COSEWIC
Assessment and Status Report

on the

Johnson's Hairstreak
Callophrys johnsoni

in Canada

SPECIAL CONCERN
2022

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:

COSEWIC. 2022. COSEWIC assessment and status report on the Johnson's Hairstreak *Callophrys johnsoni* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xi + 61 pp. ( ).

Production note:
COSEWIC would like to acknowledge Brenda Costanzo, Jennifer Heron and Dawn Marks for writing the status report on Johnson's Hairstreak, *Callophrys johnsoni*, in Canada, prepared under contract with Environment and Climate Change Canada. This report was overseen and edited by David McCorquodale, Co-chair of the COSEWIC Arthropods Specialist Subcommittee.

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:

Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur le Porte-queue de Johnson (*Callophrys johnsoni*) au Canada.

Cover illustration/photo:
Johnson's Hairstreak — Johnson's Hairstreak. Photograph by Michelle Connolly.

Catalogue No. CW69-14/819-2022E-PDF
ISBN 978-0-660-44380-5

COSEWIC
Assessment Summary

Assessment Summary – May 2022

Common name
Johnson's Hairstreak

Scientific name
Callophrys johnsoni

Status
Special Concern

Reason for designation
This butterfly is found in Canada only in southern British Columbia from Vancouver Island east to Hope. It lives in coastal old growth and late successional second growth coniferous forests with a large component of Western Hemlock. Caterpillars feed only on flowers of Hemlock Dwarf Mistletoe, a hemiparasite of Western Hemlock. Hemlock Dwarf Mistletoe reduces economic value of trees and therefore forest management practices that remove Western Hemlock to reduce mistletoe in older forests are an ongoing threat. This species could become Threatened if threats influencing its persistence are not managed.

Occurrence
British Columbia

Status history
Designated Special Concern in May 2022.

COSEWIC
Executive Summary

Johnson's Hairstreak
Callophrys johnsoni

Wildlife Species Description and Significance

Johnson's Hairstreak is a small (2.5-3.0 cm wingspan) chocolate-brown butterfly with white-tipped tails on the hindwings. Sexes differ slightly; females tend to be larger and paler brown than males.

Johnson's Hairstreak is one of a group of butterflies that reach their northern distribution limit in western Canada. Caterpillars feed on Hemlock Dwarf Mistletoe that grows in Western Hemlock dominated forests. The mistletoe is considered a pest by the forest industry.

Distribution

In Canada, the species has a small range in southwestern British Columbia (BC), extreme southeastern mainland to Hope. There are ten extant and 5 historical subpopulations; however, there are likely additional subpopulations. The global range extends to coastal California, and east to Idaho. Less than 5% of the global range is in Canada.

Habitat

In BC, Johnson's Hairstreak inhabits coastal old growth and late successional second growth (> 81 years) coniferous forests with a large (> 40%) component of Western Hemlock. Most records are under 625 m above sea level (asl); however, there is one subpopulation on Vancouver Island at 880-980 m asl.

Larvae feed on Hemlock Dwarf Mistletoe, a hemiparasitic plant dependent on Western Hemlock. As a forest stand ages, mistletoe abundance increases both on individual trees, and throughout the stand. Mistletoe forms dense brooms on different branches, produces seeds, and spreads throughout a tree. The caterpillar requires blooming shoots of Hemlock Dwarf Mistletoe upon which to feed. In BC, an estimated 15% of Western Hemlock stands host Hemlock Dwarf Mistletoe, concentrated in a north-south band about 150 km wide along the coast.

Adults spend time in the canopy and descend to open meadow where they feed on nectar from various flowers.

Biology

Johnson's Hairstreak develops through complete metamorphosis (egg, caterpillar, pupa, adult). Adults fly and mate from late May through late June in BC. The eggs are laid singly on sprouting and blooming shoots of Hemlock Dwarf Mistletoe, presumably in the upper canopy. Eggs hatch within a few weeks and larvae grow through four instars, feeding on all parts of Hemlock Dwarf Mistletoe. Johnson's Hairstreak overwinters as a pupa sheltered in a mistletoe broom. There is one generation per year in BC.

Population Sizes and Trends

Johnson's Hairstreak surveys have focused on recording new subpopulations, natural history, and habitat information, resulting in observations from 1900 to 2021. The primary survey method has been wandering transects during the adult flight period, through potential areas where flowering plants are abundant, the surveyor targeting floral patches to observe resting and feeding butterflies. No information on the Canadian population size or trends are available. A decline in the overall Canadian population is inferred and projected based on the documented historical loss of older growth forest, projected future loss of Johnson's Hairstreak habitat based on current logging practices, and long-term forest management practices that minimize mistletoe abundance to protect timber quality.

Threats and Limiting Factors

The highest impact threat to Johnson's Hairstreak and potential habitat is the removal of older growth and late successional second growth (> 81 years) forests throughout the Coastal Western Hemlock Biogeoclimatic Zone in southwestern BC. At present, approximately 1945 km^2 of old growth and late successional second growth (> 81 years) habitat remains within the potential range of Johnson's Hairstreak.

Logging and forest management recommendations that limit the spread of Hemlock Dwarf Mistletoe are effectively reducing the potential future habitat for Johnson's Hairstreak and can be used to infer and project a decline in future Johnson's Hairstreak habitat. Forest management that results in reduced mistletoe include general or targeted removal of mistletoe-infected trees (e.g., clearcut harvesting, partial harvesting with selective removal of infected trees) and historical silvicultural practices that have resulted in stand conditions that are not conducive to mistletoe growth/establishment (e.g., clearcutting followed by even-aged planting).

Protection, Status and Ranks

Johnson's Hairstreak has some protection under the provincial *Forest and Range Practices Act,* and *Protected Areas Act*. It is listed as Identified Wildlife and managed through provisions outlined in the Identified Wildlife Management Strategy. Johnson's Hairstreak is not protected under the provincial *Wildlife Act* and there are no confirmed records in provincial parks or protected areas. The species is recorded from Stanley Park

(a federal property owned by Parks Canada Agency and managed by the City of Vancouver) and Pacific Spirit Park (Metro Vancouver regional government).

Globally, Johnson's Hairstreak is ranked apparently Vulnerable (G3), nationally it is Critically Imperilled/Imperilled (N1N2) and provincially it is S1 (Critically Imperilled). The host plant is not at risk. Most extant subpopulations of Johnson's Hairstreak span multiple landowners including provincial crown forestland, municipal and regional parks, and private land.

TECHNICAL SUMMARY

Callophrys johnsoni

Johnson's Hairstreak

Porte-queue de Johnson

Range of occurrence in Canada: British Columbia

Demographic Information

Generation time	1 year
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Inferred continuing decline in habitat quality and quantity due to logging of old growth and late successional second growth, and management of second growth that limits mistletoe development and therefore numbers of butterflies.
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; b.) understood; c.) ceased?	a.) No b.) Yes c.) No
Are there extreme fluctuations in number of mature individuals?	No

Extant and Occupancy Information

Estimated extent of occurrence (EOO)	17,385 km² (extant and historical records)
Index of area of occupancy (IAO)	48 km² (extant subpopulations) 68 km² (extant and historical subpopulations)
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. Yes
Number of "locations"*	<20, but >10, based on logging

* See Definitions and Abbreviations on COSEWIC website and IUCN for more information on this term.

Is there an [observed, inferred, or projected] decline in extent of occurrence?	Yes. Inferred and projected for areas with forest management that minimizes the growth of host plant (mistletoe), including peripheral occurrences.
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Yes. Inferred and projected for areas with forest management that minimizes the growth of host plant.
Is there an [observed, inferred, or projected] decline in number of subpopulations?	Yes. Inferred and projected for areas with forest management that minimizes the growth of host plant.
Is there an [observed, inferred, or projected] decline in number of locations*?	Yes. Inferred and projected for areas with forest management that minimizes the growth of host plant.
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes. Inferred and projected for areas with forest management that minimizes the growth of host plant.
Are there extreme fluctuations in number of subpopulations?	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 (in each subpopulation)

Subpopulations (give plausible ranges)	**N Mature Individuals**
Few specimens collected and observed, insufficient information to calculate mature individuals	Unknown
Total	Unknown

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations, or 10% within 100 years]?	Not applicable, insufficient data.

* See Definitions and Abbreviations on COSEWIC website and IUCN for more information on this term.

Threats (direct, from highest impact to least, as per IUCN Threats categories)

Was a threats calculator completed for this species?
Yes, threat impact High. Completed May 25, 2021:

5.3 Logging and wood harvesting – High impact
1.1 Housing and Urban Areas – Low impact
1.2 Commercial and Industrial areas – Low impact
9.3 Agricultural & forestry effluents – Low impact

7.1 Fire & fire suppression – Unknown impact
8.1 Invasive non-native/alien species/diseases – Unknown impact
11.2 Droughts – Unknown impact
11.3 Temperature extremes – Unknown impact

What additional limiting factors are relevant?

- Caterpillar host plant specificity and quality of host plant (i.e., exposed blooming shoots).
- Morphological attributes (e.g., length of tongue limits nectar availability).
- Small population size and genetic isolation.
- Vulnerability to weather patterns.
- Limited dispersal ability.

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Washington S2S3 (Imperilled/Vulnerable); closest population to BC is 60 km
Is immigration known or possible?	Not known, unlikely; generally short dispersal distances.
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Yes, in small, isolated patches
Are conditions deteriorating in Canada?[+]	Yes, see **Threats**.
Are conditions for the source (i.e., outside) population deteriorating?	Yes, see **Rescue Effect**.
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

COSEWIC: Designated Special Concern in May 2022.

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

Status and Reasons for Designation:

Status: Special Concern	**Alpha-numeric:** Not Applicable
Reasons for designation: This butterfly is found in Canada only in southern British Columbia from Vancouver Island east to Hope. It lives in coastal old growth and late successional second growth coniferous forests with a large component of Western Hemlock. Caterpillars feed only on flowers of Hemlock Dwarf Mistletoe, a hemiparasite of Western Hemlock. Hemlock Dwarf Mistletoe reduces economic value of trees and therefore forest management practices that remove Western Hemlock to reduce mistletoe in older forests are an ongoing threat. This species could become Threatened if threats influencing its persistence are not managed.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable, insufficient data
Criterion B (Small Distribution Range and Decline or Fluctuation): EOO and IAO lower than thresholds for Threatened, and ongoing decline in habitat based on threats, but does not meet other criteria needed for Threatened as locations are at a minimum 10 but suspected to be greater, and the populations are not thought to be severely fragmented and do not undergo extreme fluctuations.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable, unknown population size
Criterion D (Very Small or Restricted Population): Does not meet criteria
Criterion E (Quantitative Analysis): Insufficient data to conduct quantitative analysis.

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 (2022)

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.

COSEWIC Status Report

on the

Johnson's Hairstreak
Callophrys johnsoni

in Canada

2022

TABLE OF CONTENTS

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Phylum	Arthropoda – arthropods
Class	Insecta - insects
Order	Lepidoptera – butterflies and moths
Superfamily	Papilionoidea – butterflies and skippers
Family	Lycaenidae – blues, coppers, hairstreaks, harvesters
Subfamily	Theclinae – hairstreaks
Tribe	Eumaeini
Genus	*Callophrys*
Species	*Callophrys johnsoni* (Skinner 1904)
Synonyms:	*Thecla johnsoni* Skinner 1904
	Mitoura johnsoni (see Ferris 1989)
	Loranthomitoura johnsoni (see Ballmer and Pratt 1992; Guppy and Shepard 2001)

Type locality: 'British Columbia' (Skinner 1904; Pelham 2008), lectotype (#7044) in Academy of Natural Sciences Philadelphia (Pelham 2008).

English common names: Johnson's Hairstreak (NatureServe 2021)
Mistletoe Hairstreak (Pyle 2002)
Brown Mistletoe Hairstreak (Pyle 2002)

French common name: Porte-queue de Johnson (iNaturalist 2022)

Taxonomic background and similarities: Callophrys johnsoni is the accepted name and there are no subspecies (Pelham 2008; Pohl *et al*. 2018). The species was first described as *Thecla johnsoni* (Skinner 1904) and moved to *Mitoura* by Ferris (1989). Ballmer and Pratt (1992) used first instar caterpillar morphology to separate *Loranthomitoura* from *Callophrys* and *Mitoura* and named it based on the mistletoe host plants. Current authorities (e.g., Scott 1986; Layberry *et al.* 1998; Pelham 2008; Pohl *et al*. 2018) combine the three genera into *Callophrys*, based on morphological similarities.

Johnson's Hairstreak is closely related to Thicket Hairstreak (*C. spinetorum*) (Layberry *et al*. 1998; Pyle 2002; Pelham 2008). In Canada the geographic ranges for these two species do not overlap (British Columbia Conservation Data Centre (BC CDC) 2021) (see **Morphological Description**). In Oregon and California, there is evidence of limited hybridization between Thicket Hairstreak and Johnson's Hairstreak (McCorkle pers. comm. 2007; Fallon and Black 2017). Thicket Hairstreak is abundant in the Oregon Cascades, and it is possible that this species is expanding into habitat previously only occupied by Johnson's Hairstreak (Fallon and Black 2017).

Morphological Description

Johnson's Hairstreak develops through complete metamorphosis: egg, larva (four instars), pupa, and adult (see **Biology**).

Adults:

Johnson's Hairstreak is a small (2.5–3.0 cm) butterfly with white-tipped tails on the hindwings (Guppy 1989) (front cover photograph and Figure 1). The dorsal wing surfaces of both sexes are dark brown (Guppy 1989). Females tend to be larger and paler than males. On the ventral wing surfaces, a white post-median stripe crosses the middle of the wings (Guppy 1989). Small blackish dots are evident on the ventral hindwing corner.

Figure 1. Comparison of Johnson's Hairstreak (*Callophrys johnsoni*) (top row left ventral view; top row right dorsal view) and Thicket Hairstreak (*C. spinetorum*) (bottom row left ventral view; bottom row right dorsal view). Note the additional black spots on the Thicket Hairstreak's ventral hindwing and blue tones on top. Photos by Raymond Davis (with permission).

Johnson's Hairstreak is similar in appearance to Thicket Hairstreak which has a more pronounced W-shape in the post-median band on the ventral hindwings, and the dorsal wing surfaces are blue rather than dark brown (Layberry *et al.* 1998; Guppy and Shepard 2001) (Figure 1).

Eggs:

Johnson's Hairstreak eggs are small (approx. 0.7 mm), compressed, round and white to pale green with numerous small divots (Figure 2) (Guppy 1989; James and Nunnallee 2011). The eggs look like gumdrops.

Figure 2. Johnson's Hairstreak (*Callophrys johnsoni*) egg (1-2 mm) on Hemlock Dwarf Mistletoe (*Arceuthobium tsugense* ssp. *tsugense*). Photograph by Raymond Davis (with permission).

Caterpillars:

First instar Johnson's Hairstreak caterpillars are 1-2 mm long (Figure 3A), yellow-green, and are covered with long hairs (Guppy 1989; James and Nunnallee 2011). There are four instars (Figure 3A-E), and as caterpillars pass through each instar, a pale green stripe with red, yellow, and white bars across each segment becomes more pronounced (Guppy 1989; James and Nunnallee 2011). These strongly raised chevrons create a sawtooth appearance (Figure 3E). Mature caterpillars are 8-15 mm in length.

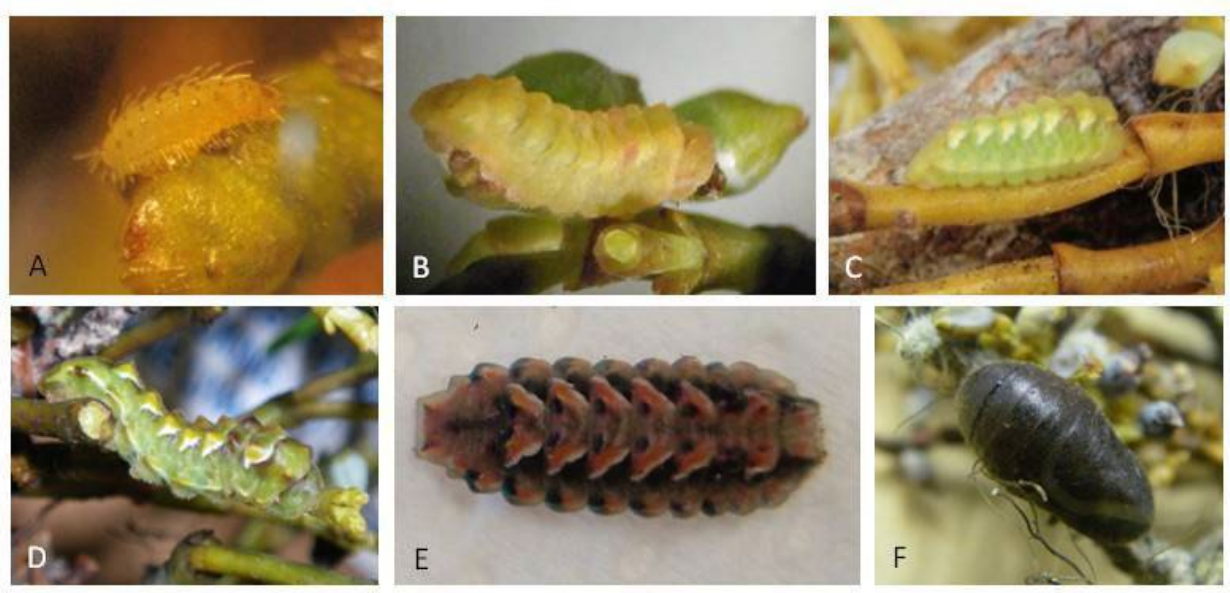

Figure 3. Caterpillars of Johnson's Hairstreak (*Callophrys johnsoni*). A. first instar (1-2 mm); B. second to third instar (2-6 mm); C. early fourth instar (6-12 mm); D. late fourth instar (12-19 mm); E. pre-pupa (8-15 mm); and F. pupa (10-12 mm). Photographs and captions by Raymond Davis (with permission).

Pupae:

Johnson's Hairstreak pupae (10-12 mm long) are dark chocolate brown and oval shaped, covered in short setae and silk girdle threads (Figure 3F) (Scott 1986; Guppy 1989; James and Nunnallee 2011). The silk threads are used to anchor the overwintering pupa to its overwintering site. They have been found in or adjacent to Hemlock Dwarf Mistletoe (*Arceuthobium tsugense* ssp. *tsugense*) shoots, branches, or brooms, or within dense evergreen needles adjacent to exposed mistletoe (James and Nunnallee 2011).

Population Spatial Structure and Variability

The population structure and variability of Johnson's Hairstreak in Canada has not been studied. The species is somewhat mobile and although dispersal distance studies have not been completed on this species, they may be able to fly up to 1 km between habitat patches (see **Dispersal and Migration** and **Rescue Effect**). The host plant occurs patchily throughout the butterfly's range in the southern portion of the Coastal Western Hemlock and Coastal Douglas-fir biogeoclimatic zones (see **Habitat**). However, extensive historical and present-day logging has and will continue to contribute to habitat fragmentation. Washington subpopulations are 10s of km from Canadian subpopulations, likely further than dispersal distance (see **Rescue Effect**). It is unknown how this habitat fragmentation has affected the population spatial structure and variability.

Designatable Units

Johnson's Hairstreak is being assessed as one designatable unit. There is no information on discreteness or evolutionary significance among subpopulations in Canada. There are no described subspecies. The species occurs within the Pacific Maritime terrestrial ecozone of Canada (Canadian Council on Ecological Areas 2014).

