Low flows have been shown to reduce Nooksack Dace growth (Avery-Gomm et al. 2014). Adults inhabit riffles and young-of-the-year school in nearby shallow pools (McPhail 1997). Riffle and shallow pool habitats are the first to shrink or disappear with lack of water in late summer and early fall. The natural vulnerability of these areas is greatly exacerbated by human water use for irrigation and domestic purposes, which peaks during the late-summer low flow period. Common land use changes that involve installing drainage infrastructure (urbanization, gravel mining, agricultural drainage) also tend to exacerbate problems with water availability during dry periods. In addition, flow reductions caused by wetland drainage, impermeable surfaces, gravel mining, and water withdrawal are likely to have population level impacts.

Harmful substances

Harmful substances are considered a high risk threat to Nooksack Dace in Canada (Table 4). At the population level, they are a high risk threat in the Brunette River, a medium risk threat in Pepin and Fishtrap creeks, and a low risk threat in Bertrand Creek (Appendix D). Specifically, a train derailment in 2013 resulted in coal dust deposition over Nooksack Dace habitat throughout the mainstem Brunette River; population impacts remain unknown. Large portions of the Fishtrap Creek, Bertrand Creek, and especially the Brunette River watersheds are urbanized. Row crop agriculture with intensive pesticide and herbicide use is also common in the Fishtrap Creek and Pepin Creek watersheds (Pearson 2004).

Harmful substances enter Nooksack Dace streams through urban storm runoff, contaminated groundwater, direct industrial discharges, aerial deposition and accidental spills (Hall et al. 1998; Harvey 2008). Data on threshold concentrations for lethal and sub-lethal effects of harmful compounds on Nooksack Dace are lacking. As a bottom-dwelling species, Nooksack Dace may be sensitive to contaminants bound to sediment as well as those in food items and the water column. The United States Environmental Protection Agency lists the closely related Longnose Dace as ‘intolerant” of pollution (EPA 2012).

Physical destruction of habitat

Physical destruction of habitat is considered a high risk threat to Nooksack Dace in Canada (Table 4). At the population level, it is a high risk threat in Fishtrap Creek, a medium risk threat in Bertrand Creek, and a low risk threat in the Brunette River and Pepin Creek (Appendix D). Historically, physical destruction of habitat was likely the most serious of the identified threats across Nooksack Dace’s Canadian range. A large proportion of Nooksack Dace habitat has been channelized and/or dredged by agricultural drainage or urban development projects, causing a loss in riffle habitat. The entire mainstem Brunette River was channelized in the 1920s and all riffles were removed from the lower 5 km of Fishtrap Creek during dredging for flood control in 1990 (Pearson 2004). Periodic channel dredging for flood control currently occurs in portions of Fishtrap Creek. Such works in Pepin and Bertrand creeks are rare but occasionally occur. Future destruction of Nooksack Dace habitat in the Brunette River is protected because the river flows primarily through public parkland.

Physical destruction of habitat may occur through channelization, channel maintenance, dredging and infilling activities that directly destroy or degrade stream habitats. The riffle habitats required by Nooksack Dace are the ‘high spots’ in a stream and tend to be targeted for removal or alteration in drainage projects. Channelization and drainage maintenance work also typically eliminates the shallow marginal pools required by newly emerged fry.

Physical destruction of habitat may also occur through the removal of riparian vegetation and may impact Nooksack Dace throughout its Canadian range. Riparian vegetation helps control sediment entry to the stream from overland flow, prevents excessive bank erosion and buffers stream temperatures, reduces nutrient loading, and provides terrestrial insects for drift-feeders in streams. Removal of riparian vegetation can also exacerbate other threats, including sediment deposition.

Hypoxia

Hypoxia, or the presence of low oxygen levels in water, is considered a high risk threat to Nooksack Dace in Canada (Table 4). At the population level, it is a high risk threat in Pepin Creek, a medium risk threat in Bertrand and Fishtrap creeks, and a low risk threat in the Brunette River (Appendix D). Specifically, severe seasonal hypoxia affects most of Pepin Creek and significant portions of Bertrand and Fishtrap creeks (Pearson 2015a). The most hypoxic areas are deeper habitats; however, riffles and shallow pools downstream of these hypoxic areas may also experience low dissolved oxygen levels. For example, the Cariboo Dam on the Brunette River passes primarily bottom water from Burnaby Lake to the Brunette River. In the summer this bottom water is hypoxic and depresses oxygen levels as far downstream in the Brunette River as Highway 1 (950 m) during the late summer low flow period (Pearson unpub. data).

Hypoxia is caused by the cumulative effects of local and watershed-scale impacts. Nutrients in Fraser Valley groundwater and streams are elevated, primarily as a consequence of over-application of manure and fertilizers to agriculture lands (Lavkulich et al. 1999; Schreier et al. 2003), but also from urban stormwater runoff and faulty septic systems (Lavkulich et al. 1999). Such nutrient loading has increased greatly with ongoing agricultural intensification in the Fraser Valley (Schöne et al. 2006; Schindler et al. 2006). Increased nutrients result in algal blooms and rampant growth of plants that deplete oxygen levels at night. Decomposition of dead vegetation may severely depress daytime oxygen levels as well. Further, hypoxia may be exacerbated by the removal of riparian vegetation because shade provided by riparian vegetation helps maintain lower water temperatures. Warmer water has less capacity for dissolved oxygen and increases the metabolic demands of fish and other organisms. In addition, reduced water movement impairs re-oxygenation of water and may be caused by channelization (Schreier et al. 2003), beaver ponds (Fox and Keast 1990; Schlosser and Kallemyn 2000) or low flows.

Lethally low levels of oxygen are unknown for Nooksack Dace but riffles are generally well-oxygenated habitats and species that are specialized to inhabit riffles are unlikely to be well adapted to tolerate hypoxia. Even moderate levels of chronic hypoxia may reduce growth, condition and fecundity. In the absence of better information, the federal guideline for the protection of aquatic life (5 mg/l; CCREM 2015) is a useful target.

Riffle loss to impoundment

Riffle loss to impoundment is considered a high risk threat to Nooksack Dace in Canada (Table 4). At the population level, it is a high risk threat in Pepin Creek and a low risk threat in the Brunette River, Bertrand Creek and Fishtrap Creek (Appendix D). In Pepin Creek in 1999, beavers had impounded 47 percent of the creek's 6.4 km mainstem. By 2001 an additional 690 m of channel was impounded by beavers, eliminating 10 percent of the 938 m of riffle recorded in the 1999 survey (Pearson 2004). The current extent of impoundment caused by beavers and humans is unknown. Some areas impounded in 2001 were free flowing in 2015 and others that were free flowing in 2001 were impounded in 2015. In the other occupied watersheds beaver dams are regularly destroyed by high flow events and rarely persist for more than a year or two (Pearson 2004).

Riffles may be lost to impoundments created by beaver or human activity. Given that Nooksack Dace are riffle specialists, impoundment is a major concern. The proportion of riffle habitat a reach contains is the best predictor of Nooksack Dace presence. The species is absent from reaches with long sections of continuous deep pool habitat, like beaver ponds, even when riffles are present in low proportions (Pearson 2004). Impoundments created by humans for agricultural or aesthetic purposes may also backwater riffles. These occasionally are built during low flow periods to enhance farm irrigation infrastructure or to create ponds for aesthetic purposes.

Habitat fragmentation

Habitat fragmentation is considered a medium risk threat to Nooksack Dace in Canada (Table 4). At the population level, it is a medium risk threat in the Brunette River, Bertrand Creek and Pepin Creek, and a low risk threat in Fishtrap Creek (Appendix D). The extensive destruction of aquatic habitat that has occurred within the Fraser Valley over the past 150 years (see Physical Destruction of Habitat above) has fragmented the range of Nooksack Dace in Canada. While Bertrand, Pepin and Fishtrap creeks are tributaries of the Nooksack River, they are isolated from one another by poor habitat conditions in the Washington State portion of their watersheds (McPhail 1997). Further, a steep fish ladder under railway tracks blocks Nooksack Dace access to most of Stoney Creek from Brunette River.

Most barriers and habitat fragmentation in Nooksack Dace watersheds date from 50 to 130 years ago, and surviving populations have shown some resilience (Pearson 2004). The effects of reduced movement between subpopulations within watersheds and reduced ability to colonize new habitat due to physical barriers and degraded habitat, however, may occur over longer time frames. Physical barriers such as perched culverts, beaver dams and agricultural weirs commonly prevent fish passage between habitats for all or part of the year. In addition, the other threats discussed may fragment habitat by preventing or curtailing movement of fish within and among affected reaches.

6. Population and distribution objectives

Population and distribution objectives establish, to the extent possible, the number of individuals and/or populations, and their geographic distribution, that is necessary for the recovery of the species. Objectives for historically precarious species for which recovery is feasible are based on the best achievable scenario that is approaching the historical condition.

The population and distribution objectives for the Nooksack Dace are based on Pearson (2004, 2016, unpub. data) and expert opinion.

1. Population objective:
    - Nooksack Dace are moderately abundant in 60 percent of currently or historically occupied reaches by 2030. Occupied reaches means those reaches that currently contain or historically contained more than 10 percent riffle habitat by length in each of the species' four native watersheds in B.C. Moderate abundance is defined by a catch per unit effort exceeding 0.25 fish per Gee minnow trap (n=10) between April 1 and September 30 or observation of more than 50 fry per riffle (n=10 riffles, or complete reach census, whichever is less) between July 1 and August 31.

Rationale: Capture efficiencies for Nooksack Dace are low using all known sampling methods and a robust quantitative method of estimating abundance has not been developed despite considerable effort (Appendix E; Pearson 2004, 2016).

2. Distribution objective:
    - Nooksack Dace presence is confirmed in 80 percent of currently or historically occupied reaches by 2030. Occupied reaches means those reaches that currently contain or historically contained more than 10 percent riffle habitat by length in each of the species four' native watersheds in B.C.

