COSEWIC
Assessment and Status Report

on the

Nooksack Dace
Rhinichthys cataractae

in Canada

ENDANGERED
2018

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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COSEWIC 2000. COSEWIC assessment and update status report on the Nooksack dace *Rhinichthys* sp. in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 9 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

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For additional copies contact:

COSEWIC Secretariat
c/o Canadian Wildlife Service
Environment and Climate Change Canada
Ottawa, ON
K1A 0H3

Tel.: 819-938-4125
Fax: 819-938-3984
E-mail: ec.cosepac-cosewic.ec@canada.ca
http://www.cosewic.gc.ca

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Nooksack Dace — Photo: Mike Pearson.

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COSEWIC
Assessment Summary

Assessment Summary – November 2018

Common name
Nooksack Dace

Scientific name
Rhinichthys cataractae

Status
Endangered

Reason for designation
This small fish is a habitat specialist dependent on stream riffles with loose, rocky substrates. In Canada, it is found in disjunct habitat patches in the Fraser River Valley Lowlands where its distribution is severely limited. It is subject to ongoing habitat loss by destruction of riffle habitat from urban, industrial, and agricultural practices. Streams where the species is found are also impacted by lack of water in late summer due to ground and surface water extraction and climate change. Sediment accumulation in riffles, caused by bank erosion, resulting from gravel mining and/or runoff from urban storm drains, has led to further degradation of water quality and habitat.

Occurrence
British Columbia

Status history
Designated Endangered in April 1996. Status re-examined and confirmed in May 2000, April 2007, and November 2018.

COSEWIC
Executive Summary

Nooksack Dace
Rhinichthys cataractae

Wildlife Species Description and Significance

Nooksack Dace is a genetically and morphologically distinct form of the Longnose Dace (*Rhinichthys cataractae*). It is a member of the 'Chehalis fauna', a group of fishes that evolved during geographic isolation in a glacial refuge in present-day Washington State. *R. cataractae* morphology reflects a preference for fast-flowing riverine habitats. Relative to other *R. cataractae* populations in the Fraser and Columbia river basins, Nooksack Dace has a more slender tail and larger scales that are fewer in number. The largest recorded Canadian specimen measured 114 mm (snout to tail fork). It is of scientific interest in the study of evolutionary biology and biogeography.

Distribution

Nooksack Dace is restricted to western Washington State and southwestern British Columbia, where it inhabits the drainages of the east shore of Puget Sound, the western side of the Olympic Peninsula, and the lower Fraser River Valley.

Within Canada, it is known from three tributaries of the Nooksack River (Bertrand, Pepin and Fishtrap creeks) and the Brunette River, a tributary of the lower Fraser River. Historical changes in the Canadian distribution are poorly documented, but some reduction over the past half-century has occurred.

Habitat

Rhinichthys cataractae is widely known as a stream-riffle specialist, but may also inhabit the rocky littoral zones of large lakes. It favours the thin boundary layer of slow moving water that forms over coarse substrates in otherwise high velocity habitats. Nooksack Dace is rarely found in reaches with less than 10% riffle by length or in reaches where long stretches of deep pool habitat separate riffles. In Canada, Nooksack Dace is associated with small- to moderate-sized channels (1-10 m in bankfull width).

In Canada, the trend in riffle habitat is one of decline in quantity and quality. Riffle compaction by sediment from bank erosion and/or urban storm-sewer effluent is widespread. Flow ceases completely in some occupied reaches of Bertrand Creek, eliminating riffle habitat, due in part to impacts of wells and surface withdrawals. Approximately half of the original riffle habitat from across the range has been lost. Losses in the past 10 years appear to have been minimal and primarily due to beaver-pond inundation of riffles in Pepin Creek.

Biology

Nooksack Dace spawns nocturnally over coarse substrate in riffles between April and early July. Both males and females establish and defend small breeding territories that are clustered at the upstream end of riffles. Fecundity ranges from about 200 to over 2,000 eggs. Eggs hatch in 7-10 days but embryos remain in the gravel for an additional week before emerging in mid-summer. Lifespan is four to six years and generation time is two years. Activity appears minimal at temperatures below 11^{o}C, and fish forage normally at temperatures in excess of 20^{o}C. Nooksack Dace typically have small home-range sizes and maximum annual range is believed to be less than 1 km. Nooksack Dace is preyed upon by Mink, River Otter, fish-eating birds and a variety of native and introduced fishes and amphibians.

Population Sizes and Trends

The Canadian populations of Nooksack Dace were estimated to be approximately 4,300 to 13,000 in 2011. However, confidence in estimates of population sizes is low due to a lack of effective quantitative sampling efforts. The largest population, in Bertrand Creek, is believed to be less than 5,700 adults. The Brunette River may support about half that number. The Pepin and Fishtrap creek populations are critically low, perhaps 100 or fewer adults each. This corresponds with known losses and degradation of riffle habitat over the past 10 years in these creeks. Continuing decline is also suggested by the apparent extirpation of Nooksack Dace from headwater tributaries of Fishtrap and Bertrand creeks since the 1960s.

Threats and Limiting Factors

Natural systems modifications, particularly those affecting instream habitat or water availability in drought periods, is the leading threat. Stream dredging and clearing of riparian vegetation are also significant threats. Stormwater drainage alters flow patterns, often exacerbating low flow impacts. Climate change will clearly exacerbate the already-serious issue of water availability in summer. Pollution from agriculture, industry, and urban wastewater is also a major threat. Nutrient pollution impacts water quality and causes habitat loss and degradation from overgrowth by invasive plants. Pesticide pollution can harm fish directly and reduce food availability. Livestock access to Nooksack Dace habitat is declining, but still occurs regularly in Fishtrap and Bertrand creeks. The large number of road, railroad, and farm crossings of these creeks creates a risk of spills and fragments habitat. All streams have also been affected by large-scale sediment releases from

construction sites and gravel mines in the past 20 years. Riffle flooding by beaver ponds has significantly reduced available habitat for Nooksack Dace in Pepin Creek. The primary limiting factors for Nooksack Dace in Canada are likely the availability of riffle habitat.

Protection, Status and Ranks

Nooksack Dace is listed as Endangered under Canada's *Species at Risk Act* (SARA) and is protected from harm and from destruction of Critical Habitat under its provisions. The federal *Fisheries Act* (R.S.C., 1985, c. F-14) and the British Columbia *Water Sustainability* Act (S.B.C. 2014, c. 15) and the *Wildlife* Act (R.S.B.C. 1996, c. 488) also provide some protection. Nooksack Dace is Red-listed in British Columbia.

TECHNICAL SUMMARY

Rhinichthys cataractae

Nooksack Dace

Naseux de la Nooksack

Range of occurrence in Canada: British Columbia

Demographic Information

Generation time	2 years
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes, inferred from loss of habitat area and projected from threats calculator results.
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	a. No b. Yes c. No
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	630 km² Unchanged from 2007 Update Status Report.
Index of area of occupancy (IAO) Based on overlaid grid of cell size 2x2 km, total area of cells intersected by occupied channel.	36 km² Increase from 14 km² in 2007 Update Status report. No change in channel length, difference due to use of finer grid (1x1 km) in 2007.

Is the population “severely fragmented” i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. No b. No
Number of “locations”* (use plausible range to reflect uncertainty if appropriat	4
Is there an [observed, inferred, or projected] decline in extent of occurrence?	Yes, projected loss of Fishtrap Creek population.
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Yes, projected loss of Fishtrap Creek population
Is there an [observed, inferred, or projected] decline in number of populations?	Yes, projected loss of Fishtrap Creek population
Is there an [observed, inferred, or projected] decline in number of “locations”*?	Yes, projected loss of Fishtrap Creek population
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes, observed decline in area, extent and quality of riffle habitat
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of “locations”*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (see discussion)

Populations	**N Mature Individuals**
Bertrand Creek	2499-7991
Pepin Creek	12-136
Fishtrap Creek	0 – 100
Brunette River	1823-4537
Total	4334-12764

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations, or 10% within 100 years]?	Unknown

* See Definitions and Abbreviations on COSEWIC web site and IUCN (Feb 2014) for more information on this term

Threats

Was a threats calculator completed for this species? Yes

i. Natural systems modifications
(Dams and water management/use; Stream dredging; Riparian removal)
ii. Pollution (Urban wastewater, Industrial and agricultural effluents)
iii. Climate change (Drought)
iv. Invasive and other problematic species and genes
v. Agriculture (Livestock farming)
vi. Transportation and service corridors (Roads and railroads)

What additional limiting factors are relevant?
Limited availability of riffle habitat in some creeks; Columbia-form Longnose Dace.

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Unknown (Nooksack River population in Washington State)
Is immigration known or possible?	Known: found on both sides of the US border in Nooksack River tributaries. Rescue of Canadian populations by Washington ones is unlikely due to limited and discontinuous suitable habitat in Washington.
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	No; suitable habitat in these streams is already occupied
Are conditions deteriorating in Canada?[+]	Yes
Are conditions for the source (i.e., outside) population deteriorating?[+]	Unknown, but likely
Is the Canadian population considered to be a sink?[+]	No
Is rescue from outside populations likely?	No

Data Sensitive Species

Is this a data sensitive species?	No

Status History

Designated Endangered in April 1996. Status re-examined and confirmed in May 2000, April 2007, and November 2018.

[+] See Table 3 (Guidelines for modifying status assessment based on rescue effect)

Status and Reasons for Designation

Status:	**Alpha-numeric codes:**
Endangered	B1ab(i,ii,iii,iv,v)+2ab(i,ii,iii,iv,v)
Reasons for designation: This small fish is a habitat specialist dependent on stream riffles with loose, rocky substrates. In Canada, it is found in disjunct habitat patches in the Fraser River Valley Lowlands where its distribution is severely limited. It is subject to ongoing habitat loss by destruction of riffle habitat from urban, industrial, and agricultural practices. Streams where the species is found are also impacted by lack of water in late summer due to ground and surface water extraction and climate change. Sediment accumulation in riffles, caused by bank erosion, resulting from gravel mining and/or runoff from urban storm drains, has led to further degradation of water quality and habitat.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable – decline rates are unknown.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Endangered, B1ab(i,ii,iii,iv,v)+2ab(i,ii,iii,iv,v). The EOO is 630 km^2, and the IAO 36 km^2. The species is known to exist at only 4 locations, and there is continuing decline in the extent and quality of habitat, and projected decline in extent of occurrence, index of area of occupancy, number of locations, subpopulations and individuals.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable. Total population estimated to be 4,334 -12,764. Although there is a continuing decline in habitat quality, the quantitative effect on population size is unknown and there are no extreme fluctuations. Threshold for subcriteria are not met.
Criterion D (Very Small or Restricted Population): Meets Threatened, D2, known from only 4 locations.
Criterion E (Quantitative Analysis): Not applicable.