Special Significance

Hairstreak butterflies are of interest because of their tight associations with host plants, taxonomic and systematic complexity, and association with some of the most at-risk plant communities in the country. Johnson's Hairstreak is tightly associated with its obligate mistletoe host plant. This species is difficult to observe because it spends most of its adult life in the tree canopy. The old growth and late successional second growth (> 81 years old) coniferous forests of southwestern British Columbia (BC) host numerous rare and at-risk invertebrates (BC CDC 2021). Johnson's Hairstreak is part of Canadian ecosystems that are important to Indigenous people, who recognize the interconnectedness of all species within the ecosystem.

The host plant, Hemlock Dwarf Mistletoe (*Arceuthobium tsugense* ssp*. tsugense*) (Figure 4), is considered a pest by the forest industry and can have an economic impact on timber of Western Hemlock (*Tsuga heterophyla*). Infections reduce the growth of the tree, and reduce the wood quality. As the mistletoe spreads on a tree, cracks in the bark allow access by pests, such as fungi.

Figure 4. The tops of Western Hemlock (*Tsuga heterophyla*) trees with Hemlock Dwarf Mistletoe (*Arceuthobium tsugense* ssp. *tsugense*) brooms. Johnson's Hairstreak (*Callophrys johnsoni*) observed at this site, Pacific Spirit Metro Vancouver Park (#13), May 28, 2007. Photo by Michelle Connolly.

DISTRIBUTION

Global Range

Globally, Johnson's Hairstreak occurs in western North America from coastal south-western BC, south through western Washington, Oregon to central California, with a potentially disjunct subpopulation in Idaho (Figure 5; Shields 1965; Layberry *et al.* 1998; Guppy and Shepard 2001; Fallon and Black 2017; BC CDC 2021). Additional information on the range of the species in the United States is detailed in Pyle (2002), Miller and Hammond (2007), Fallon and Black (2017), Lotts and Naberhaus (2020), and NatureServe

(2021). Less than 5% of the global range of Johnson's Hairstreak is in Canada (based on a convex polygon around the global range).

Hemlock Dwarf Mistletoe, which grows on Western Hemlock in forests within a 150 km band along the coast in BC (Figure 6), is the host plant for Johnson's Hairstreak (see **Biology** and **Habitat**). The global range of Hemlock Dwarf Mistletoe is from Haines, Alaska in the north, and extends southward through BC, Washington, and Oregon along the coast to northern California (Hennon *et al.* 2001). There are additional factors that limit the global range of the butterfly, which is smaller than the range of the host plant (see **Habitat** and **Biology**).

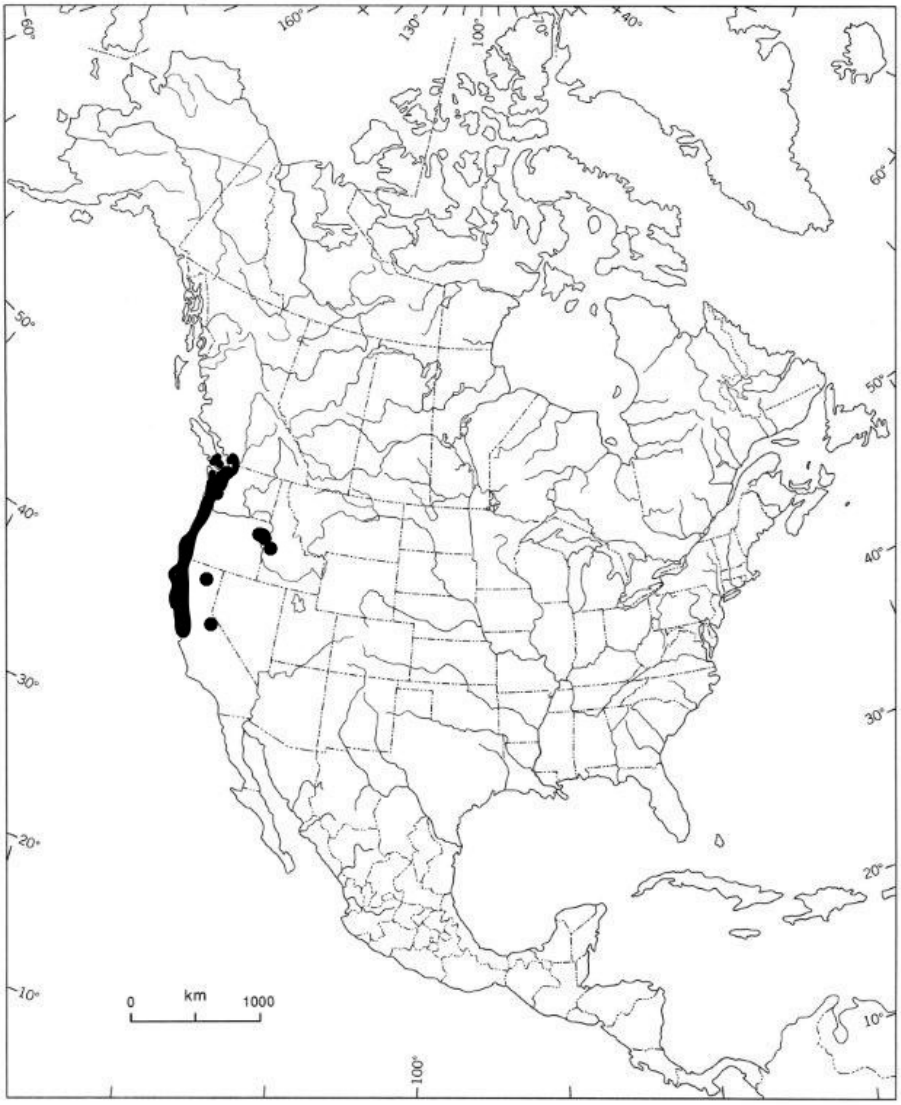

Figure 5. Global range of Johnson's Hairstreak (*Callophrys johnsoni*). Map based on Pyle (2002), Hinchliff (1996), Fallon and Black (2017) and Lotts and Naberhaus (2020).

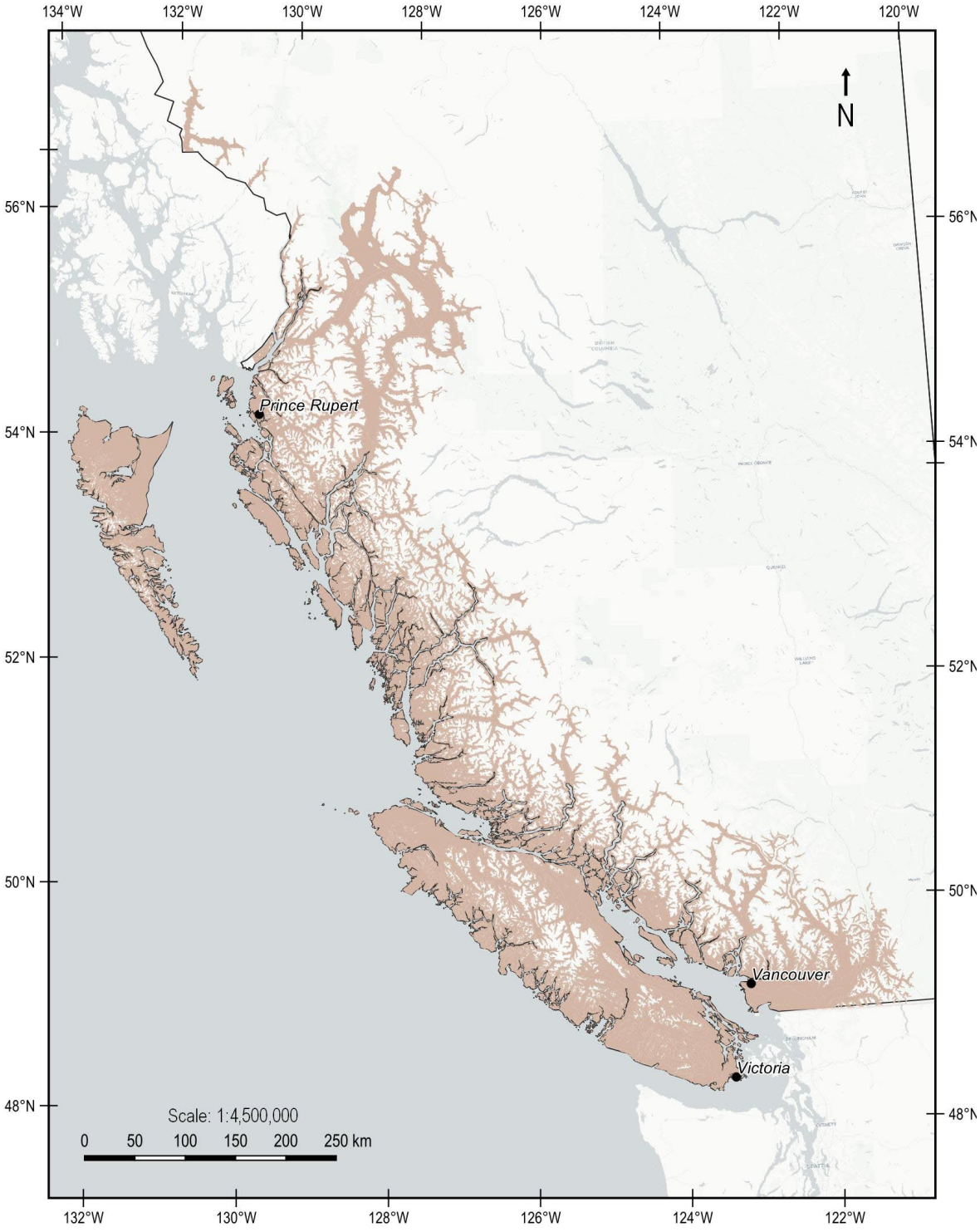

Figure 6. Hemlock Dwarf Mistletoe (*Arceuthobium tsugense* ssp. *tsugense*) distribution in British Columbia (118,329 km^2). Map created by Greg Amos (ENV).

Canadian Range

In Canada, Johnson's Hairstreak occurs in southwestern BC, from Hope in the east to Powell River in the north, including the extreme southeastern mainland and southern Vancouver Island (Figure 7). On Vancouver Island, all records are from south of Port Alberni. There are fifteen known subpopulations[1] of Johnson's Hairstreak; ten extant (#1, 2, 3, 4, 5, 11, 12, 13, 14, 15) and five historical (#6, 7, 8, 9, 10) (Figure 7). Subpopulations have been defined using a 10 km separation distance; all sites within a 10 km diameter linked by continuous habitat are considered one subpopulation. Subpopulations can be composed of multiple sites.

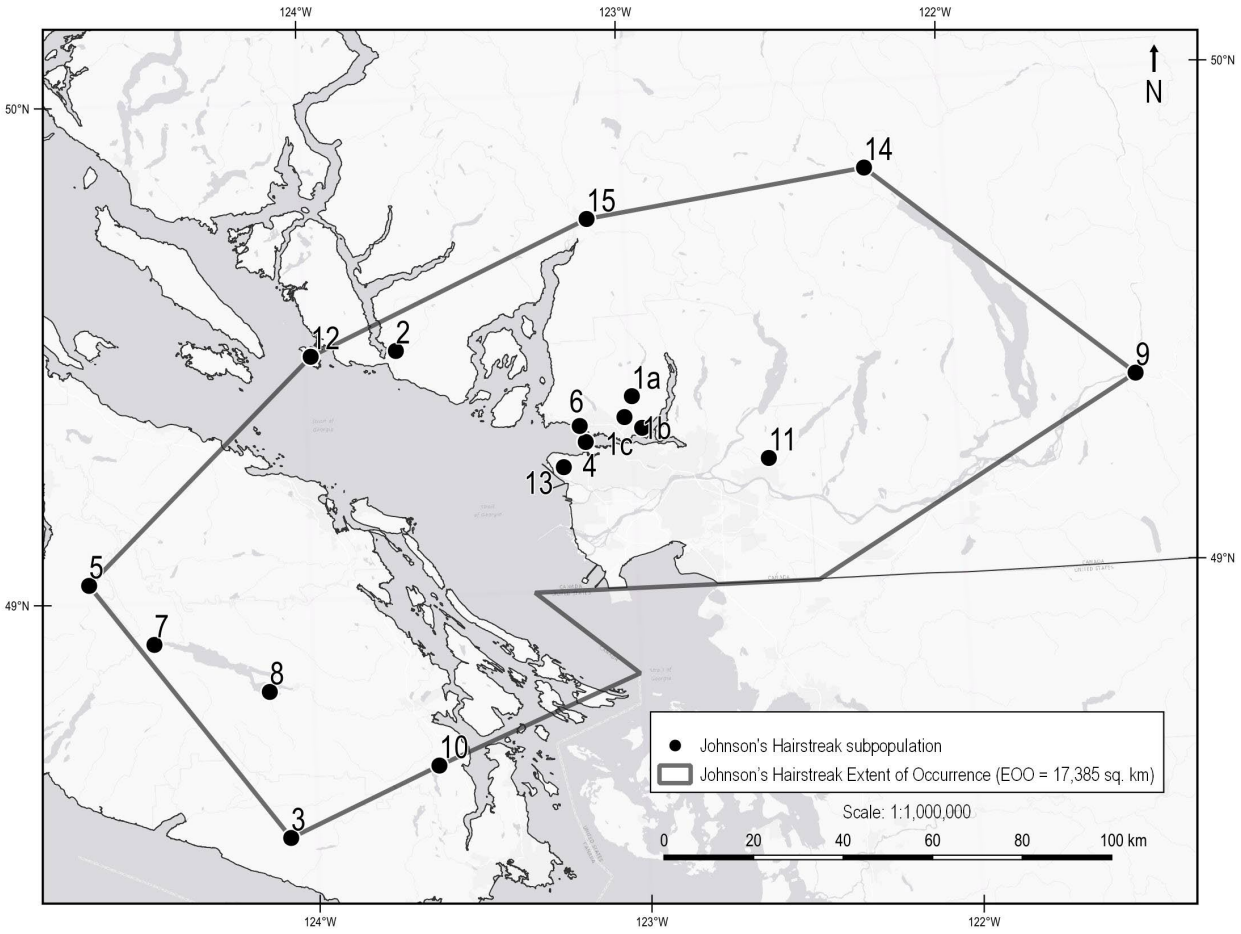

Figure 7. Canadian range of Johnson's Hairstreak (*Callophrys johnsoni*) based on convex hull polygon around known records for the species (see Table 1). The extent of occurrence (EOO) is 17,385 km^2 based on a convex hull polygon around known subpopulations and removing the portion of the polygon within the United States. Map by Greg Amos (ENV).

[1] **Subpopulations** are defined as geographically or otherwise distinct groups in the population between which there is little demographic or genetic exchange (typically one successful migrant individual or gamete per year or less). Subpopulation size is measured as numbers of mature individuals only (IUCN 2001). For Johnson's Hairstreak, the size of each subpopulation cannot be calculated based on available data (see **Population Sizes and Trends**).

There are four historical specimens that are labeled 'Vancouver', with no additional information, and these are not shown on Figure 7. A record from Spuzzum was in an early published list of records for BC (Jones 1951); however, this record was deemed a misidentification (Shields 1965).

The Canadian range of the host plant, Hemlock Dwarf Mistletoe, is restricted to coastal coniferous forests in BC; the mistletoe is not found east of the Cascade Mountains (Figure 6) (Muir *et al.* 2007; Rusch *et al.* 2019; thebeczone 2022). The absence of Johnson's Hairstreak records north of the Campbell River area and where the host plants occur (e.g., further north in coastal BC) suggests there are other factors that limit the butterfly's geographic range (see **Limiting Factors**).

The range of the Thicket Hairstreak does not overlap with Johnson's Hairstreak in Canada. Thicket Hairstreak ranges through the central and southern interior of BC (Guppy and Shepard 2001). The closest record is east of E.C. Manning Provincial Park (BC CDC 2021), approximately 100 km from the nearest Johnson's Hairstreak subpopulation in Hope (#9) (Table 1).

Table 1. Johnson's Hairstreak (*Callophrys johnsoni*) subpopulation information in Canada from 1900 to 2021 (BC CDC 2021).

Sub-population (Map) #	Sub-population Name & Area	Habitat Notes	Elevation (m) above sea level (asl)	Land Tenure	Dates and number of museum specimens / observations	Extant/ Historical/ Unknown	Most Recent General Search Effort
1abc	North Vancouver (Lower Mainland)	The areas where the butterfly was collected are within and/or adjacent to second growth coniferous forest polygons that occur across the North Shore mountain slopes. Observations at BC Parks office (Mount Seymour), North Vancouver Demonstration Forest, Lynn Canyon Regional Park and Lower Seymour Conservation Reserve (Metro Vancouver). Specific collection locality uncertain for some observations and subpopulation likely occurs in adjacent areas.		The precise collection locality of the 2021 record is unknown. Land tenure is a combination of provincial, municipal (Metro Vancouver, City of North Vancouver, District of North Vancouver) and private	1980s (at least 1 observed), 1997 (1 observed), 2004 (1 collected), 2021 (1 observed)	Extant	Connolly 2007. Ongoing interest from natural history and iNaturalist enthusiasts; most recent record from S. Ansell on iNaturalist (2021).
2	Sechelt-Dakota Forest Service Road (Sunshine Coast)	Two observations along publicly accessible forest service road adjacent to second growth coniferous Western Hemlock forest.		Provincial forest management unit	2009 (1 collected, 1 observed)	Extant	Parkinson *et al*. 2009a

Sub-population (Map) #	Sub-population Name & Area	Habitat Notes	Elevation (m) above sea level (asl)	Land Tenure	Dates and number of museum specimens / observations	Extant/ Historical/ Unknown	Most Recent General Search Effort
3	San Juan Ridge (Vancouver Island)	Roadside adjacent to a clearcut and within proximity to coniferous forest. Nectaring on willow catkins and Trailing Blackberry (Parker pers. comm. 2016).	880–980 m	Provincial Tenure - Tree Farm Licence (Schedule B) 61 held by Pacheedaht Andersen Timber Holdings Limited Partnership	2016 (7 observations, including the iNaturalist observation)	Extant	2016; one observation in iNaturalist, ongoing interest from natural history and iNaturalist enthusiasts.
4	Stanley Park (Lower Mainland)	Observations within Stanley Park including Lost Lagoon (grassy areas), near the Hollow Tree and Lees Trail.	< 50 m	Owned by Parks Canada Agency and managed by City of Vancouver	1980s (at least 1 observed), 2004 (at least 1 observed), 2007 (3 observed), 2011 (1 observed)	Extant	2011 (Worchester and Titaro 2012); Ongoing interest from natural history and iNaturalist enthusiasts.
5	Corrigan Creek	3 km northwest of Mount Olsen, and 23 km south-southeast of Port Alberni on Vancouver Island. No additional habitat information.		Provincial Tenure - Tree Farm Licence (Schedule B) 44 Huumiis Ventures Limited Partnership (“Huumiis”), a limited partnership beneficially owned by the Huu-ay-aht First Nations (“Huu-ay-aht”), and Western Forest Products Inc.	2014 (1 observed) eButterfly, Larrivee *et al.* ND	Extant	2014; Ongoing interest from natural history and iNaturalist enthusiasts.
6	West Vancouver (Lower Mainland)	No associated locality information, the collection locality is unknown.	150 m (estimated)	Unknown; likely provincial, municipal (Metro Vancouver, City of North Vancouver, District of North Vancouver) and private	1963 (1 collected) Specimen housed at the University of Oregon, originally from the private collection of John Shepard.	Historical	Ongoing interest from natural history and iNaturalist enthusiasts.
7	Nitnat Lake (Vancouver Island)	No associated locality information, the precise collection locality is unknown. The larvae were collected from mistletoe and reared to adult during the Forest Insect and Disease Survey. The locality information is vague; a generalized point in the middle of a 10 km^2 grid square.		Unknown; likely; private	1969 (3 larval specimens collected and reared to adults) Specimens housed at the Pacific Forestry Research Centre, Victoria (Esme pers. comm. 2022).	Historical	Connolly 2007; Ongoing interest from natural history and iNaturalist enthusiasts.
8	Robertson River (Vancouver Island)	No associated locality information, the precise collection locality is unknown. The larvae were collected from mistletoe and reared to adult during the Forest Insect and Disease Survey. The locality information is vague; a generalized point in the middle of a 10 km^2 grid square.		Unknown; likely private	1958 (1 larva collected and reared to adult) Specimen housed at the Pacific Forestry Research Centre, Victoria (Esme pers. comm. 2022).	Historical	Unknown; not within the past ten years (e.g., pre-2012)