      Rationale: Nooksack Dace were documented as present in 32 of 48 suitable habitat reaches (66.7 percent) across all watersheds when sampled at some point between 1997 and 2014 (Pearson unpub. data), but proportions varied widely among watersheds (Bertrand Creek: 87 percent; Brunette River: 67 percent; Pepin Creek: 75 percent; and Fishtrap Creek: 20 percent). Numbers of occupied reaches within any single year were likely lower.

7. Broad strategies and general approaches to meet objectives

7.1 Actions already completed

For a comprehensive list of actions already completed or underway, refer to the Report on the Progress of Recovery Strategy Implementation for Nooksack Dace (*Rhinichthys cataractae*) in Canada for the Period 2008 – 2015 (DFO 2017b). A summary of activities is provided below.

Surveys and inventory:

- Trapping, habitat conditions and habitat use surveys of Pepin Creek tributaries, Salish Creek and Gordon's Brook (2004; Langley Environmental Partners Society, Pearson Ecological, Habitat Stewardship Program)
- Hypoxia surveys of Bertrand Creek and Fishtrap Creek (2005; Langley Environmental Partners Society, Pearson Ecological, Habitat Stewardship Program)
- Mapping of proposed critical habitat in all occupied watersheds (Pearson 2008, 2016)
- Study of distribution and habitat use in Brunette River (2008; TI Corp, Pearson Ecological, Habitat Stewardship Program)
- Initial survey and genetic analysis confirmed hybridized Nooksack Dace presence the upper Chilliwack River (2016-2017; Pearson Ecological, UBC)

Habitat enhancement:

- Riparian enhancements in Bertrand Creek (2000-2016; Langley Environmental Partners Society, Habitat Stewardship Program, numerous other grants)
- Riffle enhancement and creation in Pepin Creek (2001-2010; UBC, Langley Environmental Partners Society, Habitat Stewardship Program, Pearson Ecological),

- Riffle enhancements in Bertrand Creek (2009; Cheema and Sons Farms, Pearson Ecological)
- Riffle enhancements in Brunette River (2012; TI Corp)

Research:

- Studies of life history, distribution, habitat use, habitat and threats (Pearson 2004)
- Studies of single pass electrofishing population estimation method (Bonamis 2011)
- Studies of impacts of low flow on Nooksack Dace growth, behaviour and habitat use (Avery-Gomm 2013; Avery-Gomm et al. 2014)
- Studies of impacts of sediment deposition on Nooksack Dace density, growth and foraging efficiency (Champion 2016)
- Surveys of fry abundance and habitat use (Pearson 2016)

Public education:

- Workshop for municipal and agency staff on Nooksack Dace and Salish Sucker (2003; Habitat Stewardship Program, Pearson Ecological)
- Landowner contact program in Bertrand Creek Watershed (2003; Habitat Stewardship Program, Langley Environmental Partners Society)
- Landowner contact in Pepin Creek and Fishtrap Creek watersheds (2004; Habitat Stewardship Program, Langley Environmental Partners Society)
- Protecting species at risk in the Matsqui Traditional Territory (2013-2014; Matsqui First Nation; Aboriginal Fund for Species at Risk)
- Watershed education for aquatic species at risk in Langley (2013-2015; Langley Environmental Partners Society; Habitat Stewardship Program)
- Annual lectures for senior Forestry and Conservation Biology classes at UBC (2001-2016; Pearson Ecological)

7.2 Strategic direction for recovery

A description of the broad strategies to address identified threats and of the research and management approaches needed to meet population and distribution objectives is presented in Table 5. These informed the development of specific recovery measures in the Action Plan for the Nooksack Dace (*Rhinichthys cataractae*) and the Salish Sucker (*Catostomus* sp.) in Canada (DFO 2017a).

Table 5. Recovery planning table.

Broad strategy	General description of research and management approaches	Priority[12]	Threat or concern addressed
Inventory and monitoring	Monitor recovery of Nooksack Dace	High	All
Research	Fill knowledge gaps that inhibit the recovery of Nooksack Dace	Medium	All
Management and coordination	Ensure the integrity and proper function and reduce the fragmentation of riparian areas throughout watersheds	High	Sediment deposition, hypoxia, physical destruction of habitat, habitat fragmentation
Management and coordination	Protect existing habitat, restore lost or degraded habitat and create new habitat	High	Physical destruction of habitat, habitat fragmentation
Management and coordination	Establish and maintain adequate baseflow in all habitats with high potential productivity	High	Seasonal lack of water, habitat fragmentation
Management and coordination	Reduce sediment entry to instream habitats	High	Sediment deposition
Management and coordination	Minimize entry of harmful substances to instream habitats	Medium	Harmful substances
Management and coordination	Reduce fragmentation of instream habitats	Medium	Habitat fragmentation
Stewardship and outreach	Encourage stewardship amongst private landowners, local governments and the general public	Medium	All
International collaboration	Explore opportunities for coordinating population assessment and recovery efforts with interested groups in United States	Low	All

8. Critical habitat

8.1 Identification of the species' critical habitat

8.1.1 General description of the species' critical habitat

[12] Priority" reflects the degree to which the approach contributes directly to the recovery of the species or is an essential precursor to an approach that contributes to the recovery of the species:

- "high" priority approaches are considered likely to have an immediate and/or direct influence on the recovery of the species
- "medium" priority approaches are important but considered to have an indirect or less immediate influence on the recovery of the species
- "low" priority approaches are considered important contributions to the knowledge base about the species and mitigation of threats

Critical habitat is defined in SARA as "…the habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in the recovery strategy or in an action plan for the species." [s. 2(1)]

Also, SARA defines habitat for aquatic species as "… spawning grounds and nursery, rearing, food supply, migration and any other areas on which aquatic species depend directly or indirectly in order to carry out their life processes, or areas where aquatic species formerly occurred and have the potential to be reintroduced." [s. 2(1)]

For the Nooksack Dace, critical habitat is identified to the extent possible, using the best available information, and provides the functions and features necessary to support the species' life-cycle processes and to achieve the species' population and distribution objectives.

This Recovery Strategy identifies aquatic critical habitat for Nooksack Dace as relatively homogenous segments of stream demarcated by distinct geomorphic or land use transitions, otherwise known as reaches, within the Bertrand Creek, Brunette River, Fishtrap Creek and Pepin Creek (also known as Pepin Brook) watersheds.

More specifically, critical habitat includes the reaches within those watersheds that consist of or are known to have previously consisted of more than 10 percent riffle habitat by length. Critical habitat within these reaches includes all the aquatic habitats, including features and attributes identified in Section 8.1.3, and all riparian areas on both banks for the entire length of the identified aquatic reaches. Riparian critical habitat is continuous and extends laterally (inland) from the top of bank to a width equal to the widest zone of sensitivity calculated for five riparian features and functions.

It is unknown if the critical habitat identified in this recovery strategy is sufficient to achieve the species' population and distribution objectives. The Schedule of Studies outlines the research required to identify additional critical habitat and acquire more detailed information about the critical habitat identified to achieve the species' population and distribution objectives.

8.1.2 Information and methods used to identify critical habitat

Defining critical habitat reaches

Critical habitat for the Nooksack Dace was defined using in-stream habitat characteristics at the scale of the reach, a natural unit of stream habitat that ranges from hundreds to thousands of metres in length (Frissell et al. 1986). There are three reasons for adopting this scale. First, the reach scale corresponds to the distribution of subpopulations within watersheds and usually contains all habitat types used during the life cycle (Pearson 2004). Second, the 'channel units' of critical habitat (riffles and pools) are dynamic and frequently move during flood events in these streams. Effective protection and management of critical habitat in these circumstances must allow for normal channel processes and must, therefore, occur at a spatial scale larger than the channel unit. The reach scale is the next largest in accepted stream habitat classifications (Frissell et al. 1986; Imhof et al. 1996) and by definition represents relatively homogenous segments of stream demarcated by distinct geomorphic or land use transitions. Third, the reach scale corresponds most closely to that of land ownership in these watersheds.

Defining aquatic critical habitat areas

The protocol used for identifying Nooksack Dace critical habitat was consistent with guidelines for documenting habitat quality and use by freshwater fishes at risk (Rosenfeld and Hatfield 2006; DFO 2007) and the approach and results were peer-reviewed (Pearson 2008). The amount of critical habitat required to achieve population targets depends upon its quality, its extent, and its spatial configuration on the landscape (Rosenfeld and Hatfield 2006). For all four Nooksack Dace populations the total amount of suitable habitat available is considered necessary to meet population and distribution objectives.

Defining riparian critical habitat areas

The identification of riparian critical habitat was informed by Pearson 2008 and expert opinion. Critical habitat includes all riparian areas on both stream banks for the entire length of the identified aquatic reaches. The required widths of riparian critical habitat vary among sites and are defined in reach scale assessments. Riparian vegetation must be of sufficient width to control sediment entry to the stream from overland flow, to prevent excessive bank erosion and to buffer stream temperatures. The effectiveness of riparian vegetation in preventing materials (e.g., sediment, nutrients, harmful substances) from entering a stream depends strongly on its longitudinal continuity and lateral width (Weller et al. 1998). Consequently, riparian vegetation adjacent to aquatic critical habitat reaches should be continuous and sufficiently wide.

Widths of riparian critical habitat for Nooksack Dace were assessed using a spatially referenced methodology adapted directly from and consistent with the British Columbia Riparian Areas Regulation (RAR) (Riparian Areas Protection Act [S.B.C. 1997, c. 21], Province of British Columbia 2006). The B.C. MOE and DFO developed and implemented this methodology for determining riparian vegetation widths required to maintain riparian function and protect fish habitat. The RAR was developed to protect “salmonids, game fish, and regionally significant fish” from the impacts of land development. In the absence of data on riparian habitat needs for a SARA-listed species, this is a reasonable standard to apply in the identification of critical habitat because it represents a benchmark and standard methodology to which both federal and provincial agencies responsible for management of species at risk have already agreed.