PREFACE

Since the last status report on Nooksack Dace was published (COSEWIC 2007), four graduate academic theses and several peer-reviewed papers have been published, providing valuable information on Nooksack Dace taxonomic status (Ruskey 2014; Ruskey and Taylor 2015; Taylor *et al.* 2015), population assessment (Bonamis 2011), and the threats of insufficient in-stream flows (Avery-Gomm 2013; Avery-Gomm *et al.* 2014), and sedimentation (Champion 2016). A Final Recovery Strategy for Nooksack Dace has been adopted under the *Species at Risk Act (SARA)*. Critical habitat is identified in the Recovery Strategy and is protected by a federal Order in Council. Nooksack Dace was not selected by the COSEWIC ATK Subcommittee to go through the formal ATK gathering process.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS (2018)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

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

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

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment and Climate Change Canada
Canadian Wildlife Service
Environnement et Changement climatique Canada
Service canadien de la faune
Canada

The Canadian Wildlife Service, Environment and Climate Change Canada, provides full administrative and financial support to the COSEWIC Secretariat.

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Class: Osteichthys

Order: Cypriniformes

Family: Cyprinidae

Genus: *Rhinichthys*

Species: *Rhinichthys cataractae*

Common names:
English Nooksack Dace
French Naseux de la Nooksack

Nooksack Dace is a genetically and morphologically distinct form of the Longnose Dace (*Rhinichthys cataractae*). It is a member of the Chehalis fauna, a group of fishes that diverged from the Columbia fauna during the Pleistocene Epoch, at least 100,000 years ago (Taylor *et al.* 2015), through geographic isolation in a glacial refuge in present-day Washington State (McPhail 1967, 1997). It is one of several closely related daces of uncertain taxonomic relationship found in the Pacific Northwest. The most widespread form is found in the Columbia and Fraser river systems. Divergent forms include Umpqua Dace (*R. evermanni* Snyder) of the Umpqua drainage and the undescribed Millicoma Dace of the Coos drainage, both in Oregon, in addition to Nooksack Dace (McPhail 1967; Bisson and Reimers 1977). None of the forms are known to occur in sympatry. Taylor *et al.* (2015) sequenced approximately 1,400 base pairs of mitochondrial DNA and found that Longnose Dace, found west of the continental divide, and Nooksack Dace constituted reciprocally monophyletic clades that differed from each other by between 2 and 3% sequence divergence. Sequence analysis at two nuclear loci (the S7 ribosomal protein and recombination activation gene 1 introns, ~1,600 base) showed no consistent difference between Longnose Dace and Nooksack Dace and several alleles were shared between them. Taylor *et al.* (2015) concluded that Nooksack Dace does not appear to warrant separate taxonomic status from Longnose Dace, but the mitochondrial DNA differences support recognition as an important (i.e. significant and irreplaceable) component of the evolutionary and biogeographic legacy of *R. cataractae*.

Morphological Description

Rhinichthys cataractae morphology reflects a preference for fast-flowing riverine habitats. The body is streamlined and nearly round in cross section (Figure 1). The head is triangular with a bulbous snout overhanging the mouth and a slight hump at the nape. The eyes are small relative to head length. Pectoral fins are large and paddle shaped, pelvic fins are small, and the caudal fin is shallowly forked with rounded lobes. Body colouration is grey-green above a dull, brassy lateral stripe and dirty white below it. The swim bladder is small and poorly developed (Scott and Crossman 1973). There are distinct pale marks on the back at the anterior and posterior base of the dorsal fin and a distinct black stripe on the head in front of the eyes, which in juveniles continues down the flanks to the tail. Males have slightly longer pectoral fins but the sexes are not otherwise distinguishable (McPhail 1997). Relative to other *R. cataractae* populations in the Fraser and Columbia river basins, Nooksack Dace has a more slender caudal peduncle and larger scales that are fewer in number (50-59 vs 60-73 on the lateral line; McPhail 1967; Bisson and Reimers 1977; Ruskey and Taylor 2015). The largest recorded Canadian specimen measured 114 mm (snout to tail fork) and weighed 16.1 g (Pearson 2004).

Figure 1. Nooksack Dace (81 mm fork length; captured September 11, 2014, Bertrand Creek, UTM 10U 534842 5429416). Photo by Mike Pearson.

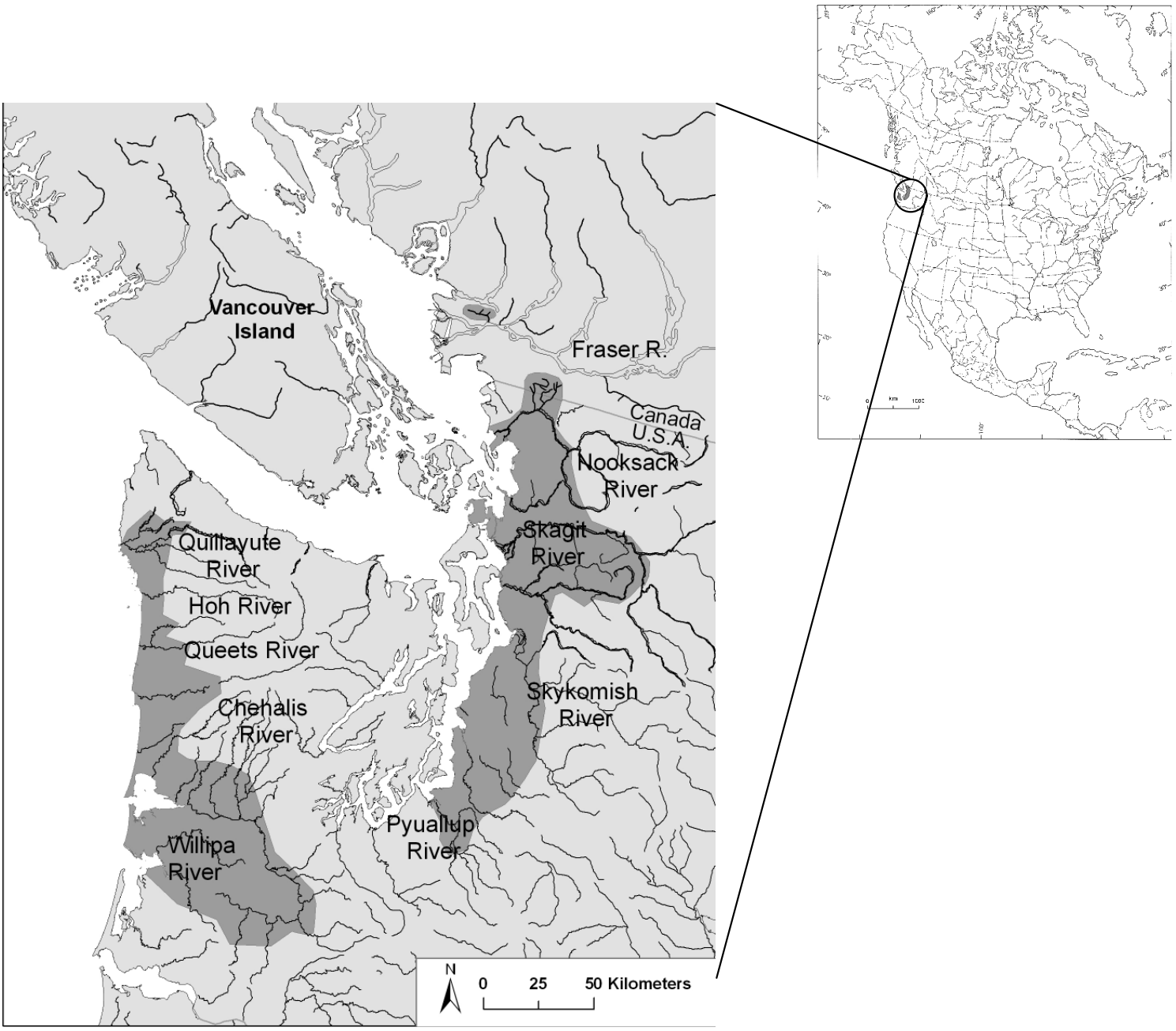

Figure 2. Global range of Nooksack Dace is restricted to northwestern Washington state and the Fraser River Valley in southwestern British Columbia. Adapted from McPhail (1997) and Mongillo and Hallock (1997).

Population Spatial Structure and Variability

Within Canada, Nooksack Dace populations occupy at least two drainages within British Columbia, the lower Fraser River, and the Nooksack River system. Dispersal between the drainages is extremely unlikely, although brief connections between tributary headwaters occur during flood events in some years. Three Fraser River tributaries contain *R. cataractae* of both Nooksack and Columbia mitochondrial haplotypes that are morphologically indistinguishable indicating that secondary contact between the two forms has resulted in admixed populations and that reproductive isolation of the two forms has not developed (Ruskey and Taylor 2015).

Designatable Units

Nooksack Dace is a designatable unit separate from other *R. cataractae* populations based on deep differences in mitochondrial DNA (Taylor *et al.* 2015; Ruskey and Taylor 2015). Genetic, morphological, and distributional distinctiveness and evolutionary significance indicate that Nooksack Dace should be considered an evolutionarily significant unit for conservation purposes (cf. McPhail and Taylor 1999; Taylor and McPhail 2015).

Special Significance

Nooksack Dace is part of the Chehalis fauna, a group of fishes that diverged from Columbia fauna populations while isolated during the most recent glaciations in an ice-free refuge located south of Puget Sound and north of the Columbia River. Nooksack Dace and Salish Sucker (*Catostomus* cf. *catostomus*), assessed as Endangered and Threatened, respectively, by COSEWIC and both listed as Endangered under SARA, are the only two members of this distinctive fauna to have dispersed, postglacially, as far north as British Columbia (McPhail 1997). Like most members of the Chehalis fauna, Nooksack Dace is closely related to, but genetically and morphologically distinct from, the western North American (Columbia-Fraser) form of a continentally distributed species (Longnose Dace). Its distribution is also characteristic of Chehalis isolates, scattered populations in the Chehalis River and rivers draining the west side of the Olympic Peninsula and the east side of Puget Sound (McPhail 1997). It is of scientific interest in the study of evolutionary biology and biogeography (McPhail 1967; Bisson and Reimer 1977; McPhail 1997; Ruskey and Taylor 2015; Taylor *et al.* 2015).

Searches of the UBC library catalogue, and a number of zoological, First Nations, and anthropological data bases yielded no reports of Indigenous use or traditional knowledge of *R. cataractae*. Nooksack Dace has not been selected by the COSEWIC ATK Subcommittee to go through the formal ATK gathering process at this time (Jones 2017).