Sub-population (Map) #	Sub-population Name & Area	Habitat Notes	Elevation (m) above sea level (asl)	Land Tenure	Dates and number of museum specimens / observations	Extant/ Historical/ Unknown	Most Recent General Search Effort
9	Hope (lower Fraser Valley)	No associated locality information, the collection locality is unknown.		Unknown; likely provincial	1972 (2 collected) Specimens housed at the Royal Ontario Museum.	Historical	Knopp *et al.* 2007, 2009, 2010
10	Shawnigan Lake (Vancouver Island)	No associated locality information, the collection locality is unknown.		Unknown; likely private	1925 (1 collected) Specimen housed at the National Museum of Natural History (Smithsonian Institution)	Historical	Connolly 2007; Page *et al.* 2008a
11	Malcolm Knapp Research Forest (lower Fraser Valley)	Observed at H9 Road/Gwendoline Lake. Research forest and operational private / woodlot forest managed by the University of British Columbia since 1949. Forest age ranges from small patches of 400 year+ old growth, some 120-year-old stands (approx. half of the western side of the forest) and remainder 70-year-old stands (approx. half of eastern forest). Regenerating forest is 40-year-old second growth to 1-year old second or third growth (MKRF 2021).		Private; woodlot licence to University of British Columbia (UBC); 5157 ha of private land belonging to UBC and 220 ha Woodlot License (Crown)	1990 (1 collected), 1999 (1 collected) Specimens housed at the Cris Guppy collection (private)	Extant	Connolly 2007; and likely interest from keen observers during ongoing academic research
12	Thormanby Island (Sunshine Coast)	Collection locality uncertain. Two provincial parks (PP) - Simson PP (South Thormanby Island) and Buccaneer Bay PP (North Thormanby Island) but unknown which area the specimen was collected.		Private and provincial; may include a provincial park	1995 (1 collected) Specimens housed at the Beaty Biodiversity Museum, University of British Columbia (Needham pers. comm. 2021).	Extant	Connolly 2007
13	Pacific Spirit Park (Lower Mainland)	Observed trailside adjacent to mistletoe trees; one observation along Imperial Trail.		Metro Vancouver Regional Park	1987 (3 collected), 1989 (1 collected), 1990 (3 collected), 2007 (2 observed) Specimens housed at the Cris Guppy collection (private)	Extant	Connolly 2007; ongoing interest from natural history and iNaturalist enthusiasts.
14	Pemberton-Douglas Forest Service Road (lower Fraser Valley)	Observed along the forest service road.		Provincial land; Forest Management Unit	2009 (1 observed)	Extant	Knopp *et al*. 2007, 2009, 2010
15	Squamish	Observed perched on a Red-osier Dogwood (*Cornus sericea*)		Private (observed in the backyard of a private residence)	2021 (1 observed; iNaturalist)	Extant	One observation on iNaturalist 2021

Sub-population (Map) #	Sub-population Name & Area	Habitat Notes	Elevation (m) above sea level (asl)	Land Tenure	Dates and number of museum specimens / observations	Extant/ Historical/ Unknown	Most Recent General Search Effort
Unknown	Vancouver (Lower Mainland)	No associated locality information, the collection locality is unknown. One of the 1904 specimens became the type specimen and is referred to as 'Vancouver' in Skinner (1904).	90 m (estimated)	Unknown; likely private (present-day)	1900 (2 collected). 1904 (2 collected) Specimens housed in the Canadian National Collection of Insects, Arachnids and Nematodes (CNC).	Historical	Unknown; ongoing interest from natural history and iNaturalist enthusiasts.

Extent of Occurrence and Area of Occupancy

The extent of occurrence (EOO) of Johnson's Hairstreak in Canada is 17,385 km^2 using a minimum convex polygon encompassing extant and historical records (Figure 7). The index of area of occupancy (IAO) is 48 km^2 (2 km X 2 km grid) including only extant records and 68 km^2 including extant and historical records (Figures 8, 9). Even given an expectation of some new occurrences, IAO is expected to be less than 100 km^2.

Search Effort

Johnson's Hairstreak museum specimens, survey observations, and photographic records in Canada date from 1900 to 2021. The first records are labelled with the vague collection locality of 'Vancouver' in 1900 and 1904 and 'West Vancouver' in 1963. The three most recent records are observations from San Juan Ridge (#3; in 2016), North Vancouver (#1; in 2021) and Squamish (#15; in 2021). There has been a minimum of 47 sight and museum records in Canada since it was first recorded in 1900 (BC CDC 2021; Table 1).

Johnson's Hairstreak searches target the adult life stage and are completed by searching for flowering plants in open habitats near Western Hemlock stands (Figure 8). Presumably, adult Johnson's Hairstreak prefer the upper tree canopy (Scott 1986; Pyle 2002): males establish territories and patrol for mates, females seek mates and search for exposed mistletoe masses upon which to oviposit (lay) eggs; and both sexes may rest and seek shelter within these areas. However, adults need to maintain a constant nectar supply, and will travel down to the ground to feed upon flowering plants, where they are observed. Eggs, caterpillars, and pupae reside in mistletoe masses in the upper strata of old growth and late successional second growth Western Hemlock (see **Life Cycle**). The difficulty in access means surveys do not target these life stages.

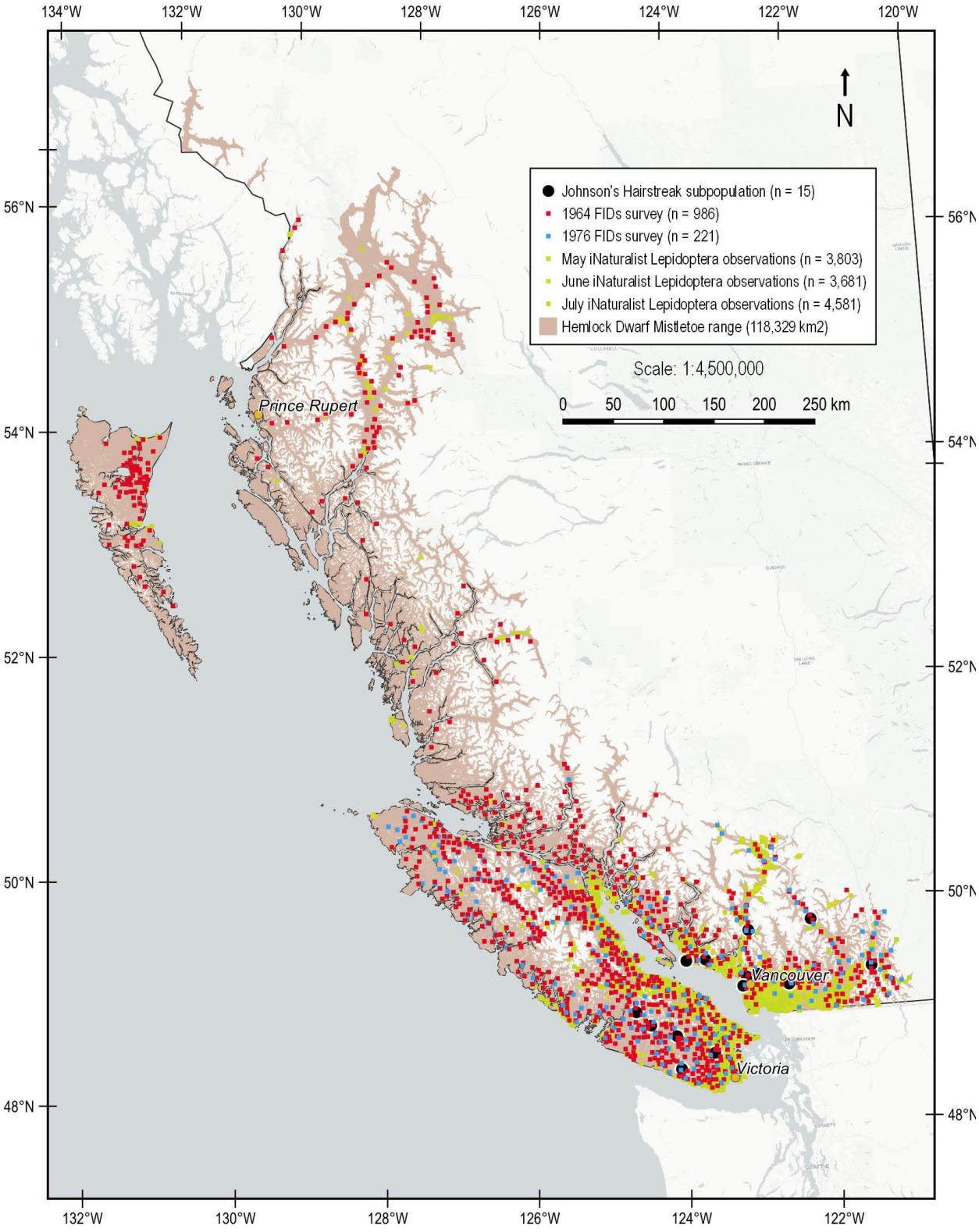

Figure 8. Hemlock Dwarf Mistletoe range with occurrences of Johnson's Hairstreak (*Callophrys johnsoni*) and sampling where no Johnson's Hairstreak were found (see **Search Effort**). Map created by Greg Amos (ENV).

Recent (in the past 25 years) surveys for Johnson's Hairstreak (Table 2, Figure 8) have focused on potential habitat, recording the species' presence and documenting habitat and natural history information. From 1997 to 2021 (including search effort completed during the preparation of this status report), butterfly search effort totals > 2248 survey hours and >12,023 km wandering transect surveys during the flight period, in suitable habitat (e.g., open areas adjacent to old growth or late successional second growth forests with mistletoe) and in the Canadian range of Johnson's Hairstreak (Table 2).

Table 2. Recent (since 2001) search effort within the potential range of Johnson's Hairstreak (*Callophrys johnsoni*) in Canada.

Survey year	Geographic Area	Person-Hours of search effort	Distance searched (km) and/or number of sites visited	Johnson's Hairstreak recorded	Reference
2001	Southern Vancouver Island and Gulf Islands	Not recorded.	90 specific sites in 10 areas were surveyed during May-July 2001	None	Guppy and Fisher 2001
2001-2004	Southern Vancouver Island – MSc thesis	Unknown	At least ten sites within southeastern Vancouver Island	None	Miskelly 2004
2003	Hornby Island Butterfly Inventory	twenty days from April to August; 106 hours	15 sites on Hornby Island	None	Miskelly 2003
2004	Metro Vancouver Parks	41 hours	13 parks	None	Grant 2004
2004	foot of Seymour Mountain Road	Not recorded.	N/A	1	C. Guppy, pers. comm. 2021
2004	Stanley Park	Not recorded.	Incidental sighting	1	Worcester and Johnstone 2007
2007	Vancouver and Sunshine Coast (May – June 2007)	148 hours	May 25 – July 11, 17 different parks/areas/sites	2 (at Pacific Spirit Park; #13)	Connolly 2007
2007	Gulf Islands National Park Reserve (May through August)	90.7 hours	18 sites (total area 1589 ha); 4 visits to each site	None	Fenneman 2007
2007	Denman and Hornby islands April 28 – June 13 (private/public land)	168.4 hours	288.1 km	None	Page *et al.* 2007
2007	Denman Island Settlement Lands, private conservation land	Surveys over a four-day period	N/A	None	Guppy 2007
2007	Lower Fraser Valley	Not recorded.	500 km roads searching for suitable habitat	None	Knopp *et al.* 2007

Survey year	Geographic Area	Person-Hours of search effort	Distance searched (km) and/or number of sites visited	Johnson's Hairstreak recorded	Reference
2008	Gulf Islands National Park Reserve (federal) May through August	Not recorded.	18 sites (total area 1589 ha); 4 visits to each site	None	Guppy 2008
2008	Courtenay, Comox, Denman Island and Hornby Island, May 15 – June 14 (private and public land)	64.3 hours	72.5 km (58.6 km by foot; 13.9km by car)	None	Page *et al.* 2008b
2008	Southern Vancouver Island May 4 – May 17, 2008 (private land)	59.3 hours	95.6 km	None	Page *et al.* 2008a
2009	Harrison Lake area; July 3-5 and July 17-22nd, 2009.	91.7 hours	217.8	None	Parkinson *et al.* 2009a
2009	Sunshine Coast from Gibsons to Lund	46.6 hours	77.2 km	1	Parkinson *et al.* 2009b
2009	Southeastern Vancouver Island (May 21 – August 26)	101.5 hours	374.2 km	None	Lilley *et al.* 2009
2009	Denman Island 2009 (private land)	17 days, 2 – 3 surveyors per day	Not available; ~ 809 ha area	None	Heron pers. data 2010
2009	Lepidoptera surveys in Victoria Parks May 30 – 31, 2009	6.2 hours	20.8 km through 8 parks in the City of Victoria	None	Page and Lilley 2009
2009	Lower Fraser Valley	107 hours (on foot);	17 km (foot); 2,555 km vehicle (scanning appropriate sites); 233 km boat (shoreline habitat)	None	Knopp *et al.* 2009
2010	Southeastern Vancouver Island	98.1 hours	310.8 km (252.5 km by foot; 58.3 by car)	None	Lilley *et al.* 2010
2010	Lower Fraser Valley	59 hours (foot)	48 km (foot); 4334 km (vehicle); 62 km (boat)	None	Knopp *et al.* 2010
2011	Stanley Park, Lees Trail	Not recorded.	Incidental sighting	1	Worcester and Titaro 2012
2011	Oregon Branded Skipper surveys on Southeastern Vancouver Island	117.5 hours	203.7 km	None	Heron unpubl. data
2014	Vancouver Island	Not recorded.	Incidental sighting	1	Larrivee *et al.* (eButterfly)
2014	Sunshine Coast	25.4 hours	73.8 km wandering transects and 26.0 km of car-based transects	None	Page and Schaefer 2014

Survey year	Geographic Area	Person-Hours of search effort	Distance searched (km) and/or number of sites visited	Johnson's Hairstreak recorded	Reference
2015	Four Northern Gulf Islands	48.1 hours	114 km	None	Page and Schaefer 2015
2016	San Juan Ridge	Not recorded.	N/A	3	Parker pers. comm. 2016
2017	Greater Victoria Area	210 hours	235 km	None	Zand *et al.* 2017
2018	Greater Victoria Area	252 hours	376 km	None	Marks *et al.* 2018
2019	Greater Victoria Area	155 hours	261.2 km	None	Heron *et al.* 2019
2019	Oyster River area, Campbell River	75.9 hours	164.1 km	None	Heron *et al.* 2020
2019	Denman and Hornby Islands	124.58 hours	146.7 km	None	Heron *et al.* 2020
2020	Oyster River area, Campbell River	9.3 hours	37.3 km	None	Heron *et al.* 2021
2020	Hornby Island	77.35 hours	116.17 km	None	Heron *et al.* 2021
2020	Denman Island	70 hours	164.1 km	None	Heron *et al.* 2021
2021	Lower Mainland and Fraser Valley	43.15 hours	96 km	None	Heron pers. data
Total 1997-2021		**> 2248 hours**	**Over 12023 km**	**10**	

Surveys completed in 2021 (during preparation of this status report) targeted seven areas with older records for Johnson's Hairstreak in the lower mainland. Search effort totalled just more than 43 hours across six days and 96 km of linear surveys (Table 1 and 2). No Johnson's Hairstreak were recorded during these surveys.

In BC, the range of Hemlock Dwarf Mistletoe (118,329 km^2) is much larger than the known range of Johnson's Hairstreak (17,385 km^2) and extends through remote areas of coastal BC, where Lepidoptera surveys are limited. Data were compiled from iNaturalist and the Canadian Forest Service to partially compensate for this (see Figure 8).

iNaturalist is an effective online archive of butterfly observations (#1, 3, and 15 are from iNaturalist; see Table 1). This and other citizen science platforms (e.g., Victoria Natural History Invertebrate Alert, BugGuide, eButterfly) can show evidence of null search effort. Lepidoptera posted to iNaturalist within the BC range of Hemlock Dwarf Mistletoe and in the Johnson's Hairstreak flight period include 3803 observations in May; 3681 observations in June and 4581 observations in July (as of March 1, 2022) (iNaturalist 2022)[2]. Of these 12,065 observations within the range of Hemlock Dwarf Mistletoe, only three (#1, 3, 15) are Johnson's Hairstreak (Figure 7).

[2] All Lepidoptera records for May, June and July (adult Johnson's Hairstreak potential flight period) were downloaded from iNaturalist and plotted. Only iNaturalist records within the geographic range of Hemlock Dwarf Mistletoe were included in the tally.

The study of forest insects and their impacts on Canada's forests became a priority in the late 1940s, and for the past 80 years there have been ongoing surveys and programs led by the Canadian Forestry Service to monitor forest insects, colloquially known as FIDS (Forest Insect and Disease Survey) (van Sickle *et al*. 2001; Natural Resources Canada 2021). From the late 1940s until the mid-1990s, general Lepidoptera (and other insect) surveys on coastal BC collected and reared live larvae to adults for identification; the specimens were tallied and deposited in museums (i.e., the Pacific Forestry Centre, Victoria) (van Sickle *et al*. 2001). For example, two historical Johnson's Hairstreak subpopulations are known from reared specimens collected during these studies (#7 in 1969, #8 in 1958). Few of these reports are available electronically, and the data are difficult to extract. However, two reports were used as exemplars: the 1964 (Canadian Forest Service 1965) report tallies 986 sites[3] within the range of Hemlock Dwarf Mistletoe were sampled for larvae and in 1976 (Canadian Forestry Service 1977), 2217 sites were sampled. No Johnson's Hairstreak were recorded during these years (Figure 8), but these are additional null data and demonstrate there has been extensive survey effort to the north of the known geographic range.

HABITAT

Habitat Requirements

Johnson's Hairstreak occurs in the Coastal Western Hemlock (CWH) and Coastal Douglas-fir (CDF) biogeoclimatic zones (BGZ)[4]. The subzones for the host plants in the CWH are very dry maritime (CWHxm); dry maritime (CWHdm); moist maritime (CWHmm), and very wet maritime (CWHvm). The CDF subzone is the moist maritime (CDFmm) (Rusch *et al.* 2019).

Ecosystem:

Johnson's Hairstreak is considered an old growth forest obligate butterfly (Layberry *et al.* 1998; Guppy and Shepard 2001; Pyle 2002). The species inhabits old growth and late successional stage (> 81 years) coniferous forests dominated by Western Hemlock (*Tsuga heterophylla*) with the species' host plant, Hemlock Dwarf Mistletoe. These forests can include areas that have not been logged (e.g., old-growth > 250 years); second or even third growth forests > 81 years, so long as the host plant is present and reproducing. Most records are below 625 m above sea level (asl) although records in the San Juan Ridge area (#3) are 880-980 m asl (BC CDC 2021). This higher-elevation record is likely a result of the south-facing aspect and nearness to the ocean that makes for a milder climate.