The identified width of the riparian critical habitat for each reach is equal to the widest zone of sensitivity (ZOS) calculated for each of five riparian features and functions: large woody debris supply for fish habitat and maintenance of channel morphology; localized bank stability; channel movement; shade; and, insect and debris fall. The ZOS values are calculated using methods consistent with those used under the RAR. The width of existing riparian vegetation and areas where riparian width is restricted by permanent structures (e.g., roads, buildings, yards) were also assessed. Further details of methods and an assessment of existing riparian vegetation in these areas can be found in Pearson (2008).

8.1.3 Identification of critical habitat

Geographic identification

For the Nooksack Dace, combined length of aquatic critical habitat is 29.3 km (of 93.9 km of surveyed stream channel) and the area of riparian critical habitat associated with the aquatic critical habitat reaches is 137.6 hectares in Bertrand Creek, Fishtrap Creek, Pepin Creek and the Brunette River. Maps delineating critical habitats are provided in Appendix F and geographic coordinates of beginnings and ends of each critical habitat reach are provided in Appendix G.

The locations of the critical habitat's functions, features and attributes have been identified using the Critical Habitat Parcel approach for both the aquatic and riparian components of critical habitat. This means that aquatic critical habitat is the exact area delineated by the identified boundaries.

Biophysical functions, features and attributes

Table 6 summarizes the best available knowledge of the functions, features and attributes for each life stage of the Nooksack Dace within the identified geographic locations (refer to Section 4.3 'Needs of the Species' for full references). Note that not all attributes in Table 6 must be present in order for a feature to be identified as critical habitat. If the features as described in Table 6 are present and capable of supporting the associated function(s), the feature is considered critical habitat for the species, even though some of the associated attributes might be outside of the range indicated in the table.

Table 6. General summary of the biophysical functions, features and attributes of critical habitat necessary for a species' survival or recovery for reaches within Bertrand Creek, Brunette River, Fishtrap Creek and Pepin Creek.

Life stage	Function[13]	Feature(s)[14]	Attribute(s)[15]
Egg, Adults, Yearlings	Spawning, incubation, rearing, feeding, refuge, overwintering	Riffle habitat	• Loose cobble, gravel or boulder substrate • Little or no additional sediment • Sufficient water velocity (>25 cm/s) and flow to maintain riffles • Sufficient intragravel flow to maintain eggs • Adequate quantity and quality of food supply (terrestrial and aquatic insects) for adults and yearlings • Dissolved oxygen >5 mg/l • Water temperature >6 and <23°C • Few or no additional nutrients • Few or no additional harmful substances

[13] Function: A life-cycle process of the listed species taking place in critical habitat (e.g., spawning, nursery, rearing, feeding and migration).
[14] Feature: Features describe how the habitat is critical and they are the essential structural component that provides the requisite function(s) to meet the species' needs. Features may change over time and are usually comprised of more than one part, or attribute. A change or disruption to the feature or any of its attributes may affect the function and its ability to meet the biological needs of the species.
[15] Attribute: Attributes are measurable properties or characteristics of a feature. Attributes describe how the identified features support the identified functions necessary for the species' life processes.

Life stage	Function[13]	Feature(s)[14]	Attribute(s)[15]
Emergent fry	Rearing	Shallow pool habitat	• Location adjacent to riffle habitats • Sand, mud or leaf litter substrates • Little or no additional sediment • Water depth <10 cm • Current velocity <5 cm/s • Adequate quantity and quality of food supply (zooplankton) • Dissolved oxygen >5 mg/l • Water temperature >6 and <23ºC • Few or no additional nutrients • Few or no additional harmful substances
First Summer	Rearing, feeding	Shallow glide habitat	• Gravel or cobble substrate • Little or no additional sediment • Shallow depth (<10 cm) • Water velocity suitable to the size of the individual • Adequate quantity and quality of food supply (zooplankton, insect drift, periphyton) • Dissolved oxygen >5 mg/l • Water temperature >6 and <23ºC • Few or no additional nutrients • Few or no additional harmful substances
Adults, Yearlings	Feeding and refuge during periods of extreme low flow	Deep pool habitat	• Residual depth >30 cm • Adequate quantity and quality of food supply (terrestrial and aquatic insects) • Dissolved oxygen >5 mg/l • Water temperature >6 and <23ºC • Few or no additional nutrients • Few or no additional harmful substances
All	Spawning, incubation, rearing, feeding	Riparian habitat	• Riparian vegetation that is continuous for the entire length of the reach and extends laterally (inland) from the top of the bank to a width equal to the widest zone of sensitivity (calculated using methods consistent with those used under the B.C. RAR) (5 to 30 m depending on stream characteristics), in order to ensure the following functions: o Protects the integrity of other aquatic features such as riffle and shallow pool habitat o Provides large and small woody debris o Provides localized bank stability o Provides shade to buffer instream temperatures o Provides terrestrial insect input o Limits entry of added nutrients o Maintains natural channel morphology

Riffle habitat

Available information indicates that Nooksack Dace require riffle habitats and that reaches with a high percentage of riffle habitats support most of the Canadian populations. Nooksack Dace typically occur in riffles with loose gravel, cobble or boulder substrates where water velocity exceeds 25 cm/s. They spawn near the upstream end of riffles between April 15 and July 15, and forage nocturnally for riffle dwelling insects (McPhail 1997). Nooksack Dace reach occupancy is most strongly predicted by the amount of riffle habitat present; riffles isolated by long stretches of deep pool are seldom inhabited (Pearson 2004). The threshold of 10 percent riffle by length is intended to exclude reaches with very small amounts of riffle habitat that contribute minimally to Nooksack Dace production and population size.

Still, a number of reaches containing less than 10 percent riffle by length when surveyed are included in critical habitat (Pearson 2008) because of evidence that they previously contained more riffle habitat and supported Nooksack Dace populations. Most of these reaches, which total 9.83 km in length, are known to have been channelized and dredged or were temporarily impounded by beaver at the time of survey.

Shallow pool habitat

Newly emerged Nooksack Dace fry inhabit shallow (<10 cm) pools adjacent to riffles where they swim above sand, mud, or leaf litter substrates and feed on chironomid pupae and ostracods (McPhail 1997). Insofar as these habitats are exclusively used for larval rearing before juveniles move into riffle habitat, the loss of these habitats would likely cause population declines.

Shallow glide habitat

Shallow glides are slow moving habitats with little surface turbulence. They are often found adjacent to higher energy riffles. As young-of-the-year Nooksack Dace develop, aggregations move into shallow glides immediately up or downstream of turbulent flow in riffles to drift-feed during daylight hours. Increasing water velocities are selected by Nooksack Dace as body size increases over the summer (Pearson 2016).

Deep pool habitat

Nooksack Dace require deep pool habitats as low-flow refugia in reaches where riffles are partially or completely dewatered during drought conditions (Avery-Gomm et al. 2014).This typically occurs in all of Bertrand Creek, parts of Fishtrap Creek and in Stoney Creek (Brunette River tributary) for some period of time between July 1 and October 15.

Riparian habitat

All riparian vegetation in identified riparian critical habitat reaches protects the integrity of in-stream critical habitat. Failure to maintain adequate riparian vegetation as part of critical habitat is likely to result in sediment deposition (Waters 1995). Sediment deposition may result in infilling of the interstitial spaces in coarse substrate that Nooksack Dace occupy, leading to decreased macroinvertebrate prey availability, impaired spawning and incubation, and loss of refuge habitat area and volume. Nutrient loading will be higher in reaches without adequate riparian vegetation (Martin et al. 1999; Dhondt et al. 2002; Lee et al. 2003) and is likely to contribute to hypoxia through eutrophication. Solar radiation in nutrient rich reaches lacking adequate riparian shading will also contribute to eutrophication and hypoxia (Kiffney et al.

2003). In habitats lacking sufficient flow or groundwater, absence of shade may also increase water temperatures to harmful levels.

The effectiveness of riparian vegetation in preventing materials (sediment, nutrients, harmful substances, etc.) from entering a stream depends strongly on its longitudinal continuity and its lateral width (Weller et al. 1998). Consequently, riparian vegetation in critical habitat reaches should be continuous and sufficiently wide. Riparian vegetation as narrow as 5 m provides significant protection from bank erosion and sediment deposition from overland flow. At least 10 m are required to maintain levels of terrestrial food inputs similar to those of forested landscapes. More than 30 m of riparian vegetation may be required to fully mitigate warming water temperatures (Brown and Krygier 1970; Lynch et al. 1984; Castelle et al. 1994) and siltation, and for long-term maintenance of channel morphology.

Riparian vegetation upstream of critical habitat is important in minimizing sedimentation and other impacts within critical habitat. For this reason stewardship programs should promote the establishment of continuous riparian vegetation throughout the watershed, not just along critical habitat reaches.

Summary of critical habitat relative to population and distribution objectives

These are areas that, based on current best available information, the Minister of Fisheries and Oceans considers necessary to partially achieve the species' population and distribution objectives required for the survival and recovery of the species. Additional critical habitat may be identified in future updates to the recovery strategy.

8.2 Schedule of studies to identify critical habitat

Further research is required to identify additional critical habitat and refine the understanding of the functions, features and attributes of the currently identified critical habitat necessary to support the species' population and distribution objectives and protect the critical habitat from destruction. Table 7 outlines further research required to identify and refine critical habitat.

Table 7. Schedule of studies to identify / refine critical habitat.