DISTRIBUTION

Global Range

Nooksack Dace is restricted to western Washington State and southwestern British Columbia where it inhabits the drainages of the east shore of Puget Sound, western side of the Olympic Peninsula, and lower Fraser River Valley. The historical range is unknown, but unlikely to have been much more extensive as the Columbia-Fraser form of *R. cataractae* occupies drainages to the west and north with a secondary contact zone in the Fraser Valley, and other members of the same clade occupy drainages south of the Columbia River (Taylor *et al.* 2015).

Canadian Range

Within Canada, Nooksack Dace occupy a restricted range. It is confirmed present in four creeks in two major watersheds in the Fraser Valley (Figure 3). Three of the creeks flow south into Washington State's Nooksack River (Bertrand Creek, Pepin Creek, Fishtrap Creek). The fourth population, discovered in 2004, occupies the Brunette River, a tributary of the lower Fraser River. The nearby Coquitlam, Alouette and Kanaka drainages, also tributary to the Fraser River, contain admixed populations (introgressed hybrids) of Nooksack Dace and Columbia-Fraser *R. cataractae*. *R. cataractae* from the Vedder River south of Chilliwack and from tributaries to Chilliwack Lake (Depot Creek and Upper Chilliwack River) are also admixed (Taylor pers. comm. 2018).

The existence of unknown populations in other Fraser River tributaries seems plausible in light of the confirmation of the Brunette River population (2005) and the discovery of *R. cataractae* with Nooksack mitochondrial haplotypes in the upper Chilliwack River (2016). Searches of occurrence records for *R. cataractae* in the Fraser Valley on the UBC Fish Museum database, British Columbia Fisheries Inventory Summary System, Canadian Museum of Nature, and Royal British Columbia Museum records yielded putative records from 72 sites in the Fraser Valley and tributaries entering the Fraser River downstream of Hope (Table 1). Those from areas not yet genetically characterized are shown in Figure 3. Even if some of these areas do contain Nooksack Dace, their overall distribution will remain highly restricted.

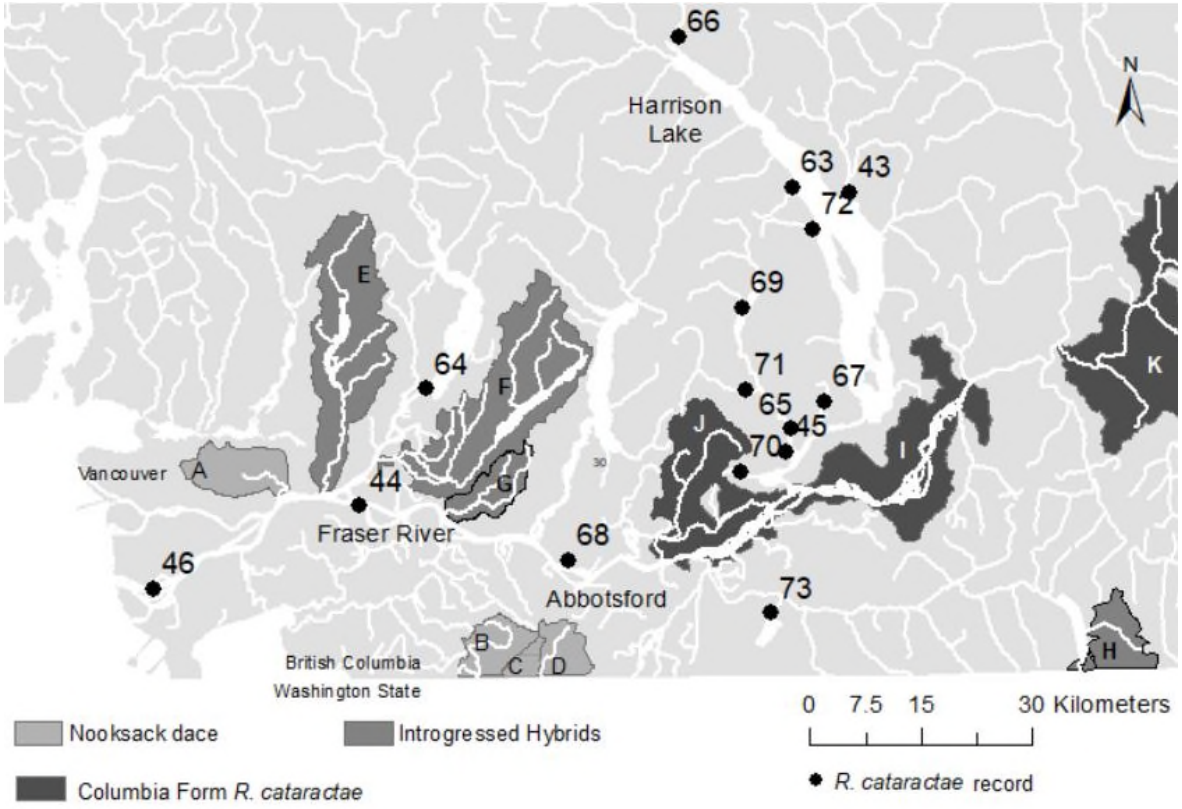

Figure 3. In Canada, Nooksack Dace populations are confirmed in the Brunette River (A, most recently caught in 2017), Bertrand Creek (B, 2015), Pepin Creek (C, 2017), and Fishtrap Creek (D, 2010). Norrish Creek (G) contains the Columbia-Fraser form of *R. cataractae*, while the Coquitlam River (E. 2017), Alouette River (F, 2012), Kanaka Creek (G, 2013), and Chilliwack River (H, 2016) contain introgressed hybrids of the two types (Ruskey and Taylor 2015; Taylor pers. comm. 2018). Populations in the Fraser River mainstem (I, 2012), Norrish Creek (J, 1996) and the Coquihalla River (K, 1956) are Columbia form (Pearson unpubl. data). Numbers refer to putative *R. cataractae* records from other watersheds as detailed in Table 1.

Table 1. Records of *Rhinichthys cataractae* in the Fraser Valley and Chilliwack River valleys in the UBC Fish Museum database[1], British Columbia Fisheries Inventory Summary System (FISS)[2] , Royal British Columbia Museum (RBCM), and Canadian Museum of Nature.

Site	Drainage	Locality	Year	Easting	Northing	Reference	Haplotypes Present
1	Bertrand Creek	Otter Road	1963			UBC 76-0027	N
2	Bertrand Creek		1993	537371	5434835	FISS HQ0517	N
3	Bertrand Creek		1977			RBCM 977-00259-001	N
4	Bertrand Creek		1979			RBCM 979-11079-001	N
5	Bertrand Creek		1984			RBCM 984-00431-001	N
6	Bertrand Creek		1958			CMNFI 1959-0090.4	N
7	Brunette River	Still Creek at Hwy 7	1956			UBC 56-0122	N
8	Brunette River	Hume Park, New Westminster	1980			UBC 60219	N

Site	Drainage	Locality	Year	Easting	Northing	Reference	Haplotypes Present
9	Brunette River	Unknown	1953			UBC55-0009	N
10	Brunette River	Unknown	2006			UBC 110019	N
11	Fishtrap Creek		1977			RBCM 977-00261-002	N
12	Coquihalla River	Near mouth	1956			UBC 59-0446	CF
13	Coquihalla River	At pipeline crossing	1956			UBC 590004	CF
14	Coquihalla River	Near mouth	1956			UBC 580587	CF
15	Fraser River	Dewdney (Nicomen Slough?)	1959			UBC 59-0601	CF
16	Fraser River	Unknown	2012			UBC 120081	CF
17	Fraser River	N of Chilliwack	2012	581617	5453351	UBC 140014	CF
18	Fraser River	Coquihalla Mouth	1956			UBC 59-0002	CF
19	Norrish Creek	2.6 km upstream	1959			UBC 59-0602	CF
20	Norrish Creek		1996			UBC 110020	CF
21	Norrish Creek	8 km upstream	1959			UBC 59-0600	CF
22	Alouette River	224 ST	1998	529110	5453616	FISS HQ2030	N/CF
23	Alouette River	232 St	1980			UBC 82-0012	N/CF
24	Alouette River	Maple Grove Park (232 St.)	1998			UBC 60128	N/CF
25	Alouette River	Alouette Lake outlet	1996	537170	5459510	FISS HQ0717	N/CF
26	Alouette River	Near hatchery	2012			UBC 140016	N/CF
27	Alouette River	N. Alouette u/s of 232 St.	2012			UBC 140017	N/CF
28	Coquitlam River	Unknown	1951			UBC 55-0008	N/CF
29	Coquitlam River	Unknown	2000			UBC 60220	N/CF
30	Coquitlam River	Coquitlam River ‘2B Site’	2012			UBC 140018	N/CF
31	Coquitlam River	Unknown	2008			UBC 140012	N/CF
32	Coquitlam River		1996	517255	5465878	FISS HQ0498	N/CF
33	Coquitlam River	Hwy 7 bridge	1956			UBC 56-0412	N/CF
34	Kanaka Creek	End of 110 Ave, Maple Ridge	2011			UBC 110519	N/CF
35	Kanaka Creek	Site 2	2013			UBC 140015	N/CF
36	Kanaka Creek	Site 3	2012			UBC 140013	N/CF
37	Kanaka Creek	Site 4	2012			UBC 140029	N/CF
38	Kanaka Creek	Site 5	2012			UBC 140019	N/CF
39	Chilliwack Lake	Among boulders S. end of lake	2017			M. Pearson unpub. data.	N/CF