[3] Survey sites within these two reports (1964 and 1976) were geospatially plotted (scanned). Only those survey sites within the geographic range of Hemlock Dwarf Mistletoe were included in the tally.

[4] The biogeoclimatic zones refer to an ecosystem classification system developed by the British Columbia Ministry of Forests (2009). The province's ecological communities are classified by this system, which aligns with broad ecological classification systems across the country.

The primary host of Hemlock Dwarf Mistletoe is Western Hemlock. Secondary hosts can be parasitized when they grow near infected primary hosts (Rusch *et al.* 2019). These include Amabilis Fir (*Abies amabilis*), Subalpine Fir (*Abies lasiocarpa*), and occasionally Grand Fir (*Abies grandis*), and Shore Pine (*Pinus contorta* var. *contorta*) (Smith 1966; Mathiasen 1994; Rusch *et al.* 2019). Patterns of mistletoe growth are variable at the tree, stand and landscape level and depend on the tree structure, age, and the forest stand disturbance history. In BC, an estimated 15% of Western Hemlock stands host Hemlock Dwarf Mistletoe, mostly in a north-south band about 150 km wide along the coast (Alfaro 1985).

The extent of suitable habitat required to sustain a subpopulation of Johnson's Hairstreak is unknown. Adult observations are often within floral meadows and roadsides, most with accurate geographic positioning system coordinates (#2, 3, 4, 11, 13, 14, 15) within 1 km of old growth or late successional stage forest cover (> 81 years, as determined using satellite imagery; Amos pers. comm. 2021). For the observations at Pacific Spirit Park (#13) (Connolly 2007), Stanley Park (#4) (Worchester and Johnson 2007), and Sechelt-Dakota Forest Service Road (#2) (Parkinson *et al*. 2009a) there is confirmed Hemlock Dwarf Mistletoe at these sites.

Adult habitat:

Johnson's Hairstreak requires forest openings, likely within 1 km of Hemlock Dwarf Mistletoe in Western Hemlock stands, with an abundance and diversity of flowering plants to provide nectar through the flight period (May – June). See Table 3 for a list of Johnson's Hairstreak nectar plants in BC (from Fallon and Black 2017).

Table 3. Nectar plants used by Johnson's Hairstreak (*Callophrys johnsoni*) that occur in British Columbia.

Scientific Name	English Common Name	References as in Fallon and Black (2017)
Acer circinatum	Vine Maple	Davis *et al.* 2011
Apocynum spp.	Dogbane	Davis *et al.* 2011; Shapiro and Manolis 2007; Art Shapiro's Butterfly Site 2021
Arctostaphylos uva-ursi	Manzanita	Shields 1965; Davis *et al.* 2011
Asclepias spp.	Milkweed	Shapiro and Manolis 2007
Berberis nervosa	Oregon Grape	Pyle 1981, 2002; Davis *et al.* 2011
Ceanothus spp.	Ceanothus	Shields 1965; Pyle 1981; Shapiro and Manolis 2007; Art Shapiro's Butterfly Site 2021
Cornus spp.	Dogwood	Shields 1965
Cornus canadensis	Bunchberry	Davis *et al.* 2011
Cornus nuttallii	Pacific Dogwood	Pyle 1981; Davis *et al.* 2011
Fragaria spp.	Strawberry	Shields 1965; Davis *et al.* 2011
Rorippa spp.	Yellowcress	Shields 1965; Davis *et al.* 2011
Rubus spp.	Blackberry	Warren 2005
Rubus ursinus	Dewberry	Davis *et al.* 2011
Taraxacum spp.	Dandelion	Shields 1965

Egg habitat:

Eggs are laid singly on an exposed mistletoe mass in the crowns of Western Hemlock (see **Biology**).

Caterpillar habitat:

Johnson's Hairstreak caterpillars feed only on Hemlock Dwarf Mistletoe, which is a hemiparasitic (both photosynthetic and parasitic), perennial seed-bearing plant with the principal host Western Hemlock (Smith 1966; Hennon *et al.* 2001). Mistletoes contain chlorophyll and can make some of their own food but also need the host tree for water and nutrients. In BC there are two subspecies of Hemlock Dwarf Mistletoe that occur along the coast: Hemlock Dwarf Mistletoe and Mountain Hemlock Dwarf Mistletoe (*A. t. mertensianae*) (BC CDC 2021). Since Johnson's Hairstreak has primarily been recorded at elevations less than 625 metres (Guppy and Shephard 2001; BC CDC 2021), it is assumed the species only feeds on Hemlock Dwarf Mistletoe (Layberry *et al.* 2001). There is one record of Johnson's Hairstreak at 880-980 m asl (#3 San Juan Ridge) but as noted the higher elevation is likely because of a milder climate in coastal Vancouver Island. Confirmation of the mistletoe subspecies and nearby host trees is needed for this subpopulation. Figure 9 shows the known occurrences of Johnson's Hairstreak and the stands of Western Hemlock presumed to be suitable to support Hemlock Dwarf Mistletoe.

Mistletoe life cycle is summarized from Rusch *et al.* (2019) and Hawksworth and Wiens (1996). Hemlock Dwarf Mistletoe seeds are surrounded by a fleshy berry, which swells with water pressure as the seed matures. When the inside water pressure becomes high enough, the berry explodes, and the seeds are discharged at speeds up to 24 m/s (Hinds and Hawksworth 1965). Seeds can travel horizontally (up to 10-15 m) and further laterally depending on their original height and position on the tree (Geils and Hawksworth 2002). The seeds are coated in a viscous, sticky substance ("viscin") that allows them to attach to any host tree's needles or branches they encounter during their flight. Rain softens the sticky viscin which enables the seed to slide down the branches or needles and become lodged at the base of a branch or needle. The viscin then hardens. The seed is protected through the winter months until germination in the spring. After germination it forms a rootlike structure that wedges its way through the bark of the host tree. These rootlike structures eventually spread under the bark and cause the host branch to swell, bloat, branch, become clumped, and sometimes develop brooms. Once the seed is rooted into the host tree, it takes 2 to 3 years to produce aerial mistletoe shoots which form minute flowers in July to August in the fourth year. These flowers contain nectar which attract insects that pollinate the female flowers in July, August, or September (Hennon *et al.* 2001). Fruits are formed in the fifth year with seed dispersal occurring in late September and October (Unger 1992). Fruit matures in 13 to 14 months (Mathiasen 1994) and seeds germinate in February to May (Smith 1966), the entire life cycle taking approximately 6 to 7 years to the seed germination stage. Hemlock Dwarf Mistletoe continues to live in the host tree if that tree is still alive; it will put out new aerial shoots if there is sufficient light for photosynthesis (Rusch *et al.* 2019). These shoots typically only live for 2 to 3 years (Baranyay and Smith 1972). Johnson's Hairstreak caterpillars seem to prefer the terminal

buds (see **Physiology and Adaptability**) of Hemlock Dwarf Mistletoe (James and Nunnallee 2011).

Hemlock Dwarf Mistletoe spread is assisted by small-scale disturbance that occurs in older forests (> 81 years). Mistletoe seeds produced in older trees can colonize nearby younger trees growing in forest gaps where there is sufficient light (Hennon *et al.* 2001). Seed dispersal is through the explosive release of the seed (as described above) as well as likely spread by attaching to the fur of small mammals and feathers of birds (Rusch *et al.* 2019).

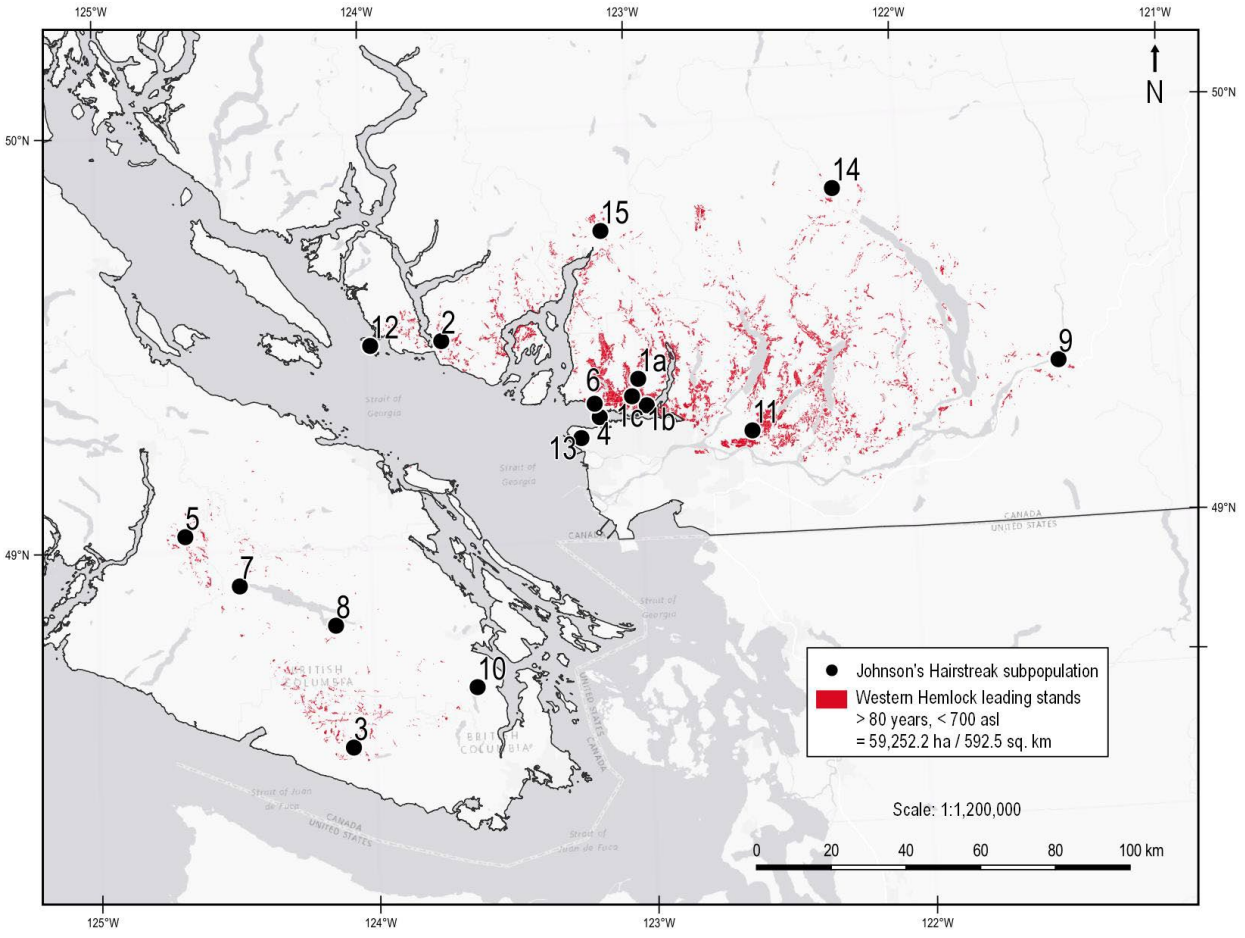

Figure 9. Johnson's Hairstreak (*Callophrys johnsoni*) subpopulations (see Table 1) and polygons of present-day (2021) Western Hemlock (*Tsuga heterophyla*) forest stands > 81 years old. The spatial data from BC government data warehouse (VRI – 2020 – Forest Vegetation Composite) were used to filter habitat with the following parameters: Coastal Western Hemlock forests > 81 years old and dominated by Western Hemlock (host plant) and under 700 m elevation asl. Map completed by Greg Amos (ENV).

Pupa habitat:

Johnson's Hairstreak overwinters as a pupa. Pupae have not been found in BC; however, pupae overwinter hidden between the needles of Western Hemlock or in dense mistletoe brooms. Keeping pupae alive is difficult (James and Nunnallee 2011).

Habitat Trends

Johnson's Hairstreak inhabits old growth or late successional second growth coniferous forests with a large component of Western Hemlock. Western Hemlock is not a tree of high commercial value; however, these same forests include Western Red-cedar (*Thuja plicata*) and Douglas-fir (*Pseudotsuga menziesii*). Both are extremely high value as timber and construction materials. The most efficient and economical method of timber extraction is clear-cut logging which cuts all standing forest, including those trees of little economic value (even when dominated by Western Hemlock). As a result, the old growth forests of coastal BC have been extensively logged over the past 150 years, including those forests with mostly Western Hemlock.

In the early 1990s the provincial government enacted the Forest Practices Code (Province of British Columbia 1996), which changed forestry in the province to include greater provisions for protecting old growth values (among many measures). This Code eventually became the *Forest and Range Practices Act* (Province of British Columbia 2002), which ensured forest management and silviculture was to certain standards (see **Legal Protection and Status**). However, most of the older growth (> 121 years) forest within the range of Johnson's Hairstreak had been harvested, and what remained was in smaller pockets or late successional second growth forest (> 81 years).

Mapping was completed to determine the area of habitat potentially available for Johnson's Hairstreak. All Johnson's Hairstreak records were mapped, and a convex polygon created around these mapped records (Figure 7). The data from BC government data warehouse (VRI – 2020 – Forest Vegetation Composite) were used to filter habitat with the following parameters: Coastal Western Hemlock forests > 81 years old and dominated (or second most frequent tree) by Western Hemlock (host plant) and under 700 m elevation asl. Finally, a 100-km radius was extended around the convex polygon for Johnson's Hairstreak (Figure 6, 7) to account for the possibility of undetected records for the species within this potential range (18,543.6 km^2, slightly more than the EOO).

The area of Western Hemlock dominated forests (both as leading and secondary species) within this potential range is 8228 km^2. Forests > 81 years = 4329 km^2 with high quality habitat, > 251 years = 2172 km^2 (Table 4). This analysis shows how little habitat is currently available for Johnson's Hairstreak, about half of the Western Hemlock dominated forests.

Table 4. Spatial area of forest stands with significant Western Hemlock within the range of Johnson's Hairstreak (*Callophrys johnsoni*) in British Columbia. Stands >81 years of age with Western Hemlock as either the leading or secondary tree species are potential habitat for Johnson's Hairstreak. This estimate includes a 100 km radius around the convex polygon around confirmed records to account for undetected subpopulations. Data from BC government VRI – 2020 – Forest Vegetation Composite, BC data warehouse.

Age Class	Age of forest (years)	Habitat Quality for Johnson's Hairstreak	2022 Western Hemlock is the Leading Tree Species in the stand (km^2)	% Western Hemlock Leading Tree - Habitat	2022: Hw Secondary Tree Species in the stand (km^2)	% Western Hemlock Secondary Tree Species - Habitat	2022 Total Habitat (km^2)	% Total Primary and secondary
1	1 – 20	Low	246.83	6%	249.72	6%	496.55	6%
2	21 – 40	Low	647.23	16%	400.09	10%	1047.32	13%
3	41 – 60	Low	831.94	20%	723.77	18%	1555.71	19%
4	61 – 80	Low	499.85	12%	299.32	7%	799.17	10%
5	81 - 100	Medium	320.87	8%	201.94	5%	522.81	6%
6	101 - 120	High	186.53	4%	488.88	12%	675.41	8%
7	121 - 140	High	96.3	2%	13.76	0%	110.06	1%
8	141 - 250	High	317.17	8%	531.18	13%	848.35	10%
9	251 +	High	1004.23	24%	1168.49	29%	2172.72	26%
Non-Johnson's Hairstreak Habitat - Age Class 1-4			2225.85	54%	1672.9	41%	3898.75	47%
Johnson's Hairstreak Habitat - Age Class 5-9			1925.1	46%	2404.25	59%	4329.35	53%
Total			4150.95	100%	4077.15	100%	8228.1	100%

Hw leading stands – Western Hemlock is the leading tree species in the stand.

Hw secondary stands – Western Hemlock is the second most abundant species in the stand (e.g., Douglas-fir or Western Red-cedar are primary).

Hemlock Dwarf Mistletoe is considered a tree disease in BC. When trees are parasitized, there is an increase in tree mortality, and a decrease in tree growth and wood quality mainly due to swellings on the stems (Muir *et al.* 2007).

Forest management to reduce mistletoe includes 1) targeted removal of mistletoe-infected trees (e.g., clearcut harvesting, partial harvesting with selective removal of infected trees) and 2) clearcutting followed by even-aged planting. Historical forest management has led to the creation of dense, even aged, second growth stands with reduced abundance of Hemlock Dwarf Mistletoe (Muir *et al.* 2007). Hemlock Dwarf Mistletoe shoots and flowers require light while dense dark understory prevents the mistletoe shoots from growing. Hence, Johnson's Hairstreak larvae cannot be sustained until pupation. Although most current forest management does not lead to these dense-even aged stands, what is present on the landscape is a legacy of regenerating stands from historical forest management.

BIOLOGY

Life Cycle and Reproduction

Johnson's Hairstreak has a one-year life cycle (Guppy 1989; Layberry *et al.* 1998; Guppy and Shepard 2001; James and Nunnallee 2011).

The adult flight period for Johnson's Hairstreak in BC is late May to late June (Guppy and Shepard 2001; BC CDC 2021). Hemlock Dwarf Mistletoe starts producing shoots in late May and flowers July through August. Adults come to the ground to nectar, bask and visit mud (Shields 1965), but also spend much time high in the trees where dwarf mistletoe grows (James and Nunnallee 2011). When disturbed, adults often fly up, high into the trees (James and Nunnallee 2011).

Eggs are laid singly, or sometimes multiple eggs are set close together, on sprouting and blooming shoots of Hemlock Dwarf Mistletoe, presumably in the upper canopy where there is the dappled light needed for the growth of mistletoe shoots and flowers (James and Nunnallee 2011). In captivity, eggs hatched in about seven days; caterpillars passed through four instars and reached the pupal stage in 31 days (James and Nunnallee 2011). Caterpillars use camouflage for protection. Caterpillars are difficult to detect and change pattern as they develop to closely match the host plant (James and Nunnallee 2011). In southern areas of the range, Johnson's Hairstreak has been reported having two broods, yet in BC only a single brood is known, based on adult observations (Guppy and Shepard 2001; James and Nunnallee 2011; BC CDC 2021). Caterpillars feed on all exposed plant parts and secrete a sugary solution which may be used by ants that in turn protect the caterpillar from predators (see **Interspecific Interactions**). Caterpillars can be found on host leaves from April to October (Allen *et al*. 2005). Johnson's Hairstreak overwinters as pupa. Captive reared caterpillars pupated in dense evergreen needles adjacent to mistletoe (James and Nunnallee 2011).

Physiology and Adaptability

Johnson's Hairstreak caterpillars are dependent on Hemlock Dwarf Mistletoe to complete their life history. Caterpillars reside in the higher parts of large trees and are only occasionally observed on lower branches (James and Nunnallee 2011). While the caterpillars have been observed feeding on a variety of parts of Hemlock Dwarf Mistletoe, they prefer the pale-blue terminal buds while in captivity (James and Nunnallee 2011). While feeding, caterpillars of all instars chew small round holes into the sides of mistletoe buds, and then hollow them out from the inside (James and Nunnallee 2011). Caterpillar feeding has not been observed in BC but is expected to follow a similar pattern.

Johnson's Hairstreak could feed on the mistletoe variety that parasitizes Mountain Hemlock (e.g., *A. t. mertensiana*). However, this has not been observed either in BC or other parts of its range.