Description of study	Rationale	Timeline
Reconnaissance surveys for undocumented Nooksack Dace populations (e.g., Chilliwack River; Harrison Lake, Stave Lake and Hayward Lake tributaries)	Critical habitat for undocumented populations can only be identified after the population is found.	2018-2022
Evaluation of riffle quality in all critical habitat reaches using measures of sedimentation, minimum flows, macroinvertebrate productivity and diversity, and relative abundance of Nooksack Dace	Nooksack Dace density varies widely among the four Canadian streams they inhabit, presumably due to differences in habitat quality and quantity. Previous work has documented the quantity and location of suitable habitat (Pearson 2004, 2007) but habitat quality has never been assessed or mapped. This would be useful in prioritizing areas for habitat enhancement or restoration and for better understanding the wide variations in Nooksack Dace abundance among streams.	2019-2023

8.3 Examples of activities likely to result in the destruction of critical habitat

Under SARA, critical habitat must be legally protected from destruction within 180 days of being identified in a final recovery strategy or action plan and included in the Species at Risk Public Registry. For the Nooksack Dace critical habitat identified in the 2008 recovery strategy (Pearson et al. 2008), legal protection was accomplished on April 21, 2016 through a SARA Critical Habitat Order made under subsections 58(4) and (5), which invoked the prohibition in subsection 58(1) against the destruction of the identified critical habitat. It is anticipated that the SARA Critical Habitat Order will be amended to reflect changes in critical habitat identification outlined in this amended recovery strategy.

The following examples of activities likely to result in the destruction[16] of critical habitat (Table 8) are based on known human activities that are likely to occur in and around critical habitat and would result in the destruction of critical habitat if unmitigated. The list of activities is neither exhaustive nor exclusive and has been guided by the threats described in Section 5. The absence of a specific human activity from this table does not preclude or restrict the Department's ability to regulate that activity under SARA. Furthermore, the inclusion of an activity does not result in its automatic prohibition, and does not mean the activity will inevitably result in destruction of critical habitat. Every proposed activity must be assessed on a case-by-case basis and site-specific mitigation will be applied where it is available and reliable. Where information is available, thresholds and limits have been developed for critical habitat attributes to better inform management and regulatory decision making. However, in many cases knowledge of a species and its critical habitat's thresholds of tolerance to disturbance from human activities is lacking and must be acquired.

[16] Destruction occurs when there is a temporary or permanent loss of a function of critical habitat at a time when it is required by the species.

Table 8. Examples of activities likely to result in the destruction of critical habitat.

Threat	Activity	Effect - pathway	Function affected	Feature affected	Attribute affected
Physical destruction of habitat Sediment deposition Hypoxia	Land use and work in or around critical habitat with excessive riparian vegetation removal, nutrient loading, or improper sediment and erosion control	Removal of riparian vegetation may: - reduce bank stability - reduce terrestrial supplied food and woody debris - increase sunlight penetration and water temperatures - increase nutrient loading, eutrophication and hypoxia - increase sedimentation rates and alter substrate composition Improper sediment and erosion control may: - reduce bank stability - increase sedimentation rates and alter substrate composition	Spawning, incubation, rearing, feeding, overwintering, refuge	Deep pool habitat, shallow pool habitat, shallow glide habitat, riffle habitat, riparian habitat	• Loose cobble, gravel or boulder substrate • Sand, mud or leaf litter substrates • Little or no additional sediment • Adequate quantity and quality of food supply • Dissolved oxygen >5 mg/l • Water temperature >6 and <23°C • Few or no additional nutrients • Riparian vegetation
Physical destruction of habitat Seasonal lack of water Riffle loss to impoundment Habitat fragmentation Hypoxia	Excessive water extraction or alteration of stream flows resulting in habitat loss, fragmentation or changes to water quality	Surface water or groundwater extraction, especially during dry periods, can reduce stream flows, contribute to hypoxia and increased water temperatures, and result in reduction or elimination of riffles habitats required for spawning and incubation. Impoundments can alter stream flows and destroy riffles by turning them into pools.	Spawning, incubation, rearing, refuge	Deep pool habitat, shallow pool habitat, shallow glide habitat, riffle habitat	• Water depth (<10 cm for shallow pool and glide habitats; >30 cm for deep pool habitats) • Sufficient water velocity (>25 cm/s) and flow to maintain riffles • Dissolved oxygen >5 mg/l • Water temperature >6 and <23°C

Threat	Activity	Effect - pathway	Function affected	Feature affected	Attribute affected
Harmful substances Sediment deposition	Release of harmful substances and sediments (e.g., surface runoff, urban storm drainage)	Surface runoff or direct discharge of harmful substances and sediments into aquatic habitats.	Spawning, incubation, rearing, feeding	Deep pool habitat, shallow pool habitat, shallow glide habitat, riffle habitat	• Little or no additional sediment • Water depth (<10 cm for shallow pool and glide habitats; >30 cm for deep pool habitats) • Sufficient water velocity (>25 cm/s) and flow to maintain riffles • Few or no additional harmful substances
Hypoxia	Excessive nutrient input through groundwater and/or surface flows as the result of point and non-point sources	Excess nutrients enter aquatic habitat via surface runoff and groundwater transport, leading to eutrophication and hypoxia.	Rearing, feeding, refuge	Deep pool habitat, shallow pool habitat, shallow glide habitat	• Dissolved oxygen >5 mg/l
Physical destruction of habitat Sediment deposition	Drainage maintenance works resulting in destruction of habitat or increased sediment inputs	Physical removal of riffles (high spots) by dredging and other drainage maintenance works. Drainage maintenance works are often associated with removal of riparian vegetation for stream access, leading to increased erosion and sediment deposition (see activity: Land use and work in or around critical habitat with excessive riparian vegetation removal, or improper sediment and erosion control).	Spawning, incubation, rearing, feeding, overwintering, refuge	Deep pool habitat, shallow pool habitat, shallow glide habitat, riffle habitat, riparian habitat	• Loose cobble, gravel or boulder substrate • Sand, mud or leaf litter substrates • Little or no additional sediment • Water depth (<10 cm for shallow pool and glide habitats; >30 cm for deep pool habitats) • Adequate quantity and quality of food supply • Dissolved oxygen >5 mg/l • Water temperature >6 and <23°C • Few or no additional nutrients • Riparian vegetation

Threat	Activity	Effect - pathway	Function affected	Feature affected	Attribute affected
Sediment deposition Hypoxia Physical destruction of habitat	Streamside livestock grazing leading to sediment inputs, changes to water quality or habitat destruction	Livestock access to streams may damage habitat through trampling or causing erosion that increases sediment deposition. Access may also contribute to nutrient loading and result in eutrophication and hypoxia.	Spawning, incubation, rearing, feeding	Deep pool habitat, shallow pool habitat, shallow glide habitat, riffle habitat, riparian habitat	• Loose cobble, gravel or boulder substrate • Sand, mud or leaf litter substrates • Little or no additional sediment • Dissolved oxygen >5 mg/l • Few or no additional nutrients

9. Measuring progress

The performance indicators presented below provide a way to define and measure progress toward achieving the population and distribution objectives. A successful recovery program will achieve the overall aim of restoring Nooksack Dace presence and density in suitable habitats within their native watersheds. Progress towards meeting these objectives will be reported on in the Report on the Progress of Recovery Strategy Implementation.

9.1 Distribution performance indicators

Nooksack Dace is present in:[17]

- more than 80 percent of reaches in each watershed, which indicates recovery of a watershed's population distribution
- more than 80 percent of reaches in all four occupied watersheds in B.C., which indicates recovery of the Nooksack Dace distribution in Canada

9.2 Population performance indicators

Nooksack Dace is found at moderate density in:[18]

- more than 60 percent of historically occupied reaches in each watershed, which indicates recovery of that watershed's population abundance
- more than 60 percent of historically occupied reaches in all four occupied watersheds in B.C., which indicates recovery of Nooksack Dace population abundance in Canada

10. Statement on action plans

The federal government's approach to recovery planning is a two-part approach. The first part is the recovery strategy and the second part is the action plan. An action plan contains specific recovery measures or activities required to meet the objectives outlined in the recovery strategy.

The Action Plan for the Nooksack Dace (*Rhinichthys cataractae*) and the Salish Sucker (*Catostomus* sp.) in Canada (DFO 2017a) was posted on the Species at Risk Public Registry on April 26, 2017.

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[17] Presence is indicated by the capture of an individual in a reach within the past 5 years.
[18] Moderate density is indicated by a catch per unit effort of >0.25 Nooksack Dace per Gee minnow trap (Pearson 2004) with a minimum effort of 1 trap per 5 m of riffle length or 20 traps per reach.

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Appendix A: effects on the environment and other species

In accordance with the Cabinet Directive on the Environmental Assessment of Policy, Plan and Program Proposals (2010), SARA recovery planning documents incorporate strategic environmental assessment (SEA) considerations throughout the document. The purpose of a SEA is to incorporate environmental considerations into the development of public policies, plans, and program proposals to support environmentally sound decision-making and to evaluate whether the outcomes of a recovery planning document could affect any component of the environment or achievement of any of the Federal Sustainable Development Strategy's goals and targets.

Recovery planning is intended to benefit species at risk and biodiversity in general. However, it is recognized that strategies may also inadvertently lead to environmental effects beyond the intended benefits. The planning process based on national guidelines directly incorporates consideration of all environmental effects, with a particular focus on possible impacts upon non-target species or habitats. The results of the SEA are incorporated directly into the strategy itself, but are also summarized below this statement.

While this recovery strategy will clearly benefit the environment by promoting the recovery of Nooksack Dace, some potentially adverse effects on other species were also considered. Nooksack Dace co-occurs with other species at risk such as Salish Sucker, Western Painted Turtle (*Chrysemys picta bellii*), Oregon Spotted Frog (*Rana pretiosa*) and others, as well as other fish species, including Steelhead (*Oncorhynchus mykiss*), Cutthroat Trout (*Oncorhynchus clarkia clarkii*) and Coho Salmon (*Oncorhynchus kisutch*). The strategy calls for the protection, creation, and enhancement of riffle habitat which might eliminate some of the deep pool and marsh habitat of Salish Sucker. The strategy recommends cooperation with local stewardship groups and agency staff on recovery. DFO addressed needs for recovery of Nooksack Dace and Salish Sucker together by coordinating recovery activities for both species in watersheds where they coexist through the development of a joint action plan (DFO 2017a). Recovery actions will contribute to overall ecosystem and watershed health, which will provide benefits to many species and ecological services to Canadians living in these areas. Taking these approaches into account, it was concluded that the benefits of this recovery strategy far outweigh any adverse effects that may result.