Site	Drainage	Locality	Year	Easting	Northing	Reference	Haplotypes Present
40	Chilliwack River	Upstream of Chilliwack Lake	2016			UBC	N/CF
41	Depot Creek	Tributary to Chilliwack Lake	2016			UBC	N/CF
42	Paleface Creek	Tributary to Chilliwack Lake	1976			CMNFI 1979-0829.1	N/CF
43	Big Silver Creek	Tributary to Harrison Lake	1995	584654	5498355	FISS obs id 419493	?
44	Centre Creek	Surrey Bend		519334	5450704	FISS obs. pt. 418715	?
45	Chehalis River		1990			FISS obs. id 193320	?
46	Fraser River	Kirkland Island	1978	491215	5439571	FISS HQ0444	?
47	Fraser River	Mouth of Vedder	1959			UBC 59-0608	?
48	Fraser River	N of Chilliwack	2000	572783	5448220	FISS HQ1489	?
49	Fraser River	N of Chilliwack	2000	574938	5451237	FISS HQ1489	?
50	Fraser River	N of Chilliwack	2000	576765	5450636	FISS HQ1489	?
51	Fraser River	N of Chilliwack	2000	576533	5452159	FISS HQ1489	?
52	Fraser River	N of Chilliwack	2000	577767	5451240	FISS HQ1489	?
53	Fraser River	N of Chilliwack	2000	578363	5453036	FISS HQ1489	?
54	Fraser River	N of Chilliwack	2000	580403	5452854	FISS HQ1489	?
55	Fraser River	S of Agassiz	2000	586617	5452439	FISS HQ1489	?
56	Fraser River	S of Agassiz	2000	590544	5451894	FISS HQ1489	?
57	Fraser River	S of Agassiz	2000	593678	5453684	FISS HQ1489	?
58	Fraser River	Herling Island	1987			RBCM 987-00234-003	?
59	Fraser River	Herling Island	1987			RBCM 987-00235-004	?
60	Fraser River	Herling Island	1987			RBVM 987-00236-001	?
61	Fraser River	Herling Island	1992			RBCM 992-00227-002	?
62	Fraser River	Chilliwack	1987			RBCM 987-00233-001	?
63	Kirkland Creek	Tributary to Harrison Lake	2015	577581	5493911	FISS obs pt. 376375	?
64	Pitt River	Main stem	1991	528068	5466523	FISS HQ0435	?
65	Pretty Creek	Tributary to Harrison River	2011	576593	5459735	FISS obs pt. 401275	?
66	Purcell Creek	Tributary to Harrison Lake	2011	562486	5511680	FISS obs.pt. 102213	?
67	Sakwi Creek	Tributary to Weaver Creek	2015	581574	5464642	FISS obs. pt. 430283	?
68	Silverdale Creek	W of Mission	1954	547100	5443000	UBC 58-0552	?
69	Skwellepil Creek	Tributary to Chehalis Lake	1990	571202	5477832	FISS obs. pt. 376270	?
70	Squakum River	Lake Errock outlet stream	1980			UBC 820096	?

Site	Drainage	Locality	Year	Easting	Northing	Reference	Haplotypes Present
71	Statlu Creek	Tributary to Chehalis River	1988	577581	5493911	FISS obs. pt. 431090	?
72	Twenty Mile Creek	Tributary to Harrison Lake	2015	580700	5487400	FISS obs. pt. 376362	?
73	Vedder River	Cultus Lake outlet	1995	574354	5436388	FISS 2FBSRY	?

[1] http://www.zoology.ubc.ca/~etaylor/nfrg/fishmuseum.html

[2]www.bcfisheries.gov.bc.ca/fishinv/fiss.html

[3]Haplotypes present: CF = Columbia-Fraser; N = Nooksack; ?= not tested

[4]Mission Creek in database.

Within watersheds, Nooksack Dace distribution is extremely clumped. Pearson (2004) compared catch per unit effort (CPUE; mean number of fish per trap; 24 h sets) in 72 reaches of the Nooksack River tributaries. CPUE was zero in most (41) reaches and high densities (CPUE>0.25 fish per trap) were found in only 8 reaches, 6 of which are contiguous in lower Bertrand Creek. He estimated that this 5 km stretch of channel constituting just 12.5% of main stem length in the Nooksack River tributaries contained more than 70% of their Nooksack Dace. Visual surveys of fry in 2015 also showed a clumped spatial pattern with the largest concentration of fish in lower Bertrand Creek (Pearson 2016).

Historical changes in the Canadian distribution are poorly documented, but a general decline over at least the past half-century seems likely. McPhail (1997) reported that Nooksack Dace was extirpated from some headwater tributaries of Bertrand and Fishtrap creeks between the late 1960s and the mid-1990s. Pearson (2004) found it only in the main stems of these creeks and observed that most of the tributaries run dry in late summer.

Extent of Occurrence and Index of Area of Occupancy

The known extent of occurrence (EOO) in Canada comprises 630 km^2, or 4.3 percent of the global extent (calculated from GIS adaptation of maps from McPhail 1997 and Mongillo and Hallock 1997 with Brunette River watershed added). The index of area of occupancy (IAO) is 36 km^2, an increase from 14 km^2 in the 2007 status report. The difference does not reflect a change in occupied channel length, but is due to use of a finer grid in the 2007 analysis (1x1 km rather than 2x2 km). The area of riffle habitat occupied is unknown. Potential habitat (Table 2), defined as the total riffle area in reaches containing more than 10% riffle by length, totalled 7300 m^2 in the three Nooksack River tributaries in 1999 (Pearson 2004). Much of this habitat is currently unoccupied due to seasonal drying, compaction with silt, or beaver impoundment. The Brunette River is much wider and contains over 20,000 m^2 of riffle and glide (Pearson 2007), most of which is occupied at very low densities. Current riffle area occupied in Canada likely exceeds 15,000 m^2 (1 ha). The extent of occurrence and area of occupancy in Washington State are unknown.

Table 2. Potential habitat and population size estimates for confirmed Nooksack Dace populations in Canada. Pearson's (2004) estimates of maximum theoretical populations are products of maximum density recorded (1.9 per m^2, Inglis *et al.*, 1994) and available riffle area in reaches with more than 10% riffle by length. A CPUE-based estimate of relative abundance among watersheds is used to calculate the adjusted theoretical maximum estimate. Bonamis (2011) estimates are based on extrapolation of density estimates from randomly selected riffles using single pass electrofishing adjusted using estimates of capture efficiency. See *Population Sizes and Trends* section for discussion.

	Pearson 2004					
Drainage	**Length of Riffle (m)**	**Area of Riffle (m^2)**	**Maximum Theoretical Population**	**CPUE ratio**	**Adjusted Maximum**	**Bonamis 2011**
Bertrand Creek	1199	2996	5700	18.9	5700	4359 (2499-7991)
Pepin Creek	1050	2300	4400	2.7	800	30 (12-136)
Fishtrap Creek	1016	2032	3900	1	300	0
Brunette River*	10473	20155	52200	NA	NA	2763 (1823-4537)
Total	13738	27483	66200		<6800	7152 (4334-12764)

*Pearson, unpubl.data

Search Effort

Search effort for *R. cataractae* populations has been moderate within the Canadian portion of the range. The earliest reliable records of *R. cataractae* in the Fraser Valley date from the 1950s (see Table 1). McPhail (pers. comm. 2006) reported that intensive sampling (using rotenone) in streams across the Fraser Valley in the 1960s did not reveal any populations other than those listed in Table 1 (the samples are not catalogued). Inglis *et al.* (1994) electrofished for Nooksack Dace at 158 sites in 34 Fraser Valley streams (1 pass of 50-100 m per site) during the summer of 1992. They recorded no *R. cataractae* outside the Nooksack River tributaries, but sampled no streams on the north side of the Fraser River. Voucher specimens exist for Columbia-Fraser *R. cataractae* in Norrish Creek on the north bank and *R. cataractae* of unknown lineage have been reported from several tributaries to Harrison Lake and the Chehalis River since 2010 (Figure 3, Table 1). The great majority (97%) of 29 *R. cataractae* sampled in 2016 and 2017 from the upper Chilliwack River system carried the Nooksack mitochondrial haplotype. These recent discoveries suggest that further surveys in lower Fraser tributary watersheds may reveal additional Nooksack Dace populations. A positive identification of a non-admixed population requires genetic analysis of tissue samples from at least 20 to 30 individuals (Taylor, pers. comm. 2018).

HABITAT

Habitat Requirements

Rhinichthys cataractae is widely known as a stream-riffle specialist (Facey and Grossman 1992; Gibbons and Gee 1972; Thompson *et al.* 2001; McPhail 1997), but also commonly inhabit the rocky littoral zones of large lakes (Gee and Machniak 1972; Pearson unpubl. data), including all five of the Great Lakes (Brazo *et al.* 1978). Although it is associated with high-velocity areas in streams, it inhabits low-velocity microhabitats within the boundary layer, which are most prevalent over unembedded coarse substrate. The proportion of riffle habitat in a stream reach is the strongest predictor of Nooksack Dace presence. It is rarely found in reaches with less than 10% riffle by length or in reaches where long stretches of deep pool habitat separate riffles (Pearson 2004). Natural habitat fragmentation occurs where low stream gradient precludes riffle formation and where beaver ponding converts riffles to pools.

Densities of adult Nooksack Dace were highest in depths of 10 to 20 cm, at water velocities greater between 20 and 35 cm/s, over loose gravel (4-10 cm diameter), cobble or boulder substrates during electrofishing surveys (Inglis *et al.* 1994; McPhail 1997; Pearson unpubl. data), although this likely underestimates the quality of habitat with higher depths and velocities due to reduced sampling efficiency (Avery-Gomm 2013). Densities were three times higher in riffles than in pools (2.04 fish/m^2 and 0.68 fish/m^2) during summer in Bertrand Creek (Avery-Gomm 2013). Nooksack Dace growth was highest under high-flow conditions in riffle habitats of in-ground constructed experimental channels and declined with reduced discharge (Avery-Gomm *et al.* 2014). Overwintering adults have been found beneath cobble substrate in fast-flowing riffles (Pearson unpubl. data).

Nooksack Dace typically spawn at night in the upstream portions of riffles (McPhail 1997). Young-of-the-year Nooksack Dace are diurnal and typically aggregate in shallow water (10-20 cm). When first emerged (June or July), they use calm eddies along the channel margins, usually over sand substrates at the downstream end of riffles (McPhail 1997). As the summer progresses and they grow larger, they cluster in microhabitats of increasing water velocity and substrate size, drift feeding (Pearson pers. obs.).

Nooksack Dace use pool habitats when low discharge reduces or eliminates riffle habitats and they have been observed foraging with juvenile salmonids (Pearson pers. obs.). Growth rate of Nooksack Dace in pools was about half that in riffles in experimental channels, but was not influenced by discharge. Dace did not increase in density in most pools during extreme low flows in Bertrand Creek, perhaps due to high predation rates. One pool, which was deeper and contained more abundant cover than the others sampled, retained extremely high densities of Nooksack Dace during this period (Avery-Gomm *et al.* 2014).

In Canada, Nooksack Dace is associated with small- to moderate-sized channels (1-10 m in bankfull width), but this probably reflects available habitat in occupied watersheds rather than a preference (McPhail 1997). On the Olympic Peninsula, mean channel width at occupied sites was 45.2 m (range 14.9-76 m, n=12, Mongillo and Hallock 1997).