Like other hairstreaks (e.g., Behr's Hairstreak, *Satyrium behrii columbia,* and Half-moon Hairstreak, *S. semiluna*), the ability of Johnson's Hairstreak to nectar on certain wildflowers is limited by the length of their proboscis (tongue); if the depth of the flower's corolla is greater than the tongue length then the butterfly is unable to feed on that flower (St. John pers. comm. 2021). The adaptability of the species is unstudied.

Dispersal and Migration

The dispersal distance of Johnson's Hairstreak has not been measured. Adults can fly quickly when startled (James and Nunnallee 2011), indicating that they are relatively strong fliers. Johnson's Hairstreak is non-migratory. Wind may play a role in dispersal; however, there is little information. The separation distance was set at 10 km through suitable habitat and 2 km across unsuitable habitat based on general knowledge from other hairstreaks (NatureServe 2020).

The subpopulations of Johnson's Hairstreak in Canada on the mainland and Vancouver Island are naturally disjunct and are separated by the Strait of Georgia. The distance between known subpopulations is in Table 5. Johnson's Hairstreak does not appear to be severely fragmented.

Table 5. Distance (km) between Johnson's Hairstreak (*Callophrys johnsoni*) extant and historical subpopulations in British Columbia. The separation distanceError! Bookmark not defined. **between subpopulations on the North Shore (#1, 6) and those in Vancouver (#4, 13) includes > 2 km of unsuitable habitat (i.e., Burrard Inlet and urban areas).**

Subpopulation	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1 North Vancouver	-														
2 Sechelt-Dakota Forest Service Road	55	-													
3 San Juan Ridge	122	112	-												
4 Stanley Park	12	47	110	-						Distance (km)					
5 Corrigan Creek	128	86	72	116	-										
6 West Vancouver	12	44	113	4	115	-									
7 Nitnat Lake	119	85	53	107	20	107	-								
8 Robertson River	102	81	33	90	47	91	28	-							
9 Hope	113	166	216	124	239	125	228	206	-						
10 Shawnigan Lake	90	93	37	80	88	82	69	41	179	-					
11 Malcolm Knapp Research Forest	32	87	137	41	155	43	144	123	84	101	-				
12 Thormanby Island	73	19	108	64	71	62	73	76	185	96	105	-			
13 Pacific Spirit Park	20	46	103	7	109	10	100	83	130	72	46	62	-		
14 Pemberton-Douglas Forest Service Road	76	113	197	87	197	86	191	177	76	164	68	131	95	-	
15 Squamish	45	52	154	50	138	46	136	127	128	127	67	69	56	63	-

Interspecific Interactions

Details regarding parasitoids, predators, diseases, or other factors influencing Johnson's Hairstreak, either in BC or elsewhere, remain unknown (James and Nunnallee 2011). Evidence of wings with bite marks on museum specimens and photographs suggests Johnson's Hairstreak is preyed upon by birds and small mammals. Caterpillars are dependent upon Hemlock Dwarf Mistletoe. Mistletoe is pollinated by wind and insects, potentially adult Johnson's Hairstreak (Hawksworth and Wiens 1996).

Many lycaenid butterflies have mutualistic relationships with ants (Formicidae), where the caterpillars secrete liquid containing amino acids and carbohydrates, which the ants consume and in return the ants protect caterpillars from predators and parasitoids (Pierce 1987; Leimar and Axén 1993). While Andrews (2010) reported that Johnson's Hairstreak caterpillars secrete a sugary solution that is used by ants that protect the caterpillars from predators, Fallon and Black (2017) found no documentation of this. Downey (1966) reported that Johnson's Hairstreak pupae stridulate (i.e., make noise by rubbing). It has been hypothesized that stridulation is an auditory signal for symbiotic ants; experts consulted by Fallon and Black (2017) confirmed the "buzzing" of the pupae as well as the possibility of myrmecophily but were not aware of recorded myrmecophily in Johnson's Hairstreak. Additional research is required to confirm the importance of ants in the life cycle of Johnson's Hairstreak.

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Johnson's Hairstreak surveys have focused on recording and confirming occurrences, and documenting natural history and habitat information. Surveys have been by transects through suitable habitat (Table 2) (see **Search Effort**) where maximum abundance on any one date is tallied. Southern Vancouver Island is a butterfly diversity hotspot, and Johnson's Hairstreak is a rarely observed species that attracts the attention of butterfly enthusiasts and naturalists. Numerous observations have been incidental (see Table 2).

Abundance

Johnson's Hairstreak abundance estimates are not available. There are approximately 47 records of the species in Canada since it was first recorded in 1900. The few data available, including maximum counts, are of one or two individuals on a few dates and it is not possible to compare across time (Table 1).

Fluctuations and Trends

There are insufficient data on abundance or distribution of Johnson's Hairstreak to assess fluctuations or trends. The natural population fluctuations in butterflies are a result of factors such as parasites, predators, weather, and distribution and abundance of mistletoe and nectar plants. There is no evidence for extreme population fluctuations based on sites visited in multiple years (Table 2).

Rescue Effect

The closest record in northern Washington (see Fallon and Black 2017) is approximately 60 km south of the closest known record in the lower Fraser Valley. At one time, before widespread logging and urbanization, natural re-establishment from Washington may have been possible. Currently there are few records for Johnson's Hairstreak in northern Washington State. There may be some intervening old growth and late successional second growth (> 81-year-old) forest. Given the few documented sites in Canada, and the fragmentation of intervening older growth and late successional second growth forest habitat, rescue is unlikely.

THREATS AND LIMITING FACTORS

Threats

Threats to Johnson's Hairstreak were assessed based on the IUCN-CMP (International Union for Conservation of Nature–Conservation Measures Partnership) unified threats classification system (see Salafsky *et al.* 2008; Master *et al.* 2012; Open Standard 2016). A brief summary of threats that apply to each subpopulation (Table 6) and results of a threats assessment (Table 7) are discussed below under the IUCN-CMP unified threats classification system headings and numbering scheme. The overall threat impact was High.

Table 6. IUCN-CMP (International Union for Conservation of Nature–Conservation Measures Partnership) unified threats classification system (see Salafsky *et al.* 2008; Master *et al.* 2012; Open Standard 2016) threats potentially applicable to Johnson's Hairstreak (*Callophrys johnsoni*) subpopulations in British Columbia. See Table 8 for threat impact and Threats section for description of threat. Threats not listed are considered not applicable.

Subpopulation Number	Subpopulation Name	Status	IUCN Threat Category Potentially Applicable (see Table 7 and Threats section in body of report)													
			1.1	1.2	1.3	2.1	4.1	4.2	5.3	6.1	7.1	7.3	8.1	9.3	11.1	11.4
Total number of subpopulations where threat applies			4	2	2	2	9	2	10 + 1?	4	15	15	15	15	15	15?
1a, b, c	North Vancouver (Lower Mainland)	Extant	x	x	x		x	x	x – in the watershed	x	x	x	x	x	x	x?
2	Sechelt-Dakota Forest Service Road (Sunshine Coast)	Extant				x	x		x – active tenure		x	x	x	x	x	x?
3	San Juan Ridge (Vancouver Island)	Extant					x		x – active tenure		x	x	x	x	x	x?
4	Stanley Park (Lower Mainland)	Extant								x	x	x	x	x	x	x?
5	Corrigan Creek (Vancouver Island)	Extant					x		x – active tenure		x	x	x	x	x	x?
6	West Vancouver (Lower Mainland)	Historical	x	x	x		x	x	x – in the watershed	x	x	x	x	x	x	x?
7	Nitnat Lake (Vancouver Island)	Historical					x		x – private forest		x	x	x	x	x	x?
8	Robertson River (Vancouver Island)	Historical					x		x – private forest		x	x	x	x	x	x?
9	Hope (lower Fraser Valley)	Historical					x		x – active tenure		x	x	x	x	x	x?
10	Shawnigan Lake (Vancouver Island)	Historical	x			x			x – private forest		x	x	x	x	x	x?
11	Malcolm Knapp Research Forest (lower Fraser Valley)	Extant							not a threat, considers biodiversity values		x	x	x	x	x	x?
12	Thormanby Island (Sunshine Coast)	Extant									x	x	x	x	x	x?
13	Pacific Spirit Park (Lower Mainland)	Extant								x	x	x	x	x	x	x?
14	Pemberton-Douglas Forest Service Road (lower Fraser Valley)	Extant					x		x – active tenure		x	x	x	x	x	x?
15	Squamish	Extant	x						? – surrounding?		x	x	x	x	x	x

Table 7. Johnson's Hairstreak (*Callophrys johnsoni*) threats assessment in Canada. The classification below is based on the IUCN-CMP (International Union for Conservation of Nature–Conservation Measures Partnership) unified threats classification system. For a detailed description of the threat classification system, see Salafsky *et al.* 2008; Master *et al.* 2012; Open Standard 2016. Threats may be observed, inferred, or projected to occur in the near term. Threats are characterized here in terms of scope, severity, and timing. Threat "impact" is calculated from scope and severity. For information on how the values are assigned, see Master *et al.* (2009) and footnotes to this table.

Scientific Name	Johnson's Hairstreak (*Callophrys johnsoni*)
Date:	May 25, 2021
Assessors:	Kristiina Ovaska (Facilitator), Brenda Costanzo (report writer), Dawn Marks (report writer), Jennifer Heron (report writer), David McCorquodale (Arthropods SSC Co-Chair), Jayme Lewthwaite (Arthropods SSC member), Jeremy deWaard (Arthropods SSC member), Sarah Semmler (Arthropods SSC member), Leah Ramsay (Arthropods SSC member), Robert Buchkowski (Arthropods SSC member), Greg Wilson (BC COSEWIC rep), Ian Cruikshank (Parks Canada Agency), Rosana Soares (COSEWIC Secretariat)
References:	

Overall Threat Impact:		**Level 1 Threat Impact Counts**	
Threat Impact		**high range**	**low range**
A	Very High	0	0
B	High	1	1
C	Medium	0	0
D	Low	2	2
Calculated Overall Threat Impact:		High	High
Assigned Overall Threat Impact:		**B = High**	
Impact Adjustment Reasons:		No adjustment	
Overall Threat Comments		Scope based on potential range, rather than on just known subpopulations. Approximately 1944 km^2 for forests > 81 years and ~1011 km2 for forests > 251 years. Some subpopulations in areas expected to be affected by forestry or development.	

Threat		**Impact[1] (calculated)**		**Scope[2] (next 10 Yrs)**	**Severity[3] (10 Yrs)**	**Timing[4]**	**Comments**
1	Residential & commercial development	D	Low	Small (1-10%)	Extreme (71-100%)	High (Continuing)	
1.1	Housing & urban areas	D	Low	Small (1-10%)	Extreme (71-100%)	High (Continuing)	See Threats and Limiting Factors.
1.2	Commercial & industrial areas	D	Low	Small (1-10%)	Extreme (71-100%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Some plans for expansion of industrial and business parks. In Lower Fraser Valley, potentially near Mission, Chilliwack and Hope.
1.3	Tourism & recreation areas		Negligible	Negligible (<1%)	Extreme (71-100%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Demand for recreational areas continues. This threat applies to many of the small natural habitat late successional stage conifer patches that are currently within municipal and regional parks, as well as undesignated provincial lands.
2	Agriculture & aquaculture		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	

Threat		Impact[1] (calculated)		Scope[2] (next 10 Yrs)	Severity[3] (10 Yrs)	Timing[4]	Comments
2.1	Annual & perennial non-timber crops		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	Development of privately held forests into small farms, especially on the Sunshine Coast is possible.
2.2	Wood & pulp plantations						Forest woodlots and woodlot management are included in 5.3.
2.3	Livestock farming & ranching						Not applicable. Cattle grazing is not considered a threat within the range of Johnson's Hairstreak. There do not appear to be crown grazing leases within these areas, although there may be a small number of cattle grazing within some of the lower-elevation areas. There is the possibility of feral sheep or goats throughout some of the sites, and these animals would graze upon the flowers and potentially impact the nectar sources for Johnson's Hairstreak. Because these animals are not owned/managed by a person, the threat of goats/sheep is not scored under this category, and instead under invasive species.
2.4	Marine & freshwater aquaculture						Not applicable.
3	Energy production & mining						
3.1	Oil & gas drilling						Not applicable.
3.2	Mining & quarrying						Not applicable. The potential for new mines is small. There is a proposed copper mine in the Campbell River area, although strong public opposition exists. The footprint of the mine may impact some Western Hemlock and there could be potential Hemlock Dwarf Mistletoe in these areas. There are currently no records of Johnson's Hairstreak from this area. There is potential for expansion of the existing gravel pit in the Sechelt area, although the impact to any Western Hemlock is likely small.
3.3	Renewable energy						Not applicable. The probability of solar energy or wind turbine construction within the area is unlikely. Johnson's Hairstreak is not impacted by light pollution.
4	Transportation & service corridors						
4.1	Roads & railroads						Not likely. Logging roads included in 5.3.
4.2	Utility & service lines						Not applicable. New utility and service lines, as well as maintenance of those lines, are historical threats. Utility and service lines are maintained as open habitats, so tree growth is limited.
4.3	Shipping lanes						Not applicable.
4.4	Flight paths						Not applicable.
5	Biological resource use	B	High	Large (31-70%)	Extreme (71-100%)	High (Continuing)	

Threat		Impact[1] (calculated)		Scope[2] (next 10 Yrs)	Severity[3] (10 Yrs)	Timing[4]	Comments
5.1	Hunting & collecting terrestrial animals						Not applicable. The potential for butterfly collectors to capture this species is considered low. It is difficult to find, and observations are typically a few at one time.
5.2	Gathering terrestrial plants						Not applicable. Hemlock Dwarf Mistletoe blooms wither very quickly after being cut or disconnected from their host. Not likely sought after for floral displays people do not collect mistletoe.
5.3	Logging & wood harvesting	B	High	Large (31-70%)	Extreme (71-100%)	High (Continuing)	See Threats and Limiting Factors.
5.4	Fishing & harvesting aquatic resources						Not applicable.
6	Human intrusions & disturbance		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	
6.1	Recreational activities		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	Recreational activities that could trample nectar plants and disturb foraging adults are highest in the lower mainland and lower Fraser Valley areas (#1, 4, 6, 10, 12, 13, 15). In both Stanley Park (#4) and Pacific Spirit Park (#13) impacts from recreation are mitigated by strong bylaws and enforcement. This threat is considered negligible.
6.2	War, civil unrest & military exercises						Not applicable. There are no records from military bases within the range of Johnson's Hairstreak, although there are pockets of old growth and late successional second growth forests within some military lands. Inventory is needed.
6.3	Work & other activities		Negligible	Negligible (<1%)	Extreme (71-100%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Hemlock Dwarf Mistletoe can weaken the host tree and cause deformities, infected branches and heavy brooms frequently break due to decay, and the branches and trees are susceptible to blow-down. These trees present a safety hazard in high-use public areas, and are frequently removed. The threat is considered negligible because removal of one or two trees in select areas is not likely to cause subpopulation extirpation. Applicable to #1, 11, 4.
7	Natural system modifications		Unknown	Small (1-10%)	Unknown	High (Continuing)	
7.1	Fire & fire suppression		Unknown	Small (1-10%)	Unknown	High (Continuing)	Wildfires occur throughout the range of Johnson's Hairstreak although wildfire suppression programs have been in place for the past 150 years. Wildfire suppression programs likely benefit the species, because older trees that may otherwise perish within wildfires are able to grow older and gain the old growth and late successional second growth attributes. Hemlock Dwarf Mistletoe can spread within the tree and eventually produce fruiting bodies.
7.2	Dams & water management/use						Not applicable.

Threat		Impact[1] (calculated)		Scope[2] (next 10 Yrs)	Severity[3] (10 Yrs)	Timing[4]	Comments
7.3	Other ecosystem modifications						Conversion of stands from Western Hemlock to other trees scored under logging. Increase in non-native flowers on disturbed sites may influence natural nectar plants, but lots of uncertainty.
8	Invasive & other problematic species & genes		Unknown	Small (1-10%)	Unknown	High (Continuing)	
8.1	Invasive non-native/ alien species/ diseases		Unknown	Small (1-10%)	Unknown	High (Continuing)	See Threats and Limiting Factors. The spread of invasive plants is scored under 7.3 Other ecosystem modifications.
8.2	Problematic native species/diseases						Not applicable.
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	D	Low	Small (1-10%)	Extreme - Serious (31-100%)	High (Continuing)	
9.1	Domestic & urban wastewater						Not applicable.
9.2	Industrial & military effluents						Not applicable.
9.3	Agricultural & forestry effluents	D	Low	Small (1-10%)	Extreme - Serious (31-100%)	High (Continuing)	See Threats and Limiting Factors.
9.4	Garbage & solid waste						Not applicable.
9.5	Air-borne pollutants						Not applicable.
9.6	Excess energy						Not applicable.
10	Geological events						
10.1	Volcanoes						Not applicable.
10.2	Earthquakes/ tsunamis						Not applicable.
10.3	Avalanches/ landslides						Not applicable.
11	Climate change & severe weather		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	
11.1	Habitat shifting & alteration		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	As climate warms there may be a shift in the range of Western Hemlock and Hemlock Dwarf Mistletoe. This needs further study.
11.2	Droughts		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	See Threats and Limiting Factors.
11.3	Temperature extremes		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	See Threats and Limiting Factors.

Threat		Impact[1] (calculated)	Scope[2] (next 10 Yrs)	Severity[3] (10 Yrs)	Timing[4]	Comments
11.4	Storms & flooding	Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	Increase in scope and severity of winter storms and blowdown (e.g., Stanley Park windstorm in 2006).
11.5	Other impacts					

[1]**Impact** – The degree to which a species is observed, inferred, or suspected to be directly or indirectly threatened, in the area, of interest. The impact of each stress is based on Severity and Scope rating and considers only present and future threats. Threat impact reflects a reduction of a species population or decline/degradation of the area of an ecosystem. The median rate of population reduction or area decline for each combination of scope and severity corresponds to the following classes of threat impact: very high (75% declines), high (40%), medium (15%), and low (3%). Unknown: used when impact cannot be determined (e.g., if values for either scope or severity is unknown).

[2]**Scope** – Proportion of the species that can reasonably be expected to be affected by the threat within 10 years. Usually measured as a proportion of the species' population in the area of interest. (Pervasive = 71–100%; Large = 31–70%; Restricted = 11–30%; Small = 1–10%)

[3]**Severity** – Within the scope, the level of damage to the species from the threat that can reasonably be expected to be affected by the threat within a 10-year or three-generation timeframe. Usually measured as the degree of reduction of the species' population (Extreme = 71–100%; Serious = 31–70%; Moderate = 11–30%; Slight = 1–10%).

[4]**Timing** – High = continuing; Moderate = only in the future (could happen in the short term [< 10 years or 3 generations]) or now suspended (could come back in the short term); Low = only in the future (could happen in the long term) or now suspended (could come back in the long term); Insignificant/Negligible = only in the past and unlikely to return, or no direct effect but limiting.

In summary, forest management which aims to reduce Hemlock Dwarf Mistletoe, and ongoing reduction of older growth hemlock stands are the primary threats to Johnson's Hairstreak. Additional threats include habitat conversion to urban and agricultural development and use of *Bacillus thuringiensis* var. *kurstaki* (Btk) to control Lepidoptera pests. Threats of unknown impact include alteration to fire regimes, invasive insects and impacts of climate change on host plant distribution and abundance.

5. Biological resource use (High threat impact)

5.3 Logging & wood harvesting (High threat impact)

The highest impact threat to Johnson's Hairstreak and potential habitat is logging through the removal of older growth and late successional second growth (> 81 years) forests throughout the Coastal Western Hemlock BGZ in southwestern BC. At present, approximately 4329 km^2 of old growth and late successional second growth (> 81 years) habitat remains within the potential range of Johnson's Hairstreak (Table 4; Figure 6; see **Habitat Trends**).