Appendix B: record of cooperation and consultation

Recovery strategies are to be prepared in cooperation and consultation with other jurisdictions, organizations, affected parties and others as outlined in SARA section 39. DFO prepared the 2008 recovery strategy (Pearson et al. 2008) in cooperation with the Province of B.C., academia, consultants, and non-governmental organizations. DFO consulted extensively on the 2008 recovery strategy (details in Appendix 1 of the 2008 recovery strategy).

Consultations on the 2008 recovery strategy occurred through a series of multi-stakeholder Community Dialogue Sessions and First Nations information exchanges in B.C. communities. A consultation weblink was sent to 198 Indigenous Organizations and other stakeholders. Notices announcing the Community Dialogue Sessions were placed in 74 newspapers and announcements specific to Nooksack Dace were placed in an additional six newspapers. A presentation and discussion session on the recovery strategy was held in Abbotsford in November 2005, with four attendees.

Input from the Province of B.C. and the Township of Langley was received during development of the document. Additional input on the 2008 recovery strategy from the public and experts was sought through a discussion guide and feedback form available on the internet (October to December 2005). No responses were received.

Consultations on critical habitat were undertaken in February 2008 and included letters to First Nations, landowners, and other interested parties followed by presentations and discussion sessions with local First Nations, regional agriculture committees, the municipalities of Abbotsford, Langley, Burnaby and New Westminster, and the Province of B.C. Public meetings that included presentations and discussions were held in Burnaby, Langley and Abbotsford.

The draft amended recovery strategy was circulated to Indigenous Organizations, local, regional and provincial governments, academia, environmental non-government organizations, and industry for a 30-day external review. Input from the Province of B.C. and the B.C. Agriculture Council was received during external review. Additional stakeholder, Indigenous Organizations and public input will be sought through the publication of the proposed document on the Species at Risk Public Registry for a 60-day public comment period.

All feedback received will be considered in the finalization of the amended recovery strategy.

Appendix C: threat assessment categories

Likelihood of Occurrence	Definition
Known or very likely to occur	This threat has been recorded to occur 91-100%
Likely to occur	There is 51-90% chance that this threat is or will be occurring.
Unlikely	There is 11-50% chance that this threat is or will be occurring
Remote	There is 1-10% or less chance that this threat is or will be occurring.
Unknown	There are no data or prior knowledge of this threat occurring now or in the future.

Level of Impact	Definition
Extreme	Severe population decline (e.g. 71-100%) with the potential for extirpation.
High	Substantial loss of population (31-70%) or Threat would jeopardize the survival or recovery of the population.
Medium	Moderate loss of population (11-30%) or Threat is likely to jeopardize the survival or recovery of the population.
Low	Little change in population (1-10%) or Threat is unlikely to jeopardize the survival or recovery of the population.
Unknown	No prior knowledge, literature or data to guide the assessment of threat severity on population.

Causal Certainty	Definition
Very high	Very strong evidence that threat is occurring and the magnitude of the impact to the population can be quantified.
High	Substantial evidence of a causal link between threat and population decline or jeopardy to survival or recovery
Medium	There is some evidence linking the threat to population decline or jeopardy to survival or recovery
Low	There is a theoretical link with limited evidence that threat is leading to a population decline or jeopardy to survival or recovery
Very low	There is a plausible link with no evidence that the threat is leading to a population decline or jeopardy to survival or recovery

Threat Occurrence	Definition
Historical	A threat that is known to have occurred in the past and negatively impacted the population.
Current	A threat that is ongoing, and is currently negatively impacting the population.
Anticipatory	A threat that is anticipated to occur in the future, and will negatively impact the population.

Threat Frequency	Definition
Single	The threat occurs once.
Recurrent	The threat occurs periodically, or repeatedly.
Continuous	The threat occurs without interruption.

Threat Extent	Definition
Extensive	71-100% of the population is affected by the threat.
Broad	31-70% of the population is affected by the threat.
Narrow	11-30% of the population is affected by the threat.
Restricted	1-10% of the population is affected by the threat.

Appendix D: population level threats analysis

Threats analyses for the four known populations of Nooksack Dace in Canada are presented in the following tables. Analyses were done in accordance with the Guidance on Assessing Threats, Ecological Risk and Ecological Impacts for Species at Risk (DFO 2014). Rationale for ratings is presented in a separate document (Pearson 2017).

Table D1. Population-level threat assessment for the Brunette River population.[19]

Threat	Likelihood of occurrence[20]	Level of impact[21]	Causal certainty[22]	Population-level threat risk[23]	Population-level threat occurrence[24]	Population-level threat frequency[25]	Population-level threat extent[26]
Sediment deposition	Known	High	High	High	Historic Current Anticipatory	Continuous	Extensive
Seasonal lack of water	Known	Low	High	Low	Current Anticipatory	Recurrent	Narrow
Harmful substances	Known	High	Low	High	Historic Current Anticipatory	Continuous	Extensive
Physical destruction of habitat	Known	Low	High	Low	Historic	Recurrent	Restricted
Hypoxia	Known	Medium	High	Medium	Historic Current Anticipatory	Continuous	Narrow
Riffle loss to impoundment	Known	Low	Low	Low	Historic	Recurrent	Restricted
Habitat fragmentation	Known	Medium	High	Medium	Historic Current Anticipatory	Continuous	Narrow

[19] The specific assessment categories and associated rankings definitions are provided in Appendix C.
[20] Likelihood of occurrence: probability of a specific threat occurring for a given population over 10 years or 3 generations, whichever is shorter.
[21] Level of impact: the magnitude of the impact caused by a given threat, and the level to which it affects the survival or recovery of the population.
[22] Causal certainty: the strength of evidence linking the threat to the survival and recovery of the population.
[23] Population-level threat risk: the product of likelihood and level of impact as determined using a risk matrix approach
[24] Population-level threat occurrence: the timing of occurrence of the threat and describes whether a threat is historical, current and/or anticipatory
[25] Population-level threat frequency: the temporal extent of the threat over the next 10 years or 3 generations, whichever is shorter.
[26] Population-level threat extent: the proportion of the population affected by the threat

Table D2. Population-level threat assessment for the Bertrand Creek population.[27]

Threat	Likelihood of occurrence[28]	Level of impact[29]	Causal certainty[30]	Population-level threat risk[31]	Population-level threat occurrence[32]	Population-level threat frequency[33]	Population-level threat extent[34]
Sediment deposition	Known	Medium	High	Medium	Historic Current Anticipatory	Continuous	Broad
Seasonal lack of water	Known	High	Very High	High	Current Anticipatory	Recurrent	Extensive
Harmful substances	Known	Medium	Low	Medium	Historic Current Anticipatory	Continuous	Broad
Physical destruction of habitat	Known	Medium	Medium	Medium	Historic Current Anticipatory	Recurrent	Narrow
Hypoxia	Known	Medium	Low	Medium	Current Anticipatory	Recurrent	Narrow
Riffle loss to impoundment	Known	Low	High	Low	Historic Current Anticipatory	Recurrent	Restricted
Habitat fragmentation	Known	Low	Low	Low	Historic Current	Continuous	Narrow

[27] The specific assessment categories and associated rankings definitions are provided in Appendix C.
[28] Likelihood of occurrence: probability of a specific threat occurring for a given population over 10 years or 3 generations, whichever is shorter.
[29] Level of impact: the magnitude of the impact caused by a given threat, and the level to which it affects the survival or recovery of the population.
[30] Causal certainty: the strength of evidence linking the threat to the survival and recovery of the population.
[31] Population-level threat risk: the product of likelihood and level of impact as determined using a risk matrix approach
[32] Population-level threat occurrence: the timing of occurrence of the threat and describes whether a threat is historical, current and/or anticipatory
[33] Population-level threat frequency: the temporal extent of the threat over the next 10 years or 3 generations, whichever is shorter.
[34] Population-level threat extent: the proportion of the population affected by the threat

Table D3. Population-level threat assessment for the Pepin Creek population.[35]

Threat	Likelihood of occurrence[36]	Level of impact[37]	Causal certainty[38]	Population-level threat risk[39]	Population-level threat occurrence[40]	Population-level threat frequency[41]	Population-level threat extent[42]
Sediment deposition	Known	Medium	High	Medium	Historic Current Anticipatory	Continuous	Extensive
Seasonal lack of water	Unlikely	Low	High	Low	Anticipatory	Recurrent	Broad
Harmful substances	Likely	Medium	Medium	Medium	Current Anticipatory	Recurrent	Extensive
Physical destruction of habitat	Likely	Low	Medium	Low	Historic Anticipatory	Recurrent	Narrow
Hypoxia	Known	High	High	High	Historic Current Anticipatory	Recurrent	Broad
Riffle loss to impoundment	Known	Extreme	High	High	Historic Current	Continuous	Extensive
Habitat fragmentation	Known	Medium	High	Medium	Historic Current	Continuous	Broad

[35] The specific assessment categories and associated rankings definitions are provided in Appendix C.
[36] Likelihood of occurrence: probability of a specific threat occurring for a given population over 10 years or 3 generations, whichever is shorter.
[37] Level of impact: the magnitude of the impact caused by a given threat, and the level to which it affects the survival or recovery of the population.
[38] Causal certainty: the strength of evidence linking the threat to the survival and recovery of the population.
[39] Population-level threat Risk: the product of likelihood and level of impact as determined using a risk matrix approach
[40] Population-level threat occurrence: the timing of occurrence of the threat and describes whether a threat is historical, current and/or anticipatory
[41] Population-level threat frequency: the temporal extent of the threat over the next 10 years or 3 generations, whichever is shorter.
[42] Population-level threat extent: the proportion of the population affected by the threat