Habitat Trends

The current extent of riffle habitats and occupancy in the Nooksack tributaries is well documented (Figures 4, 5; Pearson 1998 a,b, 2004). The trend in its quantity and quality is clearly one of decline. At least some riffles in all three creeks are compacted by sediment from bank erosion and/or urban storm-sewer effluent (Pearson 2004). In particularly dry years (e.g., 2002), flow ceases completely in some occupied reaches of Bertrand Creek, eliminating riffle habitat. Reaches with strongest baseflows still lose over 80% of riffle area relative to winter levels (Pearson unpubl. data). Aquifer draw-down by local wells is estimated to have reduced the creek's baseflow by 24% since 1960 (Golder and Associates 2004). Surface withdrawals for irrigation, both licensed and unlicensed, are also significant, but have not been quantified. The extent of change in baseflow and sediment impacts in the past decade are uncertain.

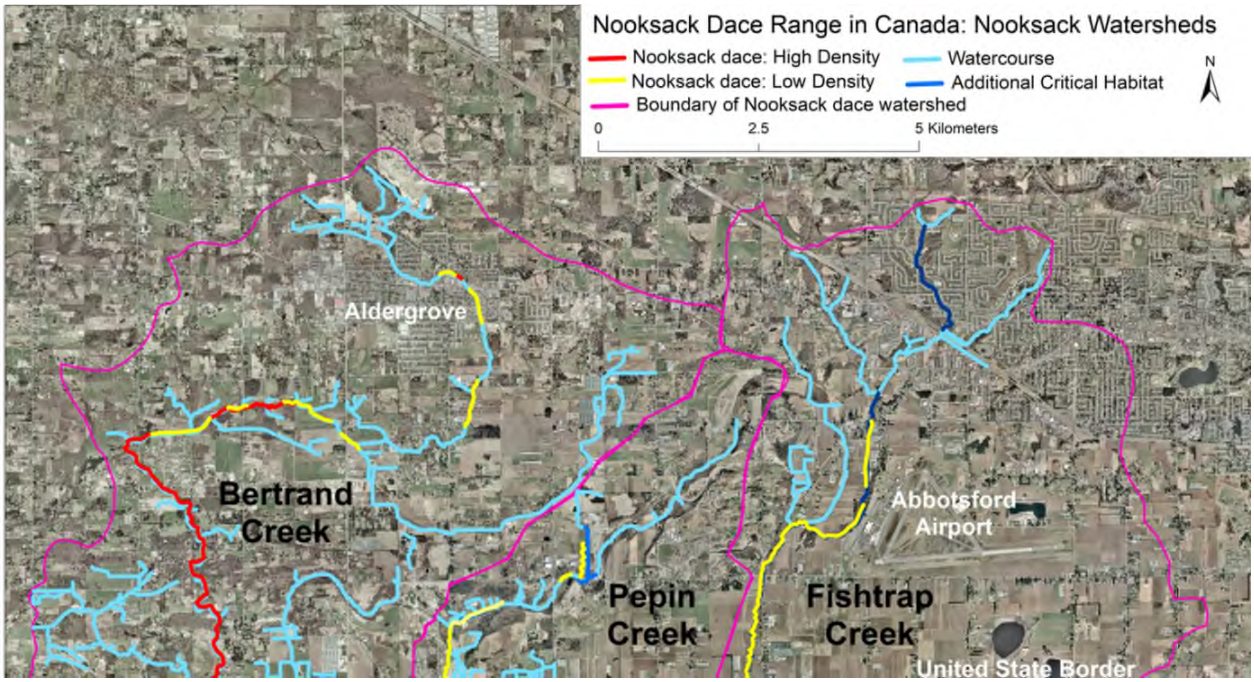

Figure 4. Occupied habitat includes all reaches in occupied watersheds containing a minimum of 10% riffle by length at low flow. Only 3.27 km of the 21.4 km coded stream length consists of riffle and could actually be occupied (adapted from Pearson *et al.* 2008).Catch per unit effort in 'High Density reaches exceeded 1.5 fish per Gee minnow trap, CPUE in 'Low Density' reaches was between 0 and 1.5 fish per Gee minnow trap (Pearson 2004, unpubl. data).

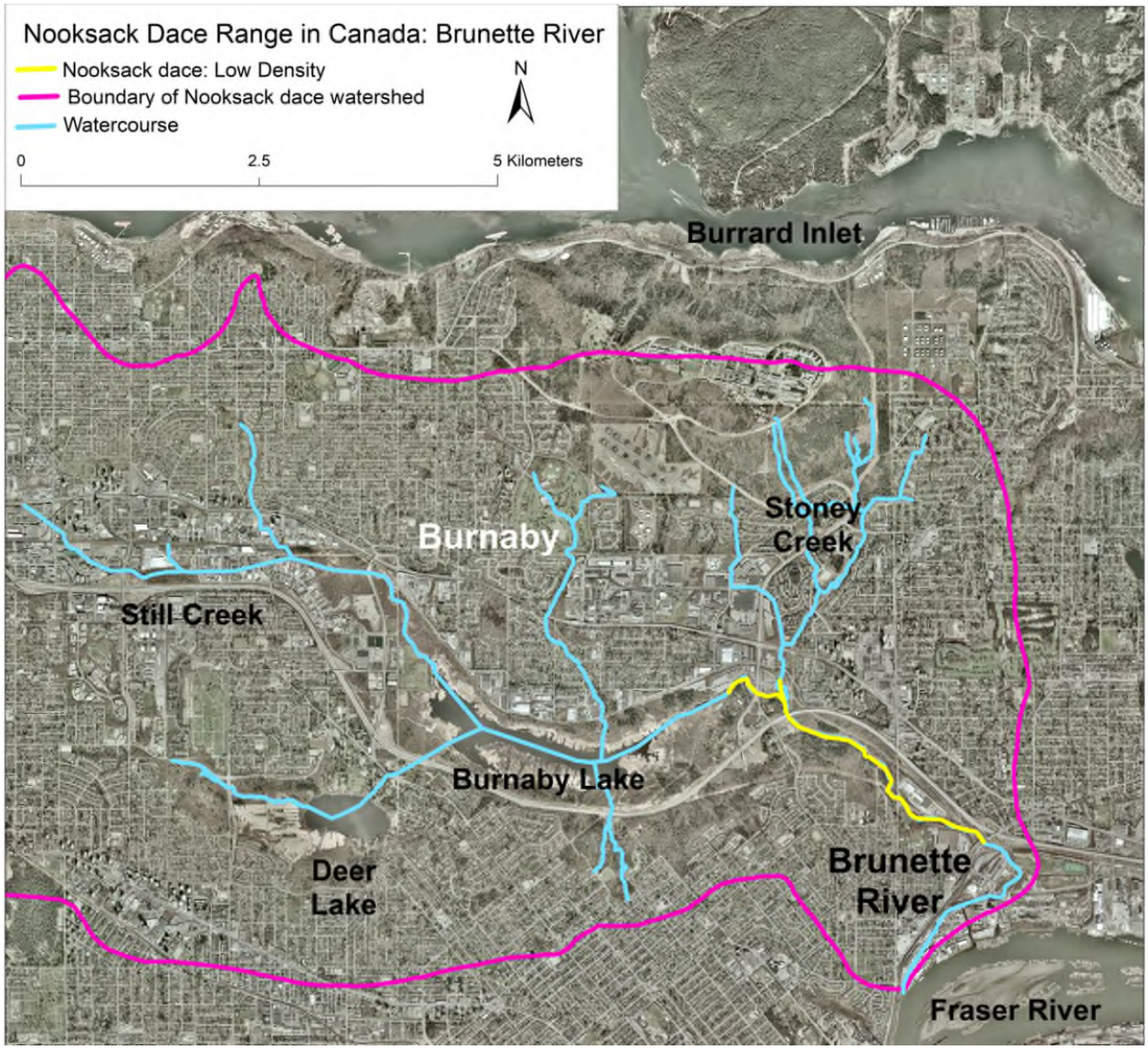

Figure 5. Nooksack Dace is found in low densities in the main stem of the Brunette River from Burnaby Lake downstream to the limit of tidal influence. It appears to be absent in the remainder of the watershed. Catch per unit effort in 'High Density' reaches exceeded 1.5 fish per Gee minnow trap, CPUE in 'Low Density' reaches was between 0 and 1.5 fish per Gee minnow trap (Pearson 2004, unpubl. data).

Only crude estimates of habitat loss are possible, due to lack of baseline data (Table 3). Approximately half of the original riffle habitat from the Nooksack tributaries has been lost, most of it prior to 1996. The main stem of Fishtrap Creek was dredged for flood control by the City of Abbotsford in 1990-1991, eliminating most of its previously abundant riffle habitat (McPhail pers. comm. 2006). The Brunette River main stem was channelized and deepened in the early 1900s from Burnaby Lake to North Road, a distance of 2.5 km (based on Vancouver and Districts Joint Sewerage and Drainage Board maps of 1924 (Metro Vancouver 2017). Losses in the past 10 years appear to have been minimal and primarily due to an increase in beaver-pond inundation of riffles in Pepin Creek (Pearson unpubl. data).

Table 3. Estimated losses of Nooksack Dace habitat in Canada. Habitat was assumed to have comprised 20% of channel length prior to 1996 (conservative estimate). Much of remaining habitat is of poor quality.

	Units	Pepin Creek**	Fishtrap Creek**	Bertrand Creek**	Brunette River*
2004 Area (from Table 2)	(m^2)	2000	2300	3000	20155
Losses to 1996	(m^2)	2500	2530	2500	?
Losses since 1996 (estimated by Pearson)	(m^2)	>1000	?	?	0
Total Loss	%	>78	>52	>46	?

*measured by Pearson (2004)

** Areas calculated as product of mean wetted widths (from Pearson 1998a) and 20% of reach length rounded to nearest 100 m^2.

BIOLOGY

Most information on the biology of the Nooksack form of *R. cataractae* is from graduate theses (Pearson 2004; Bonamis 2011; Avery-Gomm 2013; Champion 2016) and earlier work by McPhail (1997) and, where necessary, is supplemented with information on other forms of *R. cataractae*.

Life Cycle and Reproduction

Nooksack Dace spawns nocturnally over coarse substrate in riffles (McPhail 1997) between April and early July (Pearson, 2004). Both male and female *R. cataractae* in Alouette River establish and defend small breeding territories (approx. 10 cm in diameter), which are clustered at the upstream end of riffles. Females leave their territories at night to court and spawn with territorial males. The male territory contains the nest site, which the male probes repeatedly with the snout. Males do not leave the territory, even to feed, and defend it against other males for at least 24 h after spawning (Bartnik 1972, 1973).

Fertilization occurs externally. Fecundity ranges from about 200 to over 2000 eggs depending upon body size and adults are believed to spawn annually (McPhail 1997). The long spawning period suggests that females may spawn multiple clutches (Roberts and Grossman 2001).