Logging and forest management recommendations that limit the spread of Hemlock Dwarf Mistletoe (see Rusch *et al*. 2019) are effectively reducing the potential future habitat for Johnson's Hairstreak and can be used to infer and project a decline in potential future Johnson's Hairstreak habitat (see Habitat Trends and management options in Rusch *et al*. 2019). Forest management approaches that result in reduced mistletoe include 1) general or targeted removal of mistletoe-infected trees (e.g., clearcut harvesting, partial harvesting with selective removal of infected trees) and 2) historical silvicultural practices that have resulted in stand conditions that are not conducive to mistletoe growth/establishment (e.g., clearcutting followed by even-aged planting).

Clearcut harvesting involves cutting most of the standing trees. Typically, larger old growth trees are left standing, with the purpose of future or ongoing nesting, denning and other wildlife habitat values. However, if these trees pose a safety concern during harvesting (e.g., they are overly rotten, leaning towards a work zone or at risk of blowdown during harvest operations), they may be cut regardless.

Partial harvesting removes only select trees (e.g., age class, species, or a mixture of objectives), to retain ecological values. This silvicultural practice allows for increased light, variable stand height, structure, and composition, and in the longer term enables the spread and establishment of Hemlock Dwarf Mistletoe seeds. However, when Hemlock Dwarf Mistletoe is present in a stand to be harvested, site prescriptions often call for removal of all Western Hemlock trees (e.g., rather than leaving scattered trees for wildlife values) such that post-harvest silviculture costs are minimized (Rusch *et al.* 2019). This management recommendation is considered the best way to reduce future loss of timber value due to mistletoes (Rusch *et al.* 2019).

Woodlots are also included in this threat category. In BC a woodlot is defined as a holding greater than 20 ha of forest. There are two types of woodlots in the province: privately owned, and a form of area-based tenure awarded by the Province of BC under a woodlot licence as a partnership between the province and the licence holder. Coastal licences (e.g., within the range of Johnson's Hairstreak) have an 800-ha maximum amount of crown land.

There are 345 managed licence polygons (woodlot: 204, community forest: 82, First Nation woodlands: 59) within the potential range of Johnson's hairstreak, totalling 22,863 ha of remaining potential habitat (> 81 years) (data extracted from Federation of BC Woodlot Associations 2020).

Woodlots are managed for timber production, and because Hemlock Dwarf Mistletoe parasitized trees are not of high economic value, management actions (e.g., removal of trees and/or limiting the spread of Hemlock Dwarf Mistletoe) would limit natural mistletoe spread and growth throughout the woodlot or adjacent areas. Deciduous pulp plantations are short-rotation (e.g., < 41 years) and are unlikely to have Western Hemlock. Areas with high mistletoe growth could potentially be cleared (logged) and then replanted with deciduous and/or non-host trees, thus reducing future habitat for the hairstreak.

Of the ten extant subpopulations, four are within forests with active logging (#2,3,5,14) and three are within areas with adjacent logging (#1,6,11). Four of the five historical subpopulations (#7,8,9,10) are on private land. Although the precise sites are unknown, two are from areas historically part of the forest insect and disease surveys (#7,8) and it is inferred these areas could still be within private forestland.

The Malcolm Knapp Research Forest (#11) is a privately managed forest with 5157 ha of private land belonging to the University of British Columbia and a 220 ha Woodlot Licence with the provincial government. Management of this woodlot includes biodiversity values (Lawson pers. comm. 2021) and logging is considered a negligible threat.

Two subpopulations are within active Tree Farm Licences (TFL) (#3 is within TFL61 and #5 is within TFL44). TFL61 occupies 20,240 ha of land, of which 14,477 hectares is within the timber harvesting land base. The allowable annual cut (AAC) is 121,000 cubic metres (Berg 2019). Typical coastal old growth sites can yield as much as 1,500 to 1,800 cubic metres per hectare; second growth forests yield approx. 500-600 cubic metres per hectare (second growth are > 81 years but typically < 121 years). Approximate spatial habitat loss = 67-242 ha/year = 0.5-2% of the land base. TFL44 occupies 141,566 ha of land, of which 80,409 ha are in the timber harvesting land base. The AAC is 645,000 m^3/year (Nicholls 2020). Approximate spatial habitat loss = 358 - 1290 ha/year = 2-9% of the land base.

1. Residential and commercial development (Low threat impact)

1.1 Housing and urban areas (Low threat impact)

Approximately 15% of Johnson's Hairstreak's range lies within densely human-populated parts of the province (e.g., lower mainland). Most urban and rural development is historical and those pockets of habitat that remain within these urban areas are within protected areas (e.g., #1, 4, 11). Natural old growth and late successional stage coniferous forest habitats, large ravines, and riparian areas are habitat for Johnson's Hairstreak in these areas. Some of these areas contain coniferous trees > 81 years old with mistletoe. Lower elevation (< 625 m) forests of the Sunshine Coast and southeastern Vancouver Island are largely privately owned by large land holding companies. There is ongoing pressure to develop this land into rural properties and new subdivisions, which would likely remove trees with Hemlock Dwarf Mistletoe. In addition, the southern west coast of Vancouver Island near Jordan River (near one locality for Johnson's Hairstreak) and Port Renfrew are former forest lands that are currently being converted to residential developments. This threat applies to potential habitat, and portions of subpopulations #1, 6 and 10.

9. Pollution (Low threat impact)

9.3 Agricultural and forestry effluents (Low threat impact).

Aerial spray to control Spongy Moth

Spongy Moth, *Lymantria dispar dispar* (formerly known as European Gypsy Moth and LDD) is a non-native/invasive moth that has the potential to cause mass defoliation to over 100 different tree and shrub species in BC, including Western Hemlock. The moth is a threat to forests throughout much of eastern North America, although it has not established in western North America. The provincial Spongy Moth control program runs a network of

detection traps. Small numbers of the moth are detected yearly (BC Ministry of Forests, Lands and Natural Resource Operations 2021) and Spongy Moth is often recorded within the range of Johnson's Hairstreak.

A provincial Spongy Moth eradication program has been ongoing since 1997 and the species has not become established in BC (BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development 2021). The species may be controlled through the aerial application of Btk. Spores of this naturally occurring bacteria are a component of commercial products to control defoliating caterpillars including Spongy Moth. Btk causes direct mortality to most caterpillars and is applied in early April to early May in BC, which coincides with the feeding period of Johnson's Hairstreak caterpillars and therefore could cause direct mortality to this species. The Spongy Moth aerial spray program in BC is focused on areas where Spongy Moth has been detected for a minimum of two years and appears to be spreading. Therefore, spray programs have been targeted and mostly in urban areas. The subpopulations with the highest threat of Btk spray are those in urban areas, including Stanley Park (#4), Pacific Spirit Park (#13), North Vancouver (#1), and a historical subpopulation, West Vancouver (#6). The Spongy Moth spray eradication program of Btk in BC has not included subpopulations.

Aerial spray for Western Hemlock Looper (*Lambdina fiscellaria lugubrosa*)

Western Hemlock Looper is a defoliator of Western Hemlock forests. Documentation of outbreaks started in 1911, and data show outbreaks can occur every 11 to 20 or more years, lasting two to three years. Recent outbreaks have occurred within the past 20 years in the North Shore and Sunshine Coast. Aerial spray programs of Btk for long-term forestry management can be initiated by the Province of BC to decrease the defoliation of Western Hemlock (Province of British Columbia n.d.) and if Btk is sprayed it likely causes direct mortality to Johnson's Hairstreak.

Roadside herbicide spray

Herbicide spray may be applied to control both native and non-native vegetation growing adjacent to and encroaching upon forest service roads. Herbicide spray would affect flowering nectar plants during the adult flight period (e.g., May – July). This threat is potentially applicable to subpopulations #2, 3, 5, 7, 9, 15 and surrounding habitats; these subpopulations are within areas managed for timber production and other subpopulations are within protected areas and/or are historical.

Chemical application to control Hemlock Dwarf Mistletoe

Chemical management to suppress Hemlock Dwarf Mistletoe may limit the abundance of Johnson's Hairstreak (Pyle 1989; Washington Department of Fish and Wildlife 1995). Chemical control has been investigated in Canada (Unger 1992; Zeglen pers. comm. 2021); however, the chemical used is not registered for use in BC. The chemical application to the stems of the mistletoe causes the mistletoe aerial shoots to drop off the tree, but the chemical does not kill any of the material inside the branch (Zeglen pers. comm. 2021). Fungal biocontrol for Hemlock Dwarf Mistletoe has been investigated; however, the commercial application was not developed further (Zeglen pers. comm. 2021).

7. Natural system modifications (Unknown threat impact)

7.1 Fire and fire suppression (Unknown threat impact)

Johnson's Hairstreak range is in the coastal temperate rainforests which have high rainfall (summarized in Alaback 1996). Large stand-replacing fires typically recur on average every 350-1000 years (Gavin *et al*. 2001; Daniels and Gray 2006), and average of 100-350 years in CDF zones (Parminter 2003). Historically, wildfire was not a threat; however, with fire suppression and climate change, wildfire is likely to increase.

Southern BC is expected to become warmer and drier (with climate change) and will experience more frequent, severe and extensive fires, leading to more area burned (Hawkes 2005; Spittlehouse 2008). Accidental fire by discarded cigarettes, unattended campfires, or vehicles in dry vegetation is a serious threat. Over the past 100 years, fire suppression programs have altered the natural fire regime in the CDF BGZ (Coastal Douglas Fir and associated Ecosystems Conservation Partnership Conservation Strategy 2015) within the range of Johnson's Hairstreak.

Fires in Hemlock Dwarf Mistletoe-infected stands also play a role in the conservation of Johnson's Hairstreak, as they can either limit the distribution of Hemlock Dwarf Mistletoe or favour the spread of the species, depending on the intensity and pattern of the fire (Shaw *et al.* 2004). Small-scale disturbance fires can assist in the spread of Hemlock Dwarf Mistletoe as small gaps can spread fruiting bodies to younger trees that grow in the new gaps. Large stand-replacing fires can remove Hemlock Dwarf Mistletoe (Hennon *et al.* 2001).

Fire suppression may have led to an increase in the distribution and abundance of Hemlock Dwarf Mistletoe in the United States (Fallon and Black 2017). Hemlock Dwarf Mistletoe brooms can act as fuel ladders and be a fire hazard. Forest managers recommend brooms be pruned to prevent the spread of fire as well as increase the quality of the wood (Rusch *et al*. 2019).

8. Invasive and other problematic species and genes (Unknown threat impact)

8.1 Invasive non-native/alien species (Unknown threat impact)

Compsilura concinnata (Diptera: Tachinidae) is a non-native parasitic fly introduced into eastern North America in the early 1900s as biological control agent for Spongy Moth. This fly now parasitizes more than 100 native moths and butterflies in North America and may parasitize Johnson's Hairstreak (Boettner *et al.* 2000) in BC (GBIF Secretariat 2019).

11. Climate Change and severe weather (Unknown threat impact)

11.2 Droughts (Unknown threat impact)

Changes to the intensity, frequency, and longevity of droughts could impact the long-term survival and abundance of host plants. Reduced summer moisture due to climate change could increase fire frequency and severity (Hebda 1997) which could cause large stand-disturbance fires that would remove Hemlock Dwarf Mistletoe (Rusch *et al.* 2019).

11.3 Temperature extremes (Unknown threat impact)

Climate change is expected to change the range and reproductive success of Hemlock Dwarf Mistletoe (Rusch *et al.* 2019); warm temperatures are expected to increase the range and cold temperatures may reduce the reproductive success and geographic range of mistletoes (Smith and Wass 1986; Kliejunas *et al.* 2009). The latitudinal range and elevational range of Hemlock Dwarf Mistletoe is predicted to expand with increasing temperatures and reduced snowfall based on a model for southeast Alaska (Barrett *et al.* 2012).

Limiting Factors

Limiting factors are generally not human-induced and include innate biological characteristics. The main limiting factors for Johnson's Hairstreak are likely a combination of the following:

Caterpillar host plant specificity

Johnson's Hairstreak is dependent on Hemlock Dwarf Mistletoe to complete its life cycle (see **Habitat**).

Morphological attributes

Adults forage for nectar opportunistically. Their short tongue length limits them to flowers with short corollas and may limit abundance.

Small population, host plant abundance and patch size

Johnson's Hairstreak subpopulations are small, isolated, and limited to habitat patches. The average host plant patch size is unknown; however, the size of the host plant patch may limit the subpopulation within a given habitat (Spiegel 2014).

Vulnerability to weather patterns

The previous year's weather affects the abundance of the next year's generation of butterflies. Extremes in frost, temperature, humidity, and precipitation affect survival at all life stages. These factors also contribute to emergence of the next year's generation. In old growth stands where Hemlock Dwarf Mistletoe has parasitized trees for decades, trees are weakened, and branches are susceptible to windthrow and breakage. Should the tree fall, or branches break, Hemlock Dwarf Mistletoe withers and dies. Overwintering pupae would likely survive and emerge as butterflies the following spring. However, if the tree blew over or branches broke during the caterpillar feeding period, the caterpillars would not survive.

Limited dispersal capability

*J*ohnson's Hairstreak is small and does not likely disperse long distances, especially through unsuitable habitats. Isolated subpopulations may lead to decreased genetic diversity, greater genetic differences, and inbreeding depression.

Number of Locations

The highest threat to Johnson's Hairstreak subpopulations and potential habitat is logging of old growth and late successional second growth (> 81 years) forests. Eleven of the 15 known Johnson's Hairstreak subpopulations (extant and historical) are potentially at risk from logging (#1, 2, 3, 5, 6, 7, 8, 9, 11, 14, 15). Five of the ten extant subpopulations are within areas of ongoing logging (#1, 2, 3, 6, 14) and each represents a separate location (see Tables 6 and 7 for applicable threats). There are likely additional undocumented Johnson's Hairstreak subpopulations in Canada, with the total likely around 15.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

Federal protection

Johnson's Hairstreak is known from Stanley Park (#4), which is owned by Parks Canada Agency and managed by the City of Vancouver. COSEWIC assessed the species as Special Concern in May 2022. It is not listed under the *Species at Risk Act* (SARA).

Provincial Protection

In BC, there are several acts that protect species at risk in the province. The three main acts with provisions applicable to Johnson's Hairstreak are: the BC *Protected Areas Act*, the *Forest and Range Practices Act,* and the *Oil and Gas Activities Act*.

BC *Protected Areas Act* (Province of British Columbia 2000) protects invertebrate species at risk (provincially assessed as Red or Blue-listed by the BC CDC) in provincial parks and protected areas. When species at risk and the habitats they require are known to occur within a protected area, provisions for management are incorporated into the park master plan (if the park has a written and approved Master Plan). Provincial parks staff within the range of Johnson's Hairstreak are aware of the species and its provincial at-risk status (see **Non-legal Status and Ranks**). Johnson's Hairstreak is not recorded from any provincial protected areas (Table 1). However, the species has been recorded from Thormanby Island (#12) and there is potential habitat in the two provincial parks on the island: Buccaneer Provincial Park and Simson Provincial Park. When scientific research permits and other activities within parks and protected areas are proposed, parks staff consider adverse impacts from proposed activities on the butterfly and its habitat (Hirner pers. comm. 2021; McClaren pers. comm. 2021).

Forest and Range Practices Act and Oil and Gas Activities Act

The Identified Wildlife Management Strategy (IWMS) is an initiative from 1999 by the Ministry of Environment in partnership with the Ministry of Forests and Range (in consultation with other stakeholders) (see Province of British Columbia 2002). The IWMS goals are to 'minimize the effects of forest and range practices on Identified Wildlife situated on Crown land'. Under the *Forest and Range Practices Act*, the Minister responsible for the *Wildlife Act* (e.g., Minister of Environment) is authorized to establish two categories of wildlife which require special management attention to address the impacts of forest and range activities on Crown land. The Category of Species at Risk includes 'endangered, threatened, or vulnerable species of vertebrates and invertebrates, and endangered or threatened plants and plant communities that are negatively affected by forest or range management on Crown land and are not adequately protected by other mechanisms.' This Category applies to Johnson's Hairstreak butterfly (see Johnson's Hairstreak species account in BC Ministry of Water, Land and Air Protection 2004). The second Category, Regionally Important Wildlife category, does not apply to Johnson's Hairstreak. These same categories of Species at Risk and Identified Wildlife apply under the provincial *Oil and Gas Activities Act* (Province of British Columbia 2008).

Identified Wildlife are managed through the establishment of wildlife habitat areas (WHAs) and the implementation of general wildlife measures (GWMs) and wildlife habitat area objectives. Johnson's Hairstreak is listed as Identified Wildlife (BC Ministry of Water, Land and Air Protection 2004); however, no Wildlife Habitat Areas have been created to protect the species (BC Ministry of Environment 2021).

In the United States, Johnson's Hairstreak is classified as a Sensitive Species by Region 6 of the Forest Service and Oregon/Washington Bureaus of Land Management (Interagency Special Status/Sensitive Species Program 2015a, 2015b).

Non-Legal Status and Ranks

The conservation status ranks for Johnson's Hairstreak (NatureServe 2021):

- Global G3 (Vulnerable) (last reviewed Nov 2017)
- Canada N1N2 (Critically Imperilled/Imperilled)
- British Columbia S1S2 (Critically Imperilled/Imperilled) (BC CDC 2021)
- United States N3N4 (Vulnerable/Apparently Secure)
- Subnational state ranks California (SNR – status unranked), Oregon (S3), Washington (S2S3), Idaho (S1) (NatureServe 2021).

Johnson's Hairstreak has not been assessed using IUCN Red-list criteria (IUCN 2016).

Habitat Protection and Ownership

Most Johnson's Hairstreak subpopulations are on provincial land. The species is recorded from Stanley Park (Worcester and Johnstone 2007; Worcester and Titaro 2012), a municipal park managed by the City of Vancouver, on land owned by Parks Canada. Metro Vancouver regional district manages portions of subpopulations #1, 6, and 13. One subpopulation is likely within a provincial park (#12). Land ownership is listed in Table 1.

In BC, non-government conservation organizations, such as The Nature Trust of BC (McNaughton pers. comm. 2021), the South Coast Conservation Program, Salt Spring Conservancy, Garry Oak Ecosystems Recovery Team, and Stanley Park Ecological Society work with lands managers and/or private landowners to protect butterfly species at risk. Should additional information become available on Johnson's Hairstreak, these organizations may initiate stewardship actions.

ACKNOWLEDGEMENTS

Thank you to the BC Ministry of Environment and Climate Change Strategy (ENV) for providing time and resources to complete this report. The following people provided scientific information and advice: Denis Knopp, Dennis St. John, Katie Calon, Claudia Copley, Lea Gelling, Leah Ramsay, Cris Guppy, Norbert Kondla, Jeremy Gatten, Mike Yip, James Miskelly, Jeremy Tatum, Pascale Archibald, Shelley Pruss, Markus Merkens, Adam Braz, Jasmine Carlin, Sean Nightingale, Purnima Govindarajulu, and Manjit Kerr-Upal. Pascale Archibald completed 2021 surveys during preparation of this status report.

Claudia Copley (Royal BC Museum, Victoria) and Karen Needham (Spencer Entomological Collection, Beaty Biodiversity Museum at the University of British Columbia) provided access to museum specimens. Greg Amos (ENV) completed habitat mapping/modelling and habitat statistics for the species.