Table D4. Population-level threat assessment for the Fishtrap Creek population.[43]

Threat	Likelihood of occurrence[44]	Level of impact[45]	Causal certainty[46]	Population-level threat risk[47]	Population-level threat occurrence[48]	Population-level threat frequency[49]	Population-level threat extent[50]
Sediment deposition	Known	High	High	High	Historic Current Anticipatory	Continuous	Extensive
Seasonal lack of water	Known	Medium	High	Medium	Historic Current Anticipatory	Recurrent	Broad
Harmful substances	Known	Medium	Low	Medium	Historic Current Anticipatory	Continuous	Broad
Physical destruction of habitat	Known	High	High	High	Historic Anticipatory	Recurrent	Extensive
Hypoxia	Known	Medium	High	Medium	Current Anticipatory	Recurrent	Broad
Riffle loss to impoundment	Known	Low	High	Low	Historic Current Anticipatory	Recurrent	Restricted

43 The specific assessment categories and associated rankings definitions are provided in Appendix C.
44 Likelihood of occurrence: probability of a specific threat occurring for a given population over 10 years or 3 generations, whichever is shorter.
45 Level of impact: the magnitude of the impact caused by a given threat, and the level to which it affects the survival or recovery of the population.
46 Causal certainty: the strength of evidence linking the threat to the survival and recovery of the population.
47 Population-level threat risk: the product of likelihood and level of impact as determined using a risk matrix approach
48 Population-level threat occurrence: the timing of occurrence of the threat and describes whether a threat is historical, current and/or anticipatory
49 Population-level threat frequency: the temporal extent of the threat over the next 10 years or 3 generations, whichever is shorter.
50 Population-level threat extent: the proportion of the population affected by the threat

Habitat fragmentation	Unlikely	Low	Very low	Low	Anticipatory	Continuous	Narrow

Appendix E: rationale for population objective

As stated in Section 6, population and distribution objectives establish, to the extent possible, the number of individuals and/or populations, and their geographic distribution, that is necessary for the recovery of the species. The population and distribution objectives for the Nooksack Dace are based on Pearson (2004, 2016, unpub. data) and expert opinion. Further rationale for the population objective is provided below.

Population Objective:

Nooksack Dace are moderately abundant in 60 percent of currently or historically occupied reaches by 2030. Occupied reaches means those reaches that currently contain or historically contained more than 10 percent riffle habitat by length in each of the species' four native watersheds in B.C. Moderate abundance is defined by a catch per unit effort exceeding 0.25 fish per Gee minnow trap (n=10) between April 1 and September 30 or observation of more than 50 fry per riffle (n=10 riffles, or complete reach census, whichever less) between July 1 and August 31.

Rationale:

Capture efficiencies for Nooksack Dace are low using all known sampling methods, including single pass electrofishing, kick seining, Gee minnow trapping and visual surveying (Table E1). Given the difficulties of capturing Nooksack Dace, a robust quantitative method of estimating abundance has not been developed, despite considerable effort.

Single pass electrofishing has the greatest capture efficiency but the efficiency is still below 30% because Nooksack Dace tends to sink when shocked (Pearson 2015b). Further, the method has a high risk of harming individuals. Kick seining has unknown capture efficiency across habitats and can only be used in the spring and fall. Gee minnow trapping, while its capture efficiency is low, is the preferred sampling method for Nooksack Dace (Pearson 2015b). It can be replicated and used year round. Visual survey of fry after emergence (July 1 to August 31) is a new sampling technique with variable capture efficiencies (Pearson 2016).

To establish quantitative population abundance objectives for Nooksack Dace in Canada, Gee minnow trapping of adults and visual surveys of fry were selected due to:

- negligible to low risk of harm to individual Nooksack Dace
- potential ability to detect 30 percent change in abundance on 80 percent of occasions
- few timing restrictions for sampling

Using data from (Pearson 2004 and 2016), thresholds to define moderate abundance were developed based on infection points in capture and encounter data. Specifically, for adults, 0.25 fish per Gee minnow trap (Figure E1a; Pearson 2004) and 50 fry per riffle (Figure E1b; Pearson 2016). Above these levels, Nooksack Dace is considered to be moderately abundant.

Table E1. Comparison of sampling methods for Nooksack Dace.

Method	Capture efficiency	Variance in CPUE at site scale	Risk of harm to individuals or habitat	Sample timing
Single Pass Electrofishing	<30% in riffles (Bonamis 2011, Avery-Gomm 2013) Less in large substrate	Unknowable (single pass method precludes variance estimate)	Significant	March-April August-October
Kick Seine	Unknown (likely <30%) Less in large substrate (M. Pearson pers. obs.)	Unknown	Some	March-April September-October
Gee Minnow Trap	Unknown, but low (Pearson 2004)	Can be estimated from existing data	Low	All
Visual surveys of fry	High in gravel substrate Low in cobble/boulder (Pearson 2016)	Unknown (surveys have not been replicated)	Negligible	July-August

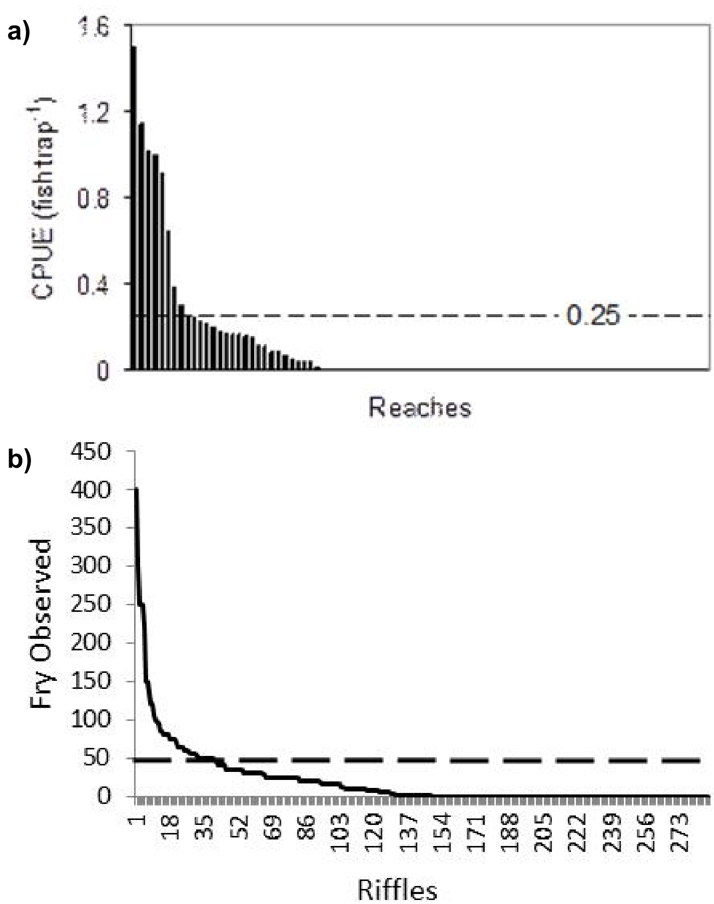

Figure E1. a) Mean number of fish per Gee minnow trap in 71 Reaches (Pearson 2004) and b) number of Nooksack Dace fry counted in 288 riffles (adapted from Pearson 2016).

Appendix F: watershed scale critical habitat maps

Critical habitat maps for the four known populations of Nooksack Dace in Canada are presented in the following figures. Critical habitat maps are also available through DFO's Projects Near Water website and the Government of Canada's Open Maps website.