Rhinichthys cataractae eggs hatch in 7-10 days at 15.6° C in Manitoba, but embryos remain in the gravel for an additional week until the yolk sac is absorbed (Scott and Crossman 1973). Young-of-the-year Nooksack Dace emerge from substrate in mid-summer. At first, they feed on zooplankton and chironomid larvae in shallow, marginal pools with sand or mud substrates, but soon begin drift feeding in progressively stronger currents. After approximately 4 months (at about 45 mm body length), they become negatively buoyant. Lifespan is four to six years and first reproduction occurs in the third spring, suggesting that generation time is two years (McPhail 1997).

Hybridization of *R. cataractae* with several co-occurring cyprinids, including Redside Shiner, *Richardonius balteatus*, a species that occurs with Nooksack Dace in the Brunette River, has been documented in other watersheds (Scott and Crossman 1973).

Physiology and Adaptability

Little information exists on tolerances or preferences of Nooksack Dace for water-quality parameters such as dissolved oxygen, pH, and temperature. Activity appears minimal at temperatures below 11° C, and fish forage normally at temperatures in excess of 20° C (Pearson 2004). Nooksack Dace were found in streams with temperatures significantly above the average during an Olympic Peninsula survey (17.6° C, range 14.0 – 22.0; Mongillo and Hallock 1997). Nooksack Dace is likely poorly adapted to hypoxia, as riffle habitats are typically well oxygenated.

In aggregate, Nooksack Dace life-history characteristics (small body size, short generation time, potential for multiple clutches annually) should permit rapid population growth, promoting early recovery from small-scale disturbances, rapid colonization of restored or created habitats within a few hundred metres of existing populations and successful (re)introductions into suitable habitat. Its life-history strategy, however, will provide little resilience in the face of large-scale or chronic disturbances (Winemiller and Rose 1992; Detenbeck *et al.* 1992).

Dispersal and Migration

Nooksack Dace typically has a small home-range size and shows no evidence of long-range dispersal as adults. Pearson (2004) showed that the distribution of Nooksack Dace movements within two, 200 m-long study areas was extremely biased towards short distances relative to the distribution of detectable movements. Over 50% of recaptured, marked adult dace were caught within 5 m, and 92% were found within 50 m of their initial capture positions in the 14-month study. Thirty percent were recaptured in exactly the same site, some after more than a year had lapsed since the previous capture. Fish were as likely to move upstream as downstream, and maximum displacement was 205 m. None of the

recaptured fish moved the 2.2 km between study reaches. Nooksack Dace colonists (n=9) did not penetrate more than 560 m into a newly constructed 960 m tributary diversion within 15 months (Pearson unpubl. data), suggesting that maximum annual range is less than 1 km. The data suggest that a large fraction of the population is sedentary. Hill and Grossman (1987) also reported small home-range size for *R. cataractae* (mean 13.7 m). The relatively long movements (hundreds of metres) of a few individuals, however, suggest that a fraction of the population may travel considerable distances from the home patch, a pattern demonstrated in a number of other stream fishes (Gowan *et al.* 1994; Smithson and Johnston, 1999; Nakamura *et al.* 2002). Juveniles may passively disperse downstream, but this has not been studied.

The clumped distribution within watersheds combined with limited adult dispersal raises the possibility that Nooksack Dace exists as metapopulations within watersheds. However, insufficient data, particularly on juvenile dispersal rates, exists for assessment.

Migration links between Canadian populations are highly unlikely as migrants would need to either traverse a minimum of 10 km of largely unsuitable habitat in Washington State or, in the case of the Brunette River, cross the divide between the Fraser and Nooksack watersheds.

Interspecific Interactions

Adult Nooksack Dace feed primarily on riffle-dwelling insects while young-of-the-year Dace primarily consume ostracods and chironomid pupae (McPhail 1997). Taxa documented from Nooksack Dace stomachs include amphipods (Amphipoda), midges (Chironomidae), mayflies (Ephemeroptera), riffle beetles (Elmidae), net-spinning caddisflies (Hydropsychidae), ostracod crustaceans (Ostracoda), stoneflies (Plecoptera), black flies (Simuliidae), and crane flies (Tipulidae) (Avery-Gomm *et al.* 2014). Competitors are probably limited to juvenile coastal Cutthroat Trout (*Oncorhynchus clarkii clarkii*) and Rainbow Trout (*O. mykiss*), the only other fishes that commonly forage in riffles inhabited by Nooksack Dace (Pearson 2004).

Little data exist regarding parasitism, but most individuals have light infestations of blackspot (*Neascus* spp.), a subcutaneous trematode cyst, which appears to have little effect at low infestation rates (Vinikour 1977).

Predation of adult *R. cataractae* by Mink (*Neovison vison*) (Champion 2016) and Green Heron (*Butorides virescens*) (Helm 2012) is documented. Great Blue Heron (*Ardea herodias fannini*), North American River Otter (*Lontra canadensis*), Coastal Cutthroat Trout, Rainbow Trout, and Prickly Sculpin (*Cottus asper*), co-occur with all known Nooksack Dace populations (Pearson 2004). Northern Pikeminnow (*Ptychocheilus oregonensis)* is a likely predator in the Brunette River, but is not found in Nooksack River tributaries (Pearson unpubl. data). Juveniles are likely taken by these species and by juvenile Coho Salmon (*O. kisutch*). All of the Canadian watersheds occupied by Nooksack Dace are also colonized by one or more introduced predators, including American Bullfrog (*Rana catesbeiana)*, Brown Bullhead (*Ameiurus nebulosus*), Pumpkinseed (*Lepomis gibbosus)*, and Largemouth Bass

(*Micropterus salmoides)* (Pearson 2004). Population-level impacts of these predators are uncertain. The nocturnal foraging habit of Nooksack Dace (McPhail 1997) likely reduces their susceptibility to diurnal predators (Culp 1989).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Estimates of population sizes have been hampered by a lack of sampling methods that are both non-destructive and effective. Pearson (2004) used catch-per-unit-effort (CPUE) in minnow traps to estimate relative abundance in the Nooksack River tributaries in 1999-2000 (minimum 10 sets in each of 74 reaches). He also attempted to quantify the size of the Bertrand Creek population using mark-recapture in two reaches in 2000-2001 (10-13 samples per reach, 32 traps per sample) but recapture rates were too low to permit an estimate. Bonamis (2011) used single-pass electrofishing calibrated with a mark-recapture estimate of capture efficiency to estimate abundance of all four documented populations in 2009.

Abundance

Insufficient data exist to reliably calculate Nooksack Dace population sizes, but an upper limit can be estimated. High-quality habitat in Bertrand Creek supported an average of 1.9 Nooksack Dace/m^2 (n=20, SE=0.35, Inglis *et al.* 1994) and 1.4/m^2 (n=5, S.E. = 0.24; McPhail 1997) in the two available estimates. The riffle area in Bertrand Creek (Fig. 4) measured 3000 m^2 in 1999 (Pearson, 2004). If all riffle areas were populated at 1.9 /m^2, the Bertrand population would be approximately 5700. This should be viewed as an upper limit for the breeding populations because much of the habitat is of lesser quality than where the density estimates were made and the samples would have included some yearling juveniles. Extending the calculations to Pepin Creek and Fishtrap Creek using riffle area yields a total Canadian population of 14000 at three locations (watersheds). However, actual densities in Pepin Creek and Fishtrap Creek are much lower than in Bertrand Creek according to a CPUE-based relative abundance model (Pearson 2004). Applying the relative-abundance ratios to the Pepin and Fishtrap creek figures gives an adjusted upper-limit abundance estimate of approximately 6800 (Table 2). Bonamis' (2011) range-wide estimate of 7150 is similar, but his single-pass electrofishing method may significantly underestimate the size of low-density populations. Pepin Creek was estimated to contain 30 adults (95 % CL 12-136) and, in a complete fish salvage (including dewatering) of approximately 150 m^2 of Pepin Creek, 27 adults were recovered in 2015 (Pearson unpubl. data). Bonamis (2011) did not capture any *R. cataractae* in Fishtrap Creek in 2009, resulting in a population estimate of 0 fish, but 3 individuals were caught in subsequent sampling (Avery-Gomm unpubl. data).

Fluctuations and Trends

No quantitative data exist on fluctuations or trends in abundance for any of the Canadian populations. Density in Bertrand Creek south of 16th Avenue appears to have remained high since the 1960s. McPhail (1997) reported 'healthy' populations in Pepin Creek and Fishtrap Creek in a 1993 survey, but density was low in most reaches of these creeks in 1999-2000 (Pearson 2004) and even lower in 2009 (Bonamis 2011). This corresponds with known losses of riffle habitat over the past 30 years in these creeks (see Habitat Trends above). Continuing decline is also suggested by the apparent extirpation of Nooksack Dace from headwater tributaries of Fishtrap and Bertrand creeks since the 1960s (McPhail 1997). The Fishtrap Creek subpopulation, in particular, appears to be on the brink of extirpation based on near-zero catch rates in sampling in the past decade (Avery-Gomm 2013).

Rescue Effect

The three Nooksack tributary populations all straddle the United States border and individuals undoubtedly move across it regularly. A rescue effect benefiting Canadian populations, however, is highly unlikely due to the very limited amount of suitable habitat in the Washington portion of these creeks (McPhail 1997) downstream of the Canadian habitat. A catastrophic event (e.g., chemical spill) that potentially caused extirpation in the Canadian portion of a creek would also likely eliminate the corresponding American population.

THREATS AND LIMITING FACTORS

Populations in Canada are probably limited by the availability of high-quality riffle, their primary habitat, and most of the identified population threats relate to its loss or degradation (McPhail 1997; Pearson 2004). To identify the nature and magnitude of threats to Nooksack Dace, a threats calculator was completed based on the IUCN-CMP (World Conservation Union-Conservation Measures Partnership) unified threats classification system (IUCN and CMP 2006; Salasky *et al.* 2008). Based on the threats calculator, the overall threat impact was estimated as "High" (Appendix 1). Threats are discussed in decreasing order of severity using the IUCN threats analysis framework.

Natural Systems Modifications

<u>Dams, water management and use (High impact)</u>

Lack of water in late summer is the most serious threat to the largest known population, that of Bertrand Creek. Riffle area is reduced by 80-100% in the best habitats during the most productive time of year (Pearson unpubl. data). Aquifer draw-down by local wells is estimated to have reduced baseflow by 24% since 1960 (Golder and Associates 2004) and significant pumping from the creek occurs for irrigation, but has not been quantified (Pearson pers. obs.). Nooksack Dace abundance at three Bertrand Creek sites

sampled in 2010 was reduced by 48% as discharge declined from 0.113 m^3/s to 0.007 m^3/s between May and August (Avery-Gomm 2013). Increased predation facilitated by low flows in riffles and fish being forced into pools was considered the most likely cause. Avery-Gomm (2013) estimated a minimum flow threshold for Bertrand Creek of 0.12 m^3/s, which is less than 10% of mean annual discharge, but more than 17 times higher than the observed lowest flow in 2010. Portions of the Brunette River and upper Fishtrap Creek also have inadequate summer flows due to the high proportion of their watersheds that are impermeable (41% for Brunette River, Lavkulich *et al.*, 1999).