Members of the Arthropods Specialist Subcommittee (Robert Buchkowski, Syd Cannings, Jeremy deWaard, Allan Harris, Colin Jones, John Klymko, Jayme Lewthwaite, Jessica Linton, Jeff Ogden, Leah Ramsay, John Richardson, Michel Saint-Germain, Sarah Semmler, Brian Starzomski, Myrle Ballard [ATK subcommittee], Dan Benoit [ATK subcommittee] and individuals from the range jurisdictions reviewed early drafts of this report and provided numerous comments. David McCorquodale (Arthropods SSC Co-chair), Rosana Nobre Soares (COSEWIC Secretariat) and Joanna James (COSEWIC Secretariat) edited and oversaw the report.

Cover photograph of Johnson's Hairstreak (*Callophrys johnsoni*), Pacific Rim Regional Park, Vancouver, BC, May 29, 2007, by Michelle Connolly. Thank you to David McCorkle and Raymond Davis for permission to use their respective photographs in this report.

AUTHORITIES CONTACTED

Anderson, Robert. Curator. Canadian Museum of Nature, Ottawa, Ontario.

Archibald, Pascale. Entomologist. British Columbia Conservation Foundation, Victoria, British Columbia.

Cannings, Syd. Canadian Wildlife Service, Environment and Climate Change Canada, Whitehorse, Yukon Territory.

Copley, Claudia. Entomology Collections Manager, Royal British Columbia Museum, Victoria, British Columbia.

Davis, Raymond. Monitoring Lead – Older Forests & Spotted Owls, Forest Service Region 6 – Pacific Northwest Region, Corvallis, Oregon.

Fraser, David (retired). Ecosystems Branch, BC Ministry of Environment and Climate Change Strategy, Victoria, British Columbia.

Fyson, Andrew. Lepidopterist, Denman Island, British Columbia.

Gatten, Jeremy. Lepidopterist, Victoria, British Columbia.

Gelling, Lea. Program Zoologist, BC CDC, Victoria, British Columbia.

Goulet, Gloria. Co-chair Aboriginal Traditional Knowledge COSEWIC Subcommittee, Manitoba.

Govindarajulu, Purnima. Unit Head, Species at Risk Conservation Unit, Ecosystems Branch, BC Ministry of Environment and Climate Change Strategy, Victoria, British Columbia.

Guppy, Crispin. Lepidopterist, Whitehorse, Yukon Territory.

Hirner, Joanna. Conservation Specialist, Parks and Protected Areas, North Vancouver, British Columbia.

Holden, David. Western Area Survey Biologist, Canadian Food Inspection Agency, Burnaby, British Columbia.

Esme, John. Research Biologist. Pacific Forestry Centre, Canadian Forest Service, Natural Resources Canada, Victoria, British Columbia.

Knopp, Denis. BC's Wild Heritage Consulting, Sardis, British Columbia.

Kondla, Norbert. Lepidopterist, Calgary, Alberta.

Lilley, Patrick. Biologist, North Vancouver, British Columbia.

McClaren, Erica. Conservation Specialist, Parks and Protected Areas, Black Creek, British Columbia.

Miskelly, James. Independent entomologist, Victoria, British Columbia.

Needham, Karen. Spencer Entomological Collection, Beaty Biodiversity Museum at the University of British Columbia, Vancouver, British Columbia.

Neilson, Joanne. Executive Director, Fraser Valley Conservancy, Mission, British Columbia.

Page, Nick. Biologist, Raincoast Applied Ecology, Courtenay, British Columbia.

Penny, Jenifer. Program Botanist, BC CDC, Victoria, British Columbia.

Pohl, Greg. Insect/Disease Identification Officer, Northern Forestry Centre, Northwest Edmonton, Alberta.

Ramsay, Leah (retired). Program Zoologist, BC Conservation Data Centre, Ecosystems Branch, BC Ministry of Environment and Climate Change Strategy, Victoria, British Columbia.

Richardson, John. Professor. Faculty of Forestry, University of British Columbia, Vancouver, British Columbia.

St. John, Dennis. Private Entomologist, Agassiz, British Columbia.

Swan, John. Curator. University of Calgary, Alberta.

Tatum, Jeremy. Private Lepidopterist, Victoria, British Columbia.

Yip, Mike. Nature photographer, Nanoose Bay, British Columbia.

Zack, Richard. Department of Entomology, Washington State University, Pullman, Washington USA.

Zeglen, Stefan. Forest Pathologist, BC Ministry of Forests, Lands, Resource Operations and Rural Development, Nanaimo, British Columbia.

Zevit, Pamela. Biodiversity Conservation Planner, Surrey Parks-Urban Forestry, Surrey, British Columbia.

INFORMATION SOURCES

Alaback P.B. 1996. Biodiversity Patterns in Relation to Climate: The Coastal Temperate Rainforests of North America. In: Lawford R.G., Fuentes E., Alaback, P.B. (eds) High-Latitude Rainforests and Associated Ecosystems of the West Coast of the Americas. Ecological Studies (Analysis and Synthesis), vol 116. Springer, New York, New York.

Alfaro, R. 1985. Survey and appraisal of dwarf mistletoe in second growth western hemlock. *In* Proceedings of a Workshop on Management of Hemlock Dwarf Mistletoe, Aug. 15-16, 1983. J. Muir (editor). BC Ministry of Forests, Burnaby, BC Forest Pest Management Report No. 4, Pp. 10-21.

Amos, G., pers. comm. 2021. *Oral and email communication with Jennifer Heron*. BC Ministry of Environment and Climate Change Strategy

Andrews, H. 2010. Species fact sheet: Johnson's hairstreak (*Callophrys johnsoni*) Interagency Special Status/Sensitive Species Program. (Revised in August 2011 by Rob Huff to update documented status for National Forests and BLM Districts.

Art Sharpiro's Butterfly Site. 2021. *Mitoura johnsoni* webpage. Information Center for the Environment (ICE). University of California, Davis. [accessed February 18, 2021].

British Columbia Conservation Data Centre (BC CDC). 2021. BC Species and Ecosystems Explorer: Johnson's Hairstreak. BC Ministry of Environment, Victoria, British Columbia. [accessed February 12, 2021].

British Columbia Ministry of Environment and Climate Change Strategy. 2021. Approved wildlife habitat areas. BC Min. Environ., Victoria, BC [accessed February 12, 2021].

British Columbia Ministry of Forests, Lands and Natural Resource Operations. 2021. Spongy Moth in British Columbia. . [accessed February 12, 2021].

British Columbia Ministry of Forests, Lands and Natural Resource Operations. 2021. Western Hemlock Looper. [accessed October 12, 2021].

British Columbia Ministry of Forests. 2009. Biogeoclimatic Ecosystem Classification, Zone and Provincial Classification Reports. [accessed February 12, 2021].

British Columbia Ministry of Water, Land and Air Protection. 2004. Procedures for managing identified wildlife. Version 2004. BC Min. Water, Land and Air Protection, Victoria, BC [accessed February 12, 2021].

British Columbia Ministry of Water, Land and Air Protection. 2004. IWMS report for Johnson's Hairstreak. [accessed July 6, 2021].

Ballmer, G.R. and G.F. Pratt. 1992. *Loranthomitoura*, a new genus of Eumaeini (Lepidoptera: Lycaenidae: Theclinae). Tropical Lepidoptera. 3:37-46.

Baranyay, J.A. and R.B. Smith. 1972. Dwarf mistletoes in British Columbia and recommendations for their control. Canadian Forestry Service, Pacific Forest Research Centre, Victoria, British Columbia.

the beczone. 2022. Distribution of Hemlock Dwarf Mistletoe in British Columbia (spatial files). Forest Health dataset. [accessed March 1, 2022].

Berg, S. 2019. British Columbia Ministry of Forests, Lands, Natural Resource Operations and Rural Development Tree Farm Licence 61 held by Pacheedaht Anderson Timber Holdings Limited Partnership rationale for Allowable Annual Cut (AAC) Determination effective October 31, 2019. [accessed March 3, 2022].

Buck, M., pers. comm. 2020. *Email correspondence with Jennifer Heron*. Assistant Curator, Invertebrate Zoology, Royal Alberta Museum, Edmonton, Alberta.

Canadian Council on Ecological Areas. 2014. Ecozones of Canada. Available at [accessed February 12, 2021].

Coastal Douglas Fir and associated Ecosystems Conservation Partnership Conservation Strategy. 2015. Coastal Douglas Fir and associated Ecosystems Conservation Partnership Conservation Strategy 2015.

Canadian Forest Service. 1965. Annual Districts Reports Forest insect and disease survey in 1964, British Columbia. Interim report, Forest Research Laboratory, Victoria, British Columbia. 342 pp.

Canadian Forestry Service. 1977. Annual districts reports forest insect and disease survey in 1976, Part 1, Vancouver Forest District 1 - British Columbia. Edited by E. V. Morris and C. S. Wood, Pacific Forest Research Centre, Victoria, British Columbia. 40 pp.

Connolly, M. 2007. Surveys for Johnson's Hairstreak (*Callophrys johnsoni*) at historical sites in British Columbia. Completed under contract to the BC Ministry of Water, Land and Air Protection, UBC Campus, 2202 Main Mall, Vancouver, British Columbia. 5 pp.

Copley, C., pers. comm. 2020. *Phone and email communication with Jennifer Heron and Dawn Marks*. Collections Manager, Royal British Columbia Museum, Victoria, British Columbia.

Daniels, L.D., and R.W. Gray. 2006. Disturbance regimes in coastal British Columbia. Journal of Ecosystems and Management 7:44–56.

Davis R., D. McCorkle, and D. Ross. 2011. Survey protocol (v1.2) for Johnson's hairstreak butterfly (*Callophrys johnsoni*) in Washington and Oregon. Interagency Special Status Sensitive Species Program. [accessed February 18, 2021].

Downey J. C. 1966. Sound production in pupae of Lycaenidae. Journal of the Lepidopterists' Society 20:129-155.

Entomological Society of Canada. 2022. Entomological Society of Canada adopts spongy moth as new common name for *Lymantria dispar* [accessed March 2, 2022].

Esme, J., pers. comm. 2022. *Email and verbal communication to Jennifer Heron*. Research Biologist. Pacific Forestry Centre, Canadian Forest Service, Natural Resources Canada, Victoria, British Columbia.

Fallon, C., and S. H. Black. 2017. Conservation Assessment for Johnson's Hairstreak (*Callophrys johnsoni* Skinner 1904). Prepared for USDA Forest Service Region 6 and USDI Bureau of Land Management, Oregon, and Washington. 49 pp.

Federation of British Columbia Woodlot Associations. 2020. [accessed February 13, 2022].

Fenneman, J.D. 2007. Butterfly inventory of Gulf Islands National Park Reserve. Report by LGL Limited environmental research associates for the BC Ministry of Environment, Vancouver, BC 62 pp.

Geils, B.W., and F.G. Hawksworth. 2002. Damage, effects, and importance of dwarf mistletoes. In: Mistletoes of North American conifers. B.W. Geils, J.C. Tovar, and B. Moody (technical co-ordinators). General Technical Report RMRS-GTR-98U.S. Department of Agriculture. Forest Service, Fort Collins, Colorado.

Grant, M. 2004. Final Report for Survey of Butterflies at Risk in Greater Vancouver Regional District Lands/Parks (Project File #: CAT04-2-310). BC Ministry of Environment, Lands and Parks, UBC Campus, 2202 Main Mall, Vancouver, British Columbia. 5 pp.

Guppy, C. S. 1989. Johnson's Hairstreak: an endangered Canadian butterfly. Discovery. December 1989. 18(4).

Guppy, C.S. 2007. Taylor's Checkerspot Butterfly on the Denman Island Settlement Lands. Report prepared for Parks Canada, Victoria, BC 26 pp.

Guppy, C.S. 2008. Butterfly inventory 2008 of the Gulf Islands National Park Reserve. Unpublished report submitted to the BC Ministry of Environment and Parks Canada Agency, Vancouver, British Columbia.

Guppy, C. S., pers. comm. 2021. *Email correspondence to Jennifer Heron*. January - February 2021, Lepidopterist, Whitehorse, Yukon Territory.

Guppy, C.S., and A.I. Fischer. 2001. Inventory of rare butterflies of southern Vancouver Island, 2001 field season. Prepared for the BC Ministry of Environment, Lands and Parks. 60 pp.

Guppy, C.S., and J.H. Shepard. 2001. Butterflies of British Columbia. University of British Columbia Press, Vancouver, British Columbia. 414 pp.

Hawkes, B. 2005. Climate change and forest fire in British Columbia. In Conference proceedings: Implications of climate change in British Columbia's southern interior forests. April 26–27, 2005 in Revelstoke, BC. Columbia Mountains Institute, Revelstoke. . [accessed July 6, 2021].

Hawksworth, F.G. and D. Wiens 1996. Dwarf mistletoes: biology, pathology and systematic. U.S. Department of Agriculture Forest Service, Washington District of Columbia. Agricultural Handbook 709. 410 pp.

Hebda, R.J. 1997. Impact of climate change on biogeoclimatic zones of British Columbia and Yukon. *In* Responding to global climate change in British Columbia and Yukon, vol. 1 (E. Taylor and B. Taylor editors). BC Ministry of Environment, Lands and Parks, Victoria, British Columbia. http://publications.gc.ca/collections/Collection/En56-119-1997E.pdf [Accessed February 12, 2021].

Hennon, P.E., J.S. Beatty, and D. Hildebrand. 2001. Hemlock Dwarf Mistletoe Forest Insect and Disease Leaflet 135. January. United States Department of Agriculture and Forest Service. Web site: https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsbdev2_043670.pdf [accessed February 16, 2021].

Heron, J., P. Archibald, D. Marks, B. Bains, and T. Ebata. 2019. Inventory of butterflies and rare diurnal moths in the parks and protected areas of greater Victoria, British Columbia, April 17 – June 14, 2019. British Columbia Ministry of Environment and Climate Change Strategy, Victoria, British Columbia. 134 pp.

Heron, J., E. McClaren, D. Moore, H. Steere, J. Godfrey, and D. Marks. 2020. Annual report on Taylor's Checkerspot (*Euphydryas editha taylori*) Recovery Program in British Columbia, Canada: April 2019 – March 2020. BC Ministry of Environment and Climate Change Strategy, Species Conservation Science Unit, Victoria, British Columbia. 119pp. + 12 Appendices.

Heron, J., D. Marks, E. McClaren, D. Moore, and H. Steere. 2021. Annual report on Taylor's Checkerspot (*Euphydryas editha taylori*) Recovery Program in British Columbia, Canada: April 2020 – March 2021. BC Ministry of Environment and Climate Change Strategy, Species Conservation Science Unit, Victoria, British Columbia. 73 pp. + 9 Appendices.

Hinchliff, J. 1996. An Atlas of Oregon Butterflies. The Evergreen Aurelians. Corvallis Oregon.

Hinds, T.E, and F.G. Hawksworth. 1965. Seed Dispersal Velocity in Four Dwarfmistletoes. Science. 148:517-519.

Hirner, J., pers. comm. 2021. *Email communication with Jennifer Heron.* Conservation Specialist, Parks and Protected Areas, North Vancouver, British Columbia.

Interagency Special Status/Sensitive Species Program. 2015a. Attachment 1 - Federal Threatened, Endangered & Proposed Species and Sensitive and Strategic Species Lists.

Interagency Special Status/Sensitive Species Program. 2015b. Federally Threatened, Endangered, & Proposed Species, and Bureau Sensitive and Strategic Species List [cited 2017 Apr 5].

ITIS (Integrated Taxonomic Information System). 2017. *Callophrys johnsoni* (Skinner, 1904) Integrated Taxonomic Information System on-line database. http://www.itis.gov [accessed February 13, 2021].

IUCN (International Union for Conservation of Nature Standards and Petitions Committee). 2019. Guidelines for Using the IUCN Red List Categories and Criteria. Version 14. Prepared by the Standards and Petitions Committee. Available from: https://www.iucnredlist.org/resources/redlistguidelines [accessed February 18, 2021].

IUCN (International Union for Conservation of Nature). 2012. IUCN Red List Categories and Criteria: Version 3.1. Second edition. Gland, Switzerland and Cambridge, UK: IUCN. iv + 32pp. https://www.iucnredlist.org/resources/categories-and-criteria [accessed February 18, 2021].

IUCN (International Union for Conservation of Nature). 2016. Red List of Threatened Species. Version 2016-3. Available from: http://www.iucnredlist.org/ [accessed February 17, 2021].

James, D.G., and D. Nunnallee. 2011. Life histories of Cascadia butterflies. Oregon State University Press, Corvallis, Oregon. 448 pp.

Jones, J.R. 1951. An annotated checklist of the macrolepidoptera of British Columbia. The Entomological Society of British Columbia, Occasional Papers 1:1-148. https://journal.entsocbc.ca/index.php/journal/article/view/259/250 [accessed February 17, 2021].

Knopp, D, L. Larkin, and J. Heron. 2007. Survey for Dun Skipper (*Euphyes vestris*) in the Lower Fraser Valley, BC, BC Ministry of Environment, Ecosystems Branch, Wildlife Science Section, UBC Campus, 315 – 2202 Main Mall, Vancouver, British Columbia. 53 pp.

Knopp, D, L. Larkin, and J. Heron. 2009. Surveys for Dun Skipper (*Euphyes vestris*) in the Lower Fraser Valley, BC, BC Ministry of Environment, Ecosystems Branch, Wildlife Science Section, UBC Campus, 315 – 2202 Main Mall, Vancouver, British Columbia. 53 pp.

Knopp, D, L. Larkin, and J. Heron. 2010. Surveys for Dun Skipper (*Euphyes vestris*) and Western Bumblebee (*Bombus occidentalis*) in the Lower Fraser Valley, BC, BC Ministry of Environment, Ecosystem Protection and Sustainability Branch, Terrestrial Conservation Science Section, UBC Campus, 315 – 2202 Main Mall, Vancouver, BC 53 pp.

Kroeker, N., pers. comm. 2021. *Email correspondence with Jennifer Heron*. February 2021. Species at Risk Manager, Coastal BC Field Unit, Parks Canada / Government of Canada, Victoria, British Columbia.

Larrivee, M., K.L. Prudic, K.P. McFarland, and J. Kerr. No Date. eButterfly: a citizen-based butterfly database in the biological sciences. http://www.e-butterfly.org.

Lawson, P., pers. comm. 2021. *Email correspondence with Jennifer Heron.* February 2021. University of British Columbia, Malcolm Knapp Research Forest, Maple Ridge, BC.

Layberry, R.A., P.W. Hall, and J.D. LaFontaine. 1998. The Butterflies of Canada. University of Toronto Press, Toronto, Ontario. 280 pp. + color plates.

Leimar, O., and A.H. Axén. 1993. Strategic behaviour in an interspecific mutualism; interactions between lycaenid larvae and ants. Animal Behaviour 46:1177-1182.

Lilley, P., N. Page and J. Heron. 2009. Surveys for Taylor's Checkerspot and Other Butterfly Species at Risk on Southeastern Vancouver Island (2009). Report prepared for BC Ministry of Environment by Raincoast Applied Ecology. 16 pp + appendices.

Lilley, P., N. Page and J. Heron. 2010. Surveys for Butterfly Species at Risk on Private and Municipal Lands on Southeastern Vancouver Island and the Gulf Islands, British Columbia (2010). BC Ministry of Environment, Terrestrial Conservation Science Section, Vancouver, BC 37 pp + appendices.

Lotts, K., and T. Naberhaus (coordinators). 2020. Butterflies and Moths of North America, Johnson's Hairstreak (*Callophrys johnsoni*). http://www.butterfliesandmoths.org/ [accessed February 17, 2021].