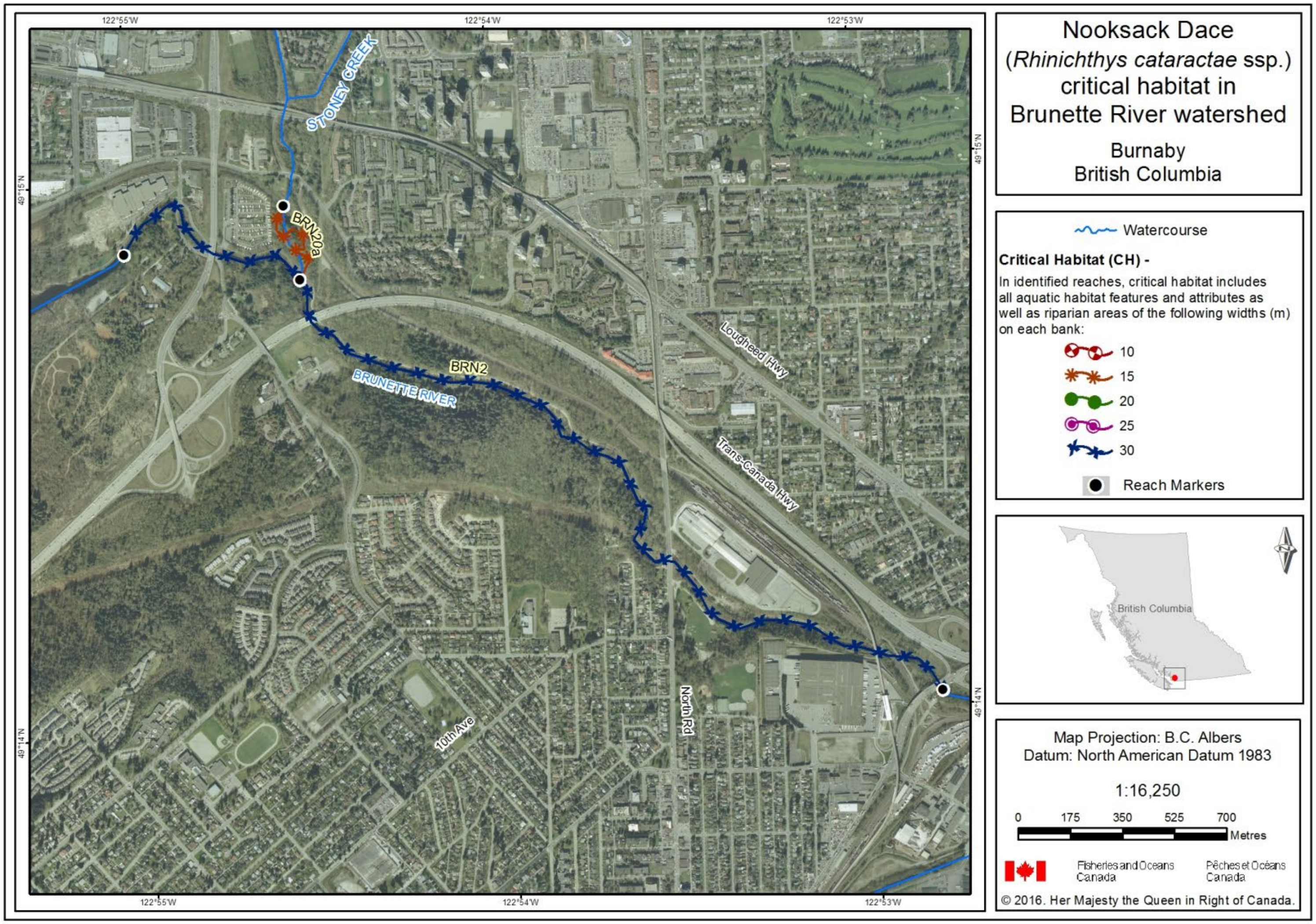

Figure F1. Map of critical habitat reaches for Brunette River.

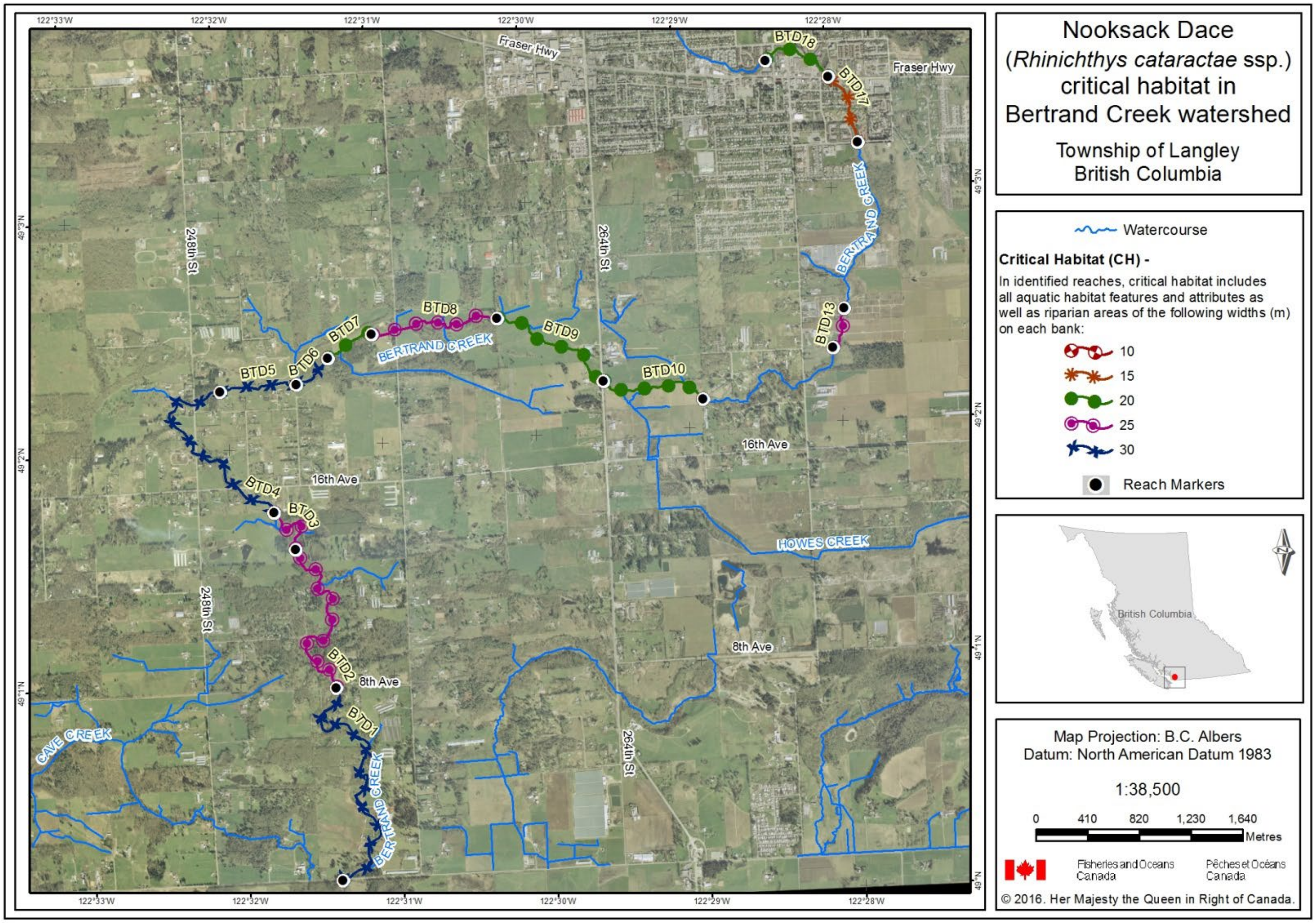

Figure F2. Map of critical habitat reaches for Bertrand Creek.

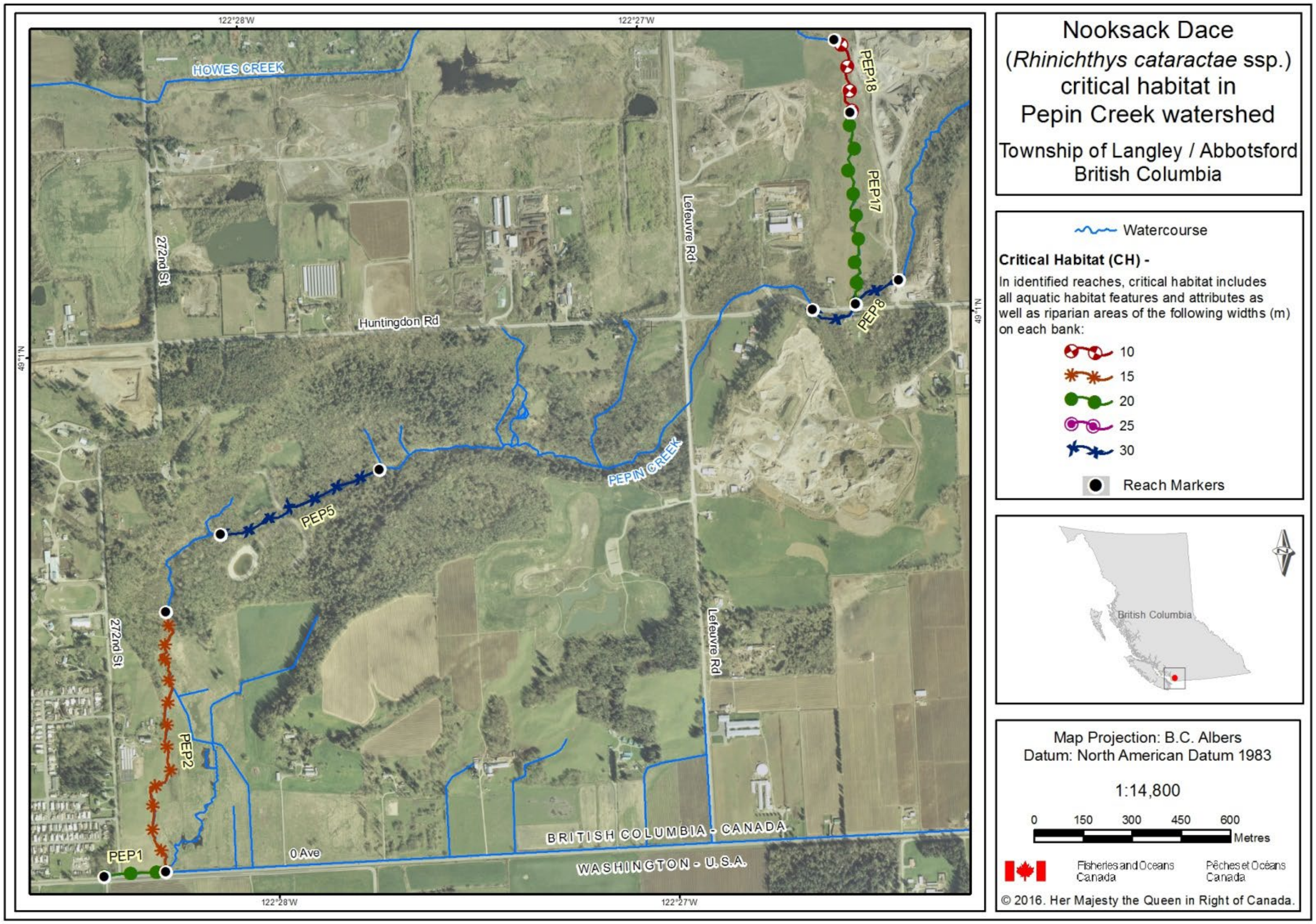

Figure F3. Map of critical habitat reaches for Pepin Creek.