Storm-water discharge, particularly in urban settings, alters stream hydrographs, resulting in higher peak flows and reduced low flows. Even relatively low levels of urbanization (7% watershed area) often excludes sensitive benthic fishes like *R. cataractae* (Snyder *et al.* 2003; Roy *et al.* 2006).

The Cariboo Dam on the Brunette River spills primarily bottom water from Burnaby Lake to the Brunette River. In summer, this water is hypoxic and depresses oxygen levels as far downstream as Highway 1 (950 m) under late summer low-flow conditions (Pearson unpubl. data).

As the 'high spots' in a stream, riffle habitats tend to be targeted for removal or alteration in drainage projects, which are common in the urban and agricultural landscapes that dominate these watersheds. Both authorized and illegal alterations occur annually in these watersheds (McPhail 1997; Pearson pers. obs.). These alterations often result in sediment release into the channel. Sediment accumulation in riffles clogs the spaces between and under coarse riffle substrate where Nooksack Dace spawn, forage, and rest. Substrate embeddedness increases the vulnerability of Nooksack Dace to predation and decreases density and availability of macroinvertebrate prey species (Champion 2016).

Other ecosystem modifications (High impact)

Reed Canary Grass (*Phalaris arundinacea*) and other invasive species proliferate where nutrient loads are high, clogging the channel and narrowing it by forming sod. This reduces riffle area and increases velocity, reducing both habitat area and quality.

Clearing of riparian trees and shrubs commonly occurs on private lands, resulting in loss of riparian functions including channel shading, bank stabilization, large woody debris supply, and interception of runoff.

Pollution

Urban wastewater (High-Medium impact), Industrial effluents (High-Medium impact) Agricultural effluents (High impact)

The United States Environmental Protection Agency lists *Rhinichthys cataractae* as 'intolerant" of pollution (EPA 2012). Untreated stormwater commonly produces levels of copper, lead, zinc, and manganese that exceed federal guidelines for aquatic life in both

water and sediments of the Brunette River (Hall *et al.* 1998). Similar conditions presumably occur in the urbanized headwaters of Fishtrap Creek and Bertrand Creek. *R. cataractae* populations had female-skewed sex ratios and elevated levels of estrogen-like compounds at multiple sites downstream of sewage treatment plants and intensive agricultural operations in the Oldman River, Alberta (Jeffries *et al.* 2008). They actively avoided an urban stormwater channel in Ontario (Crawford *et al.* 2016). Pesticide impacts may affect fishes through direct toxicity, bioaccumulation, and reduced availability of macroinvertebrate prey (Kattwinkel *et al.* 2015). Non-migratory benthic invertebrates would be particularly vulnerable to this form of pollution. Pesticide use is widespread in the Nooksack tributary watersheds, particularly on the extensive berry fields of lower Fishtrap and Bertrand creeks.

Severe nutrient pollution from agricultural sources is well documented in Bertrand, Pepin and Fishtrap creeks, primarily by Washington state agencies concerned about declining fish populations and shellfish bed closures in the Nooksack River estuary. In many eutrophic reaches, oxygen levels remain low for long periods of time, particularly during summer drought conditions. Levels below 2 mg/l have been documented in 30-45 % of the length of the main stem channels of these streams (Pearson 2015). Riffles tend to have higher oxygen levels than other stream habitats during episodes of hypoxia (due to water turbulence), but little data exist and critical levels for the species are unknown.

A large number of road, rail and farm crossings occur within or upstream of occupied habitats. While the risk of a spill at any particular crossing is low, some significant spills will inevitably impact Nooksack Dace habitats over the long term. Some are also at risk of spills resulting from train derailment on the CN line. A train derailment in 2013 resulted in coal-dust deposition over Nooksack Dace habitat throughout the Brunette River mainstem. The existing Kinder-Morgan Trans Mountain pipeline and the proposed corridor for a second pipeline crosses directly upstream of occupied habitat in the Brunette River (Trans Mountain 2015). Seasonal channels and ditches add many more points from which spills could enter Nooksack Dace habitat.

The Brunette River was impacted by a large sediment deposition event in November 2015 caused by slope failure at a construction site. At least two large-scale releases from gravel pits (ca. 1997) have infilled habitat in Pepin Creek. Mining continues in this watershed and expanded into the Fishtrap Creek watershed after 2012. Sand deposits from these events and from a debris flow in 2008 have been slowly moving through Pepin Creek for years.

Climate Change

Droughts (High impact), Temperature extremes (Low impact)

Climate trends in southwestern British Columbia are predicted to include more frequent and severe summer droughts and heat waves (Metro Vancouver 2016). This can only exacerbate the impacts of low flows on Nooksack Dace discussed above (Water Management and Use). Nooksack Dace is relatively tolerant of warm water, but the low-flow conditions and lack of shade due to riparian clearing may elevate temperatures above tolerance limits in some reaches.

Invasive and Other Problematic Species and Genes

Invasive non-native/Alien species/Diseases (High-Medium impact), Problematic native species/Diseases (Low impact)

All occupied watersheds contain introduced predators (see Interspecific Interactions, above). In some watersheds, Brown Bullhead, Largemouth Bass (DFO 2011), and Pumpkinseed have coexisted with Nooksack Dace for at least 20 years (Pearson 2000), but their impacts are unknown. These predators thrive in warm-water littoral zones (Scott and Crossman 1973; Corkran and Thoms 1996) and are rarely found in riffles. Predation rates on young-of-the-year Nooksack Dace may be high and lack of flow sometimes forces Nooksack Dace out of riffles and into pools, where they appear to be highly susceptible to increased predation (Avery-Gomm *et al.* 2014).

Riffle lost to flooding by beaver ponds is a significant threat to Nooksack Dace in Pepin Creek, where riffle area is limited. An estimated 600 m^2 of riffle (10% of total available habitat for population) was inundated due to beaver damming between 1999 and 2001 (Pearson 2004) and additional losses have accumulated since (Pearson pers. obs.). Beaver activity poses no threat to Nooksack Dace in other watersheds within the Canadian range.

Agriculture

Livestock farming (Low impact)

Agricultural impacts may include riparian clearing, livestock trampling of habitat, drainage works that modify habitat, and sedimentation due to erosion. Nutrient and chemical pollution are discussed above (Pollution). The prevalence of livestock access to Nooksack Dace streams has decreased considerably over the past 20 years, primarily due to the efforts of a few determined non-profit stewardship organizations. Cattle still trample riffles occupied by Nooksack Dace at several farms on Bertrand Creek and Fishtrap Creek. Most riparian clearing was done decades ago in these watersheds. Approximately 30-60% of mainstem bank length in the four occupied watershed had less than 5 m buffers of woody riparian vegetation in 2004 (Pearson 2008).

Transportation and Service Corridors

Roads and railroads (Negligible impact)

Habitat fragmentation caused by transportation corridors likely has some long-term impacts to Nooksack Dace populations, but the magnitude is difficult to assess. Access to several kilometres of apparently suitable habitat in Stoney Creek for Nooksack Dace is precluded by a perched CN Rail culvert. A concrete bridge foundation blocks upstream access at 248th Street on Bertrand Creek at most flow levels. Most barriers in Nooksack Dace watersheds date from 50-130 years ago and surviving populations have shown some resilience. The effects of less movement between populations/metapopulations and reduced ability to colonize new habitat, however, may occur over longer time frames (Pearson 2004).

Limiting Factors

The primary limiting factors for Nooksack Dace in Canada are likely the availability of riffle habitat in occupied streams and the presence of the Columbia-form of *R. cataractae* in many of the other watersheds in the lower Fraser Valley. The majority of the length of Pepin, Fishtrap and Bertrand creeks consists of pool habitats (Pearson 2004), primarily due to naturally low channel gradient. A great deal of riffle has been lost due to human activity but, even prior to this, riffle area would likely have limited populations within these streams. The presence of admixed Columbia-Nooksack *R. cataractae* populations in some watersheds (Ruskey and Taylor 2015) suggest that hybridization would prevent successful establishment of pure Nooksack Dace populations in most other suitable streams within the Fraser Valley.

Number of Locations

Each of the four watersheds known to be occupied represents a single location. The leading threats, natural systems modifications (water management and use), pollution, and climate change (drought and increased water temperature), are likely to affect the entire populations of the Brunette and Bertrand watersheds and Fishtrap Creek upstream of Abbotsford airport. The severity of impact in each watershed will depend, in part on water-use patterns and policies. The entire Fishtrap Creek population would be impacted from a spill in an industrial or urban area in the headwaters or from an accident on Highway 1. In Pepin Creek, the entire population may be impacted by loss of riffles to beaver ponding.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

As a federally listed species at risk under SARA (Endangered, 2003) the Nooksack Dace is protected from harm or capture in all Canadian waters. Critical habitat (33.1 km of channel) is identified in the SARA Recovery Strategy (Pearson *et al.* 2008) and protected

by order of the Governor in Council. Nooksack Dace habitat is also provided some protection by the federal *Fisheries Act* and the *BC Water Sustainability Act*. The Nooksack Dace is not protected in Washington State or by the American *Endangered Species Act*.

Non-Legal Status and Ranks

The non-legal status and conservation ranks of Nooksack Dace in North America are provided in Table 5.

Habitat Protection and Ownership

Stream beds and water are owned by the province. There is no known Nooksack Dace riparian habitat on federal or provincial lands, but approximately 2 km of occupied habitat in the Nooksack River tributaries (Table 4) and at least 2.8 km of occupied habitat in the Brunette River (Pearson unpubl. data) occur on regional or municipal parkland. This amounts to somewhat more than 10% of suitable habitat.

Virtually all aquatic habitat outside these parks is on private, urban, or agricultural lands. Here, stewardship agreements of various sorts are possible, but landowner receptivity will depend strongly on the availability of tax incentives and on compensation under SARA for actively farmed lands.

Table 4. Public lands bordering or upstream of occupied or suitable Nooksack Dace habitat in Canada.