Malcolm Knapp Research Forest (MKRF). 2021. https://www.mkrf.forestry.ubc.ca/ [accessed February 12, 2021].

Marks, D., E. Bland, and J. Heron. 2019. Surveys for Taylor's Checkerspot and other butterflies in Denman Provincial Park and Protected Area, BC, 2019. BC Ministry of Environment and Climate Change Strategy, Victoria, BC 33pp. Appendix 4 In Heron, J., E. McClaren, D. Moore, H. Steere, J. Godfrey and D. Marks. 2020. Annual report on Taylor's Checkerspot (*Euphydryas editha taylori*) Recovery Program in British Columbia, Canada: April 2019 – March 2020. BC Ministry of Environment and Climate Change Strategy, Species Conservation Science Unit, Victoria, BC 115 pp. + 11 Appendices.

Marks, D., J.M. Heron, T. Barbin, B. Bains, and T. Ebata. 2018. Inventory of butterflies and rare diurnal moths in the parks and protected areas of greater Victoria, British Columbia, May 16 – July 6, 2018. British Columbia Ministry of Environment and Climate Change Strategy, Victoria, British Columbia. 100 pp.

Master, L.L., D. Faber-Langendoen, R. Bittman, G.A. Hammerson, B. Heidel, L. Ramsay, K. Snow, A. Teucher, and A. Tomaino. 2012. NatureServe conservation status assessments: factors for evaluating species and ecosystems at risk. NatureServe, Arlington, VA. < <https://www.natureserve.org/biodiversity-science/publications/natureserve-conservation-status-assessments-factors-evaluating> [accessed February 12, 2021].

Mathiasen, R.L. 1994. Natural infection of new hosts by hemlock dwarf mistletoe. Res. Note RM-530. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest, and Range Experiment Station, Fort Collins, Colorado. 6 pp.

McClaren, E., 2021. *Email communication with Jennifer Heron.* Conservation Specialist, Parks and Protected Areas, Black Creek, British Columbia.

McCorkle, D., 2007. *Email correspondence to M. Connolly as cited in Conolly 2007*. Entomologist, Corvallis, Oregon.

McNaughton, C., pers. comm. 2021. *Email communication with Jennifer Heron*. Interior and Coastal Mainland, Conservation Land Manager, The Nature Trust of British Columbia.

Miller, J. C., and Hammond, P.C. 2007. Butterflies and moths of Pacific Northwest forests and woodlands: rare, endangered, and management-sensitive species. USDA Forest Service, Morgantown, West Virginia.

Miskelly, J. 2003. Hornby Island: Rare and endangered butterfly inventory 2003. BC Ministry of Water, Land and Air Protection, Vancouver, British Columbia. Internal report.

Miskelly, J. 2004. Habitat requirements and conservation of the butterflies *Euchloe ausonides insulanus* (Pieridae) and *Euphydryas editha taylori* (Nymphalidae) in southwestern British Columbia. A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in the Department of Biology, University of Victoria, Victoria, British Columbia. 115 pp. Available at https://dspace.library.uvic.ca/bitstream/handle/1828/627/miskelly_2004.pdf?sequence=1&isAllowed=y [accessed February 17, 2021].

Muir, J.A., P.E. Hennon and R.W. Negrave. 2007. Biology, Ecology and Management of Western Hemlock Dwarf Mistletoe in Coastal British Columbia: A Synthesis of the Literature. Research Section, Coast Forest Region, BC Ministry of Forests and Range, Technical Report TR-037.

NatureServe. 2021. NatureServe explorer: an online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, VA. https://www.natureserve.org/ [Accessed February 12, 2021].

Needham, K., 2020. *Email and phone communication with Jennifer Heron.* Entomology Curator, Spencer Entomological Collection at the Beaty Biodiversity Museum, University of British Columbia, Vancouver, British Columbia.

Nicholls, D. 2020. British Columbia Ministry of Forests, Lands, Natural Resource Operations and Rural Development Tree Farm Licence 44 Rationale for Allowable Annual Cut (AAC) Determination effective December 8, 2020. https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/stewardship/forest-analysis-inventory/tsr-annual-allowable-cut/tree-farm-license/44tfra_2020_partition.pdf [accessed March 3, 2022].

Natural Resources Canada. 2022. Canadian Forest Service Publications https://cfs.nrcan.gc.ca/publications?lang=en_CA [accessed March 3, 2022].

Open Standards. 2016. IUCN-CMP Threats and Actions Classifications. <https://cmp-openstandards.org/library-item/threats-and-actions-taxonomies/> [Accessed February 12, 2021].

Opler, P. A., and A. D. Warren. 2002. Butterflies of North America. 2. Scientific Names List for Butterfly Species of North America, north of Mexico. C.P. Gillette Museum of Arthropod Diversity, Department of Bioagricultural Sciences and Pest Management, Colorado State University, Fort Collins, Colorado. 79 pp.

Page, N. 2020. Taylor's Checkerspot Distribution Survey in the Oyster River Area, Campbell River, BC – May – June 2020 (Confidential Report). Appendix 1 In Heron, J., E. McClaren, D. Moore, H. Steere and D. Marks. 2021. Annual report on Taylor's Checkerspot (*Euphydryas editha taylori*) Recovery Program in British Columbia, Canada: April 2020 – March 2021. BC Ministry of Environment and Climate Change Strategy, Species Conservation Science Unit, Victoria, British Columbia.

Page, N., and C. Schaefer. 2014. Butterfly surveys targeting habitat for Johnson's Hairstreak (*Callophrys johnsoni*) and Dun Skipper (*Euphyes vestris*) on provincial Crown lands on the Sunshine Coast, BC, 2014. Unpublished report prepared for BC Ministry of Environment by Raincoast Applied Ecology under contract CS15JHQ-054. 13 pp + appendices.

Page, N., and C. Schaefer. 2015. Butterfly surveys on provincial Crown lands on Texada, Lasqueti, Jedediah, and Hornby Islands, BC, 2015. Unpublished report prepared for BC Ministry of Environment by Raincoast Applied Ecology under contract 410626-001. 19 pp + appendices.

Page, N., J. Heron, C. Webb, and N. Kroeker. 2007. Survey for Taylor's Checkerspot and other butterflies on Denman and Hornby Islands (2007). Report prepared for BC Ministry of Environment and Parks Canada Agency, Vancouver, British Columbia.

Page, N., P. Lilley, J. Heron, and N. Kroeker. 2008b. Distribution and Habitat Characteristics of Taylor's Checkerspot on Denman Island and Adjacent Areas of Vancouver Island (2008). Report prepared for BC Ministry of Environment and Parks Canada Agency. Vancouver, British Columbia. v + 32 pp.

Page, N., P. Lilley, J. Miskelly, M. Connolly and J. Heron. 2008a. Survey for Taylor's Checkerspot and other butterflies in the Shawnigan Lake area. Report prepared for BC Ministry of Environment, Vancouver, British Columbia.

Page, N., and B. Zand. 2019. 2019 Taylor's Checkerspot Survey in the Oyster River Area, Campbell River, BC Appendix 3 (CONFIDENTIAL) In Heron, J., E. McClaren, D. Moore, H. Steere, J. Godfrey and D. Marks. 2020. Annual report on Taylor's Checkerspot (*Euphydryas editha taylori*) Recovery Program in British Columbia, Canada: April 2019 – March 2020. BC Ministry of Environment and Climate Change Strategy, Species Conservation Science Unit, Victoria, British Columbia. 115 pp + 11 Appendices.

Parker, D., pers. comm. 2016. *Email communication to Jennifer Heron.* Record submitted to the BC CDC (San Juan Ridge), Naturalist, Victoria, British Columbia.

Parkinson, L., S.A. Blanchette, and J. Heron. 2009a. Surveys for Dun Skipper (*Euphyes vestris*) in the Harrison Lake Area, British Columbia, July 2009. BC Ministry of Environment, Ecosystems Branch, Wildlife Science Section, Vancouver, British Columbia. 51 pp.

Parkinson, L., S.A. Blanchette, and J. Heron. 2009b. Surveys for Johnson's Hairstreak (*Callophrys johnsoni*) in Sechelt and Roberts Creek, British Columbia, June 2009, BC Ministry of Environment, Ecosystems Branch, Wildlife Science Section, Vancouver, British Columbia.

Parminter, J. 2003. Natural Fire Regimes in British Columbia and the Summer of 2003. Botanical Electronic News. No. 329: May 14, 2004. https://www.ou.edu/cas/botany-micro/ben/ben329.html [accessed July 6, 2021].

Pelham, J. P. 2008. A catalogue of the butterflies of the United States and Canada with a complete bibliography of the descriptive and systematic literature. The Journal of Research on the Lepidoptera. 40:1-658.

Pierce, N.E. 1987. The evolution and biogeography of associations between lycaenid butterflies and ants. Oxford Surveys in Evolutionary Biology 4:89-116.

Pohl, G., pers. comm. 2020. *Email communication with Jennifer Heron*. Insect/Disease Identification Officer, Canadian Forest Service, Northern Forestry Centre, Edmonton, Alberta/

Province of British Columbia. 1982. *Wildlife Act* [RSBC 1996] c. 488. Queen's Printer, Victoria, British Columbia. http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/00_96488_01 [accessed Accessed February 12, 2021].

Province of British Columbia. 1996a. *Forest Practices Code of British Columbia Act*. [RSBC 1996] c. 159. Queen's Printer, Victoria, British Columbia. https://www.bclaws.gov.bc.ca/civix/document/id/complete/statreg/96159_01 [accessed February 16, 2021].

Province of British Columbia. 2000. *Protected Areas of British Columbia Act* [SBC 2000] c. 17. Queens's Printer, Victoria, British Columbia. http://www.bclaws.ca/civix/document/id/complete/statreg/00017_00 [accessed February 12, 2021].

Province of British Columbia. 2002. *Forest and Range Practices Act* [RSBC 2002] c. 69. Queen's Printer, Victoria, British Columbia. http://www.for.gov.bc.ca/tasb/legsregs/http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/00_02069_01 [accessed February 12, 2021].

Province of British Columbia. 2004. Identified wildlife management strategy. BC Ministry of Environment, Victoria, British Columbia. http://www.env.gov.bc.ca/wld/frpa/iwms/index.html [accessed February 12, 2021].

Province of British Columbia. 2008. *Oil and Gas Activities Act* [SBC 2008] c. 36. Queen's Printer, Victoria, British Columbia. http://www.for.gov.bc.ca/tasb/legsregs/http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/00_08036_01 [accessed Accessed February 12, 2021].

Province of British Columbia. n.d. Western hemlock looper biology and history. https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/forest-health/defoliators/western_hemlock_looper_biology.pdf [accessed July 6, 2021].

Pruss, S., pers. comm. 2021. *Email communication to Jennifer Heron*. Species Conservation, Conservation Programs Branch, Parks Canada, Government of Canada, Fort Saskatchewan, Alberta.

Pyle, R.M. 1981. The Audubon Society Field Guide to North America Butterflies. Chanitcleer Press, Alfred A. Knopf, New York. 916 pp, 759 colour figures.

Pyle, R. M. 1989. Washington butterfly conservation status report and plan. Prepared for the Washington Department of Wildlife, Nongame Program, Olympia, Washington. 217 pp.

Pyle, R. M. 2002. The Butterflies of Cascadia, A Field Guide to All the Species of Washington, Oregon, and Surrounding Territories. Seattle Audubon Society, Seattle, Washington. 420 pp.

Rusch, D., H. Kope, M. Murray, J. Yurkewich, and S. Zeglen. 2019. Dwarf Mistletoe Management in British Columbia. Land Management Handbook 73. Province of British Columbia. https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/forest-health/forest-health-docs/dwarf-mistletoes/lmh73.pdf [accessed February 17, 2021].

Salafsky, N., D. Salzer, A.J. Stattersfield, C. Hilton-Taylor, R. Neugarten, S.H.M. Butchart, B. Collen, N. Cox, L.L. Master, S. O'Connor, and D. Wilkie. 2008. A standard lexicon for biodiversity conservation: unified classifications of threats and actions. Conservation Biology. 22:897–911.

Scott, J.A. 1986. The Butterflies of North America: A Natural History and Field Guide. Stanford University Press, Stanford, California. vii+583 pp.

Shapiro A.M., and T.D. Manolis. 2007. Field guide to butterflies of the San Francisco Bay and Sacramento Valley regions. University of California Press, Berkeley, California. 345 pp.

Shaw, D.C., D.M. Watson, and R.L. Mathiasen. 2004. Comparison of dwarf mistletoes (*Arceuthobium* spp. Viscaseae) in the western United States with mistletoes (*Amyema* spp. Loranthaceae) in Australia: ecological analogues and reciprocal models for ecosystem management. Australian Journal of Botany 52:481-498.

Sheffield, C., 2020. *Personal communication with Jennifer Heron and Dawn Marks*. Curator of Invertebrates and Plants, Royal Saskatchewan Museum, Regina, SK.

Shields, O. 1965. *Callophrys* (*Mitoura*) *spinetorum* and *C*. (*M*.) *johnsoni*: their known range, habits, variation, and history. Journal of Research on the Lepidoptera 4: 233-250.

Shpeley, D., 2020. *Email communication with Jennifer Heron*. Strickland Entomological Museum, Department of Biology, University of Alberta, Edmonton, AB

Skinner, H. 1904. A new *Thecla* for the Northwest. Entomological News 15:298-99.

Smith. R.B., and E.F. Wass. 1986. Infection trials with three dwarf mistletoe species within and beyond their known ranges in British Columbia. Canadian Journal of Plant Pathology 1:47–57.

Spiegel, L. 2014. Johnson's Hairstreak butterfly (*Callophrys johnsoni*) in the Blue Mountains. USDA Forest Service, Pacific Northwest Region, Blue Mountains Forest Insects and Disease Center. BMPMSC-14-01. 8 pages.

Spittlehouse, D.L. 2008. Climate Change, impacts, and adaptation scenarios: climate change and forest and range management in British Columbia. Technical Report 045, British Columbia Ministry of Forests and Range, Research Branch, Victoria, British Columbia. http://www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr045.htm [accessed July 6, 2021].

St. John, D., pers. comm. *Email communication with Jennifer Heron*. Private Entomoloigst, Agassiz, British Columbia.

Swann, J., pers. comm. 2020. *Email communication with Jennifer Heron*. University of Calgary, Insects & Invertebrate Zoology Museum, Department of Biological Sciences, Calgary, Alberta.

Tatum, J., pers. comm. 2020. *Personal communication with Jennifer Heron*. Independent Lepidopterist, Victoria, British Columbia.

Trzesicka, G. 2021. *Personal communication to Dawn Marks* February 16, 2021. Cortes Island Museum and Archives, Cortes Island, British Columbia.

Unger, L. 1992. Dwarf mistletoes. Forest Pest Leaflet. Forestry Canada.

van Sickle, A., R.L. Fiddick, and C.S. Wood. 2001. II. The forest and insect disease survey in the Pacific Region. Journal of the Entomological Society of British Columbia 98:169-176.

Warren, A.D. 2005. Lepidoptera of North America 6. Butterflies of Oregon: Their taxonomy, distribution, and biology. Contributions of the C.P. Gillette Museum of Arthropod Diversity, Colorado State University, Fort Collins, Colorado. 408 pp.

Washington Department of Fish and Wildlife. 1995. Management Recommendations for Washington's Priority Species, Volume I: Invertebrates. Eric M. Larsen, Elizabeth Rodrick, and Ruth Milner, Technical Editors Volume I: Invertebrates.

Worcester, R. and K. Johnstone. 2007. Species at Risk in Stanley Park: A Preliminary Report. Prepared for Vancouver Park Board. Stanley Park Ecology. [accessed February 18, 2021].

Worcester, R., and B. Titaro. 2012. Best management practices for species of significance in Stanley Park. Stanley Park Ecology Society. Report prepared for Vancouver Park Board. Vancouver, British Columbia. 182 pp. https://stanleyparkecology.ca/wp-content/uploads/2021/07/Worcester_SPES_SOSReport-2012.pdf [accessed February 18, 2021].

Zand, B., P. Archibald, J. Heron, T. Ebata, and B. Bains. 2017. Inventory of butterflies and rare diurnal moths in the parks and protected areas of greater Victoria, British Columbia June 1 – July 27, 2017. British Columbia Ministry of Environment and Climate Change Strategy, Victoria, British Columbia. 115 pp.

Zeglen, S., pers. comm. 2021. *Personal communication with Jennifer Heron*. February 2021. Forest Pathologist, BC Ministry of Forests, Lands, Resource Operations and Rural Development, Nanaimo, British Columbia.

BIOGRAPHICAL SUMMARY OF REPORT WRITERS

Brenda Costanzo is the Senior Vegetation Specialist with the Conservation Science Section, BC Ministry of Environment and Climate Change Strategy. For the past 18 years Brenda has been involved in leading recovery teams and/or writing numerous recovery plans for plants at risk in BC. Her background includes an M.Sc. from the University of Victoria in biology on the seed germination of two native shrubs from BC. She has written several status reports on rare vascular plants from BC.

Jennifer M. Heron is the provincial Invertebrate Conservation Specialist with the Conservation Science Section, BC Ministry of Environment and Climate Change Strategy. She directs and manages the provincial approach to invertebrate conservation, including the development and implementation of provincial legislation, policy, procedures, and standards for Conservation, and recovery of invertebrate species at risk, their habitats and ecosystems, and to keep these species from becoming at risk. Her background includes an M.Sc. from the University of BC. Her interests include the native bees of western Canada and thermal spring's invertebrates.

Dawn Marks is the Invertebrate Conservation Environmental Biologist with the Conservation Science Section, BC Ministry of Environment and Climate Change Strategy. Over the past ten years she has conducted inventories, mapping, report writing, invertebrate policy and recovery plan development that has centred on invertebrate species at risk in BC. She has also worked with the BC CDC on species mapping.

ONLINE DATA SOURCES AND COLLECTIONS EXAMINED

British Columbia Conservation Data Centre (BC CDC). BC Species and Ecosystems Explorer: Johnson's Hairstreak. (online database, see Table 1, February 2021)

BugGuide® (online database, no records for BC, February 2021)

Butterflies and Moths of North America (online database, no records for BC, February 2021)

Canadian National Collection of Insects, Arachnids and Nematodes, Agriculture and Agri-Food Canada, Ottawa, ON (online database, see Table 1, February 2021)

Crispin Guppy Lepidoptera Collection, Whitehorse Yukon Territory (no BC records, Guppy pers. comm. 2021)

Cortes Island Museum and Archives, Cortes Island, British Columbia. (online database) https://cortesmuseum.com/museum/butterfly-sightings/ (no records, Trzesicka pers. comm. 2021)

eButterfly: a citizen-based butterfly database in the biological sciences. http://www.e-butterfly.org (one BC record, February 2021)

iNaturalist® www.inaturalist.ca (three BC records, February 2022)

Invertebrate Zoology, Royal Alberta Museum, Edmonton, Alberta. (no BC records, Buck pers. comm. 2021)

Northern Forestry Centre, Canadian Forest Service, Natural Resources Canada, Edmonton, Alberta. (no BC records, Greg Pohl pers. comm. 2021)

Pacific Forestry Centre, Canadian Forest Service, Natural Resources Canada, Victoria, British Columbia. (see Table 1, Esme pers. comm. 2022)

Royal British Columbia Museum, Victoria, British Columbia. (see Table 1, Copley pers. comm. 2021)

Royal Saskatchewan Museum, Regina, Saskatchewan. (no BC records, Sheffield pers. comm. 2021)

Spencer Entomological Collection, Beaty Biodiversity Museum, University of British Columbia, Vancouver, British Columbia. (see Table 1, Needham