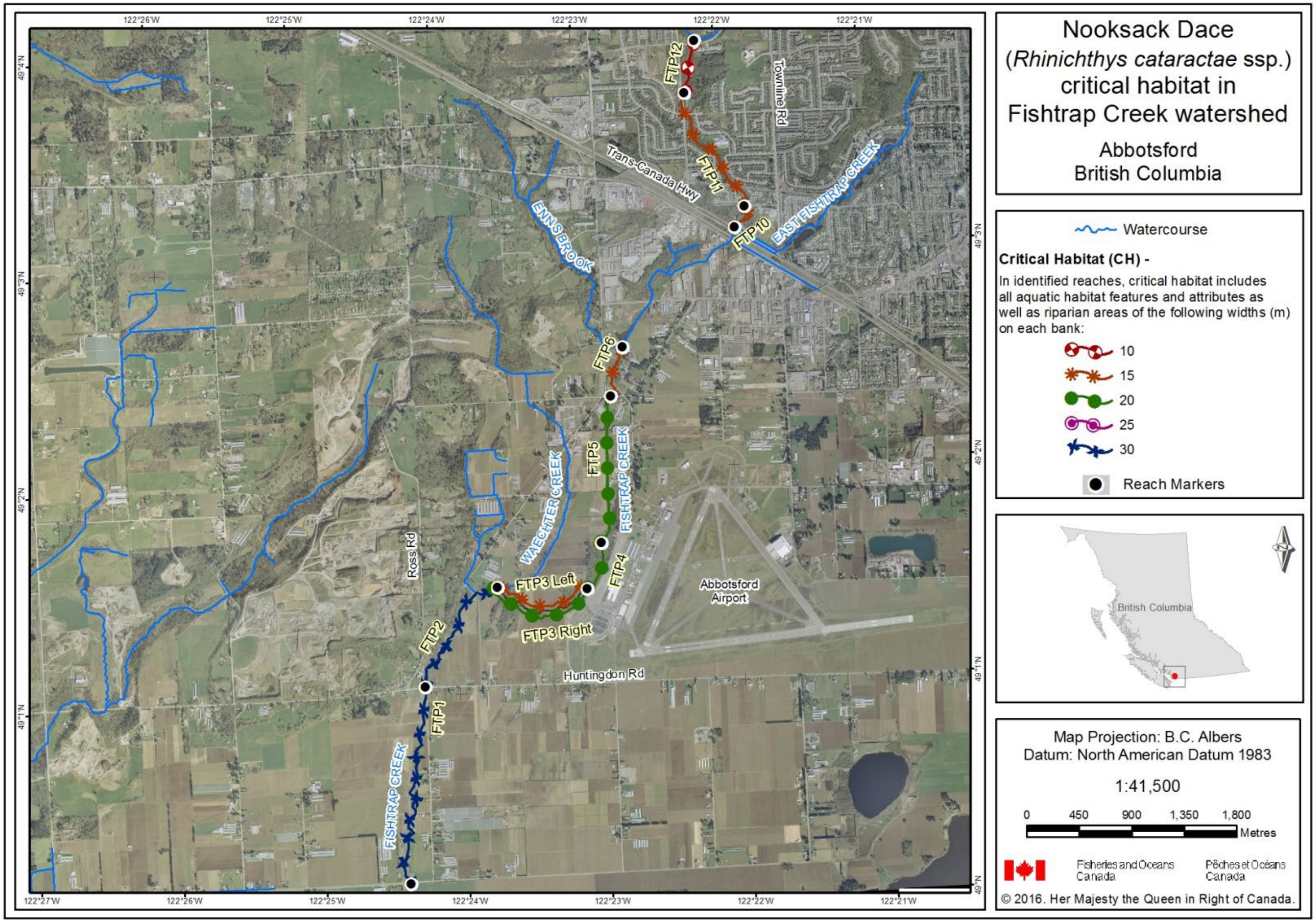

Figure F4. Map of critical habitat reaches for Fishtrap Creek.

Appendix G: geographic coordinates of critical habitat

Watershed	Reach	Reach length (m)	Start Coordinate point[51] - Latitude	Start Coordinate point[52] - Longitude	End Coordinate point[53] - Latitude	End Coordinate point[54] - Longitude	Riparian critical habitat width on each bank for entire reach length (m)	Area of riparian critical habitat associated with the reach (ha)
Brunette River	BRN2	3704	49° 14' 1.487"" N	122° 52' 48.679"" W	49° 14' 52.479"" N	122° 55' 1.040"" W	30	22.2
Brunette River	BRN20a	458	49° 14' 48.952"" N	122° 54' 32.083"" W	49° 14' 57.064"" N	122° 54' 34.302"" W	15	1.4
Bertrand Creek	BTD1	2408	49° 0' 7.976"" N	122° 31' 23.941"" W	49° 0' 57.558"" N	122° 31' 22.899"" W	30	14.5
Bertrand Creek	BTD2	1803	49° 0' 57.558"" N	122° 31' 22.899"" W	49° 1' 33.726"" N	122° 31' 36.116"" W	25	9
Bertrand Creek	BTD3	579	49° 1' 33.726"" N	122° 31' 36.116"" W	49° 1' 43.488"" N	122° 31' 43.848"" W	25	2.9
Bertrand Creek	BTD4	1847	49° 1' 43.488"" N	122° 31' 43.848"" W	49° 2' 15.104"" N	122° 32' 2.658"" W	30	11.1
Bertrand Creek	BTD5	651	49° 2' 15.104"" N	122° 32' 2.658"" W	49° 2' 16.166"" N	122° 31' 32.575"" W	30	3.9
Bertrand Creek	BTD6	351	49° 2' 16.166"" N	122° 31' 32.575"" W	49° 2' 22.538"" N	122° 31' 19.801"" W	30	2.1
Bertrand Creek	BTD7	450	49° 2' 22.538"" N	122° 31' 19.801"" W	49° 2' 28.146"" N	122° 31' 2.317"" W	20	1.8
Bertrand Creek	BTD8	1137	49° 2' 28.146"" N	122° 31' 2.317"" W	49° 2' 30.644"" N	122° 30' 12.954"" W	25	5.7
Bertrand Creek	BTD9	1105	49° 2' 30.644"" N	122° 30' 12.954"" W	49° 2' 13.188"" N	122° 29' 32.800"" W	20	4.4
Bertrand Creek	BTD10	968	49° 2' 13.188"" N	122° 29' 32.800"" W	49° 2' 7.269"" N	122° 28' 54.114"" W	20	3.9
Bertrand Creek	BTD13	356	49° 2' 18.891"" N	122° 28' 2.385"" W	49° 2' 28.887"" N	122° 27' 57.388"" W	25	1.8
Bertrand Creek	BTD17	616	49° 3' 11.450"" N	122° 27' 48.878"" W	49° 3' 28.648"" N	122° 27' 59.000"" W	15	1.8

[51] Coordinate start point indicates the location of the beginning of the reach in question along the watercourse.
[52] Coordinate start point indicates the location of the beginning of the reach in question along the watercourse.
[53] Coordinate end point indicates the location of the end of the reach in question along the watercourse.
[54] Coordinate end point indicates the location of the end of the reach in question along the watercourse.

Watershed	Reach	Reach length (m)	Start Coordinate point[51] - Latitude	Start Coordinate point[52] - Longitude	End Coordinate point[53] - Latitude	End Coordinate point[54] - Longitude	Riparian critical habitat width on each bank for entire reach length (m)	Area of riparian critical habitat associated with the reach (ha)
Bertrand Creek	BTD18	638	49° 3' 28.648"" N	122° 27' 59.000"" W	49° 3' 33.605"" N	122° 28' 23.294"" W	20	2.6
Pepin Creek	PEP1	191	49° 0' 8.363"" N	122° 28' 26.168"" W	49° 0' 8.588"" N	122° 28' 16.952"" W	20	0.8
Pepin Creek	PEP2	926	49° 0' 8.588"" N	122° 28' 16.952"" W	49° 0' 34.270"" N	122° 28' 14.986"" W	15	2.8
Pepin Creek	PEP5	543	49° 0' 41.629"" N	122° 28' 6.212"" W	49° 0' 47.251"" N	122° 27' 41.848"" W	30	3.3
Pepin Creek	PEP8	327	49° 1' 0.919"" N	122° 26' 35.740"" W	49° 1' 3.395"" N	122° 26' 22.542"" W	30	2
Pepin Creek	PEP17	670	49° 1' 1.281"" N	122° 26' 29.218"" W	49° 1' 20.237"" N	122° 26' 28.560"" W	20	2.7
Pepin Creek	PEP18	263	49° 1' 20.237"" N	122° 26' 28.560"" W	49° 1' 27.452"" N	122° 26' 30.447"" W	10	0.5
Fishtrap Creek	FTP1	1989	49° 0' 8.088"" N	122° 24' 24.817"" W	49° 1' 2.627"" N	122° 24' 14.623"" W	30	11.9
Fishtrap Creek	FTP2	1239	49° 1' 2.627"" N	122° 24' 14.623"" W	49° 1' 29.218"" N	122° 23' 42.308"" W	30	7.4
Fishtrap Creek	FTP3	965	49° 1' 29.218"" N	122° 23' 42.308"" W	49° 1' 27.557"" N	122° 23' 4.356"" W	a) left bank: 15 b) right bank: 20	3.4
Fishtrap Creek	FTP4	459	49° 1' 27.557"" N	122° 23' 4.356"" W	49° 1' 40.185"" N	122° 22' 57.513"" W	20	1.8
Fishtrap Creek	FTP5	1300	49° 1' 40.185"" N	122° 22' 57.513"" W	49° 2' 20.647"" N	122° 22' 50.355"" W	20	5.2
Fishtrap Creek	FTP6	458	49° 2' 20.647"" N	122° 22' 50.355"" W	49° 2' 34.055"" N	122° 22' 44.598"" W	15	1.4
Fishtrap Creek	FTP10	282	49° 3' 5.780"" N	122° 21' 54.743"" W	49° 3' 11.494"" N	122° 21' 50.076"" W	15	0.8
Fishtrap Creek	FTP11	1250	49° 3' 11.494"" N	122° 21' 50.076"" W	49° 3' 43.717"" N	122° 22' 13.032"" W	15	3.8
Fishtrap Creek	FTP12	475	49° 3' 43.717"" N	122° 22' 13.032"" W	49° 3' 58.172"" N	122° 22' 7.889"" W	10	0.9