Watershed	Ownership	Description	Channel Length Present/ Suitable/Occupied	Status/Comments
Pepin Creek	Greater Vancouver Regional District	Aldergrove Regional Park	4825 m Pepin Brook and tributaries 1660 m occupied	Regional parkland.
Bertrand Creek	Township of Langley	Otter Park	225 m Bertrand Creek 225 m occupied	Municipal parkland Extremely vulnerable to drying.
	Federal Government Dept. Nat. Defence	Naval Station Aldergrove	2850 m Bertrand Creek 0 suitable	Military lands. Extreme headwaters
	Township of Langley	Vanetti Park	175 m Bertrand Creek 0 suitable	Municipal parkland Upstream of suitable habitat.
	Township of Langley	Creekside Park	185 m Bertrand Creek 0 suitable	Municipal parkland
Fishtrap Creek	City of Abbotsford	Gardner Park	260 m Enn's Brook 120 m suitable	Municipal parkland
	City of Abbotsford	East Fishtrap Creek Park	1500 m East Fishtrap Creek 0 suitable	Municipal parkland Upstream of suitable habitat.
Brunette River	Greater Vancouver Regional District	Burnaby Lake Regional Park	9000 m of main stem and tributaries 2450 occupied	Regional parkland
	City of New Westminster	Hume Park	415 m Brunette River 415 m occupied	Municipal parkland

Table 5. Non-legal status and conservation ranks of Nooksack Dace in North America.

Authority	Status
NatureServe Ranks[1]	
Global	G3
National Canada	N1
US	N3
Regional	
Canada, BC	S1
US - WA	S3
Province: BC	Red
COSEWIC (2007)	Endangered 1996, 2000, 2007
American Fisheries Society	Endangered

*(NatureServe 2017)

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Authorities Contacted

Dr. Rhonda Millikin
Species at Risk Biologist
Pacific Wildlife Research Centre
Canadian Wildlife Service
Environment Canada
Delta, British Columbia

Dr. Simon Nadeau
Jennifer Shaw
Martin Nantel
Fisheries and Oceans Canada
Ottawa, Ontario

Neil Jones
Aboriginal Traditional Knowledge
COSEWIC Secretariat
Canadian Wildlife Service
Environment Canada
Gatineau, Quebec

Dr. Shelley Pruss
Parks Canada
Fort Saskatchewan, Alberta

Rachel McDonald
Department of National Defence
Ottawa, Ontario

Dr. J.D. McPhail
Professor Emeritus
Department of Zoology
University of British Columbia
Vancouver, British Columbia

Dr. Jordan Rosenfeld
Fisheries Research
BC Ministry of Environment
Vancouver, British Columbia

Katrina Stipec
Data Request Specialist
BC Conservation Data Centre
Victoria, British Columbia

Noel Alfonso
Research and Collections
Canadian Museum of Nature
Ottawa, Ontario

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BIOGRAPHICAL SUMMARY OF REPORT WRITER

Mike Pearson holds an M.Sc. in Zoology from the University of Guelph (1990) and a Ph.D. in Resource Management and Environmental Science from UBC (2004). His doctoral research focused on the ecology, status and recovery prospects of Nooksack Dace and Salish Sucker, another COSEWIC-listed species. His consulting firm, Pearson Ecological, specializes in species at risk and aquatic habitat restoration and monitoring in the Fraser Valley. He continues to lead monitoring efforts and participate in research and recovery efforts concerning Nooksack Dace.

COLLECTIONS EXAMINED

University of British Columbia Fish Museum
Vancouver, BC

Royal British Columbia Museum
Victoria, BC

University of Washington Fish Collection
Seattle, WA
http://uwfishcollection.org

Canadian Museum of Nature
Ottawa, Ontario.

Appendix 1. Threats calculator for Nooksack Dace.

Species or Ecosystem Scientific Name	*Rhinichthys cataractae* Nooksack Dace
Date:	23/01/2018
Assessor(s):	Mike Pearson, Dwayne Lepitzki (moderator), Nick Mandrak SSC Co-Chair), Mark Ridgway, Tim Haxton, Jennifer Shaw, Andrew Baylis
References:	Pearson 2004, COSEWIC 2007, SARA Recovery Strategy, Pearson pers. obs.; COSEWIC draft updated report

Overall Threat Impact Calculation:

	Threat Impact	Level 1 Threat Impact Counts: high range	low range
A	Very High	0	0
B	High	4	3
C	Medium	0	1
D	Low	3	3
Calculated Overall Threat Impact:		Very High	Very High

Assigned Overall Threat Impact:	**B = High**
Impact Adjustment Reasons:	10-70% decline in population more plausible as most threats overlap geographically.
Overall Threat Comments	Chilliwack Lake tributaries have pure Nooksack Dace (E. Taylor pers. comm., Jan 19/17). Generation time 3 years therefore timeframe for severity and timing is 10 years. Three tribs of Nooksack River + Brunette RIver, all Lower Fraser Valley; Tech Summary: ~69% Bertand Creek, 27% Brunette River (Burnaby), 3% Pepin Creek, < 1% Fishtrap Creek, on its way to extirpation. ~ 1/2 original riffle habitat in Nooksack tribs lost, most prior to 1996 (l. 378-379) [past threat]. N.B. Since the Threats Calculator call, fish in the Chilliwack Lake tributaries have been confirmed to be hybrids (Taylor pers. comm. 2018) and subsequently, excluded from the assessment. The Threats Calculator has been adjusted accordingly.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
1	Residential and commercial development						
1.1	Housing and urban areas						Not applicable
1.2	Commercial and industrial areas						Not applicable
1.3	Tourism and recreation areas						Not appicable
2	Agriculture and aquaculture	D	Low	Small (1-10%)	Moderate - Slight (1-30%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2.1	Annual and perennial non-timber crops						Not applicable
2.2	Wood and pulp plantations						Not applicable
2.3	Livestock farming and ranching	D	Low	Small (1-10%)	Moderate - Slight (1-30%)	High (Continuing)	Trampling of riffles by livestock.
2.4	Marine and freshwater aquaculture						Not applicable
3	Energy production and mining	D	Low	Small (1-10%)	Slight (1-10%)	High - Moderate	
3.1	Oil and gas drilling						Not applicable
3.2	Mining and quarrying	D	Low	Small (1-10%)	Slight (1-10%)	High - Moderate	Illegal gravel mining in Bertrand. Impacts eggs, fry, juveniles.
3.3	Renewable energy						Not applicable
4	Transportation and service corridors		Negligible	Negligible (<1%)	Negligible (<1%)	High - Moderate	
4.1	Roads and railroads						Perched culverts = past threats.
4.2	Utility and service lines		Negligible	Negligible (<1%)	Negligible (<1%)	High - Moderate	Kinder-Morgan pipeline may cross Stony Creek above dace habitat. Impact likely to be mitigated.
4.3	Shipping lanes						Not applicable
4.4	Flight paths						Not applicable
5	Biological resource use		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	
5.1	Hunting and collecting terrestrial animals						Not applicable
5.2	Gathering terrestrial plants						Not applicable
5.3	Logging and wood harvesting						Not applicable.
5.4	Fishing and harvesting aquatic resources		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Some scientific monitoring and research sampling with low mortality and limited lethal sampling.
6	Human intrusions and disturbance	D	Low	Small (1-10%)	Moderate - Slight (1-30%)	High (Continuing)	
6.1	Recreational activities	D	Low	Small (1-10%)	Moderate - Slight (1-30%)	High (Continuing)	Dogs and people entering riffles, primarily in Brunette R.
6.2	War, civil unrest and military exercises						No documented occurrences on military land.
6.3	Work and other activities		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Monitoring and research activities for other aquatic species.
7	Natural system modifications	B	High	Large (31-70%)	Extreme - Serious (31-100%)	High (Continuing)	
7.1	Fire and fire suppression						Not applicable

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
7.2	Dams and water management/use	B	High	Large (31-70%)	Extreme - Serious (31-100%)	High (Continuing)	Water use: agricultural, municipal, industrial, domestic. Stream dredging, channelization and infilling on private property and by municipalities; Sediment releases due to riparian clearing. Highest in Bertrand Ck.
7.3	Other ecosystem modifications	B	High	Large (31-70%)	Serious (31-70%)	High (Continuing)	Canary Reed Grass (*Phalaris arundinacea*) reduces aquatic habitat, changes flow. Pesticides reduce prey availability.
8	Invasive and other problematic species and genes	BC	High - Medium	Large (31-70%)	Serious - Moderate (11-70%)	High (Continuing)	
8.1	Invasive non-native/alien species/diseases	BC	High - Medium	Large (31-70%)	Serious - Moderate (11-70%)	High (Continuing)	Risk of introduced predatory species. Likely on the lower end of severity.
8.2	Problematic native species/diseases	D	Low	Small (1-10%)	Extreme - Serious (31-100%)	High (Continuing)	Riffle loss to beaver ponding (Pepin Ck). Hybridization with other native species.
8.3	Introduced genetic material						Not applicable
8.4	Problematic species/diseases of unknown origin						Not applicable
8.5	Viral/prion-induced diseases						Not applicable
8.6	Diseases of unknown cause						Not applicable
9	Pollution	B	High	Large (31-70%)	Serious (31-70%)	High (Continuing)	
9.1	Domestic and urban waste water	BC	High - Medium	Large (31-70%)	Serious - Moderate (11-70%)	High (Continuing)	Urban storm runoff (nutrients, salt).
9.2	Industrial and military effluents	BC	High - Medium	Large (31-70%)	Extreme - Moderate (11-100%)	High - Moderate	Accidental industrial spills.
9.3	Agricultural and forestry effluents	B	High	Large (31-70%)	Serious (31-70%)	High (Continuing)	Agricultural manure and chemicals (including air-borne). Forestry effluents.
9.4	Garbage and solid waste		Negligible	Large (31-70%)	Negligible (<1%)	High (Continuing)	
9.5	Air-borne pollutants		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	Not applicable
9.6	Excess energy		Unknown	Restricted (11-30%)	Unknown	High (Continuing)	Light pollution (species is nocturnal).
10	Geological events		Negligible	Small (1-10%)	Negligible (<1%)	Moderate - Low	
10.1	Volcanoes						Not applicable
10.2	Earthquakes/tsunamis		Negligible	Small (1-10%)	Negligible (<1%)	Low (Possibly in the long term, >10 yrs/3 gen)	Not applicable
10.3	Avalanches/landslides						Not applicable

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11	Climate change and severe weather	B	High	Large (31-70%)	Serious (31-70%)	High (Continuing)	
11.1	Habitat shifting and alteration						Not applicable
11.2	Droughts	B	High	Large (31-70%)	Serious (31-70%)	High (Continuing)	
11.3	Temperature extremes	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	Not Bertrand.
11.4	Storms and flooding		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	
11.5	Other impacts						Not applicable.

Classification of Threats adopted from IUCN-CMP, Salafsky *et al.* (2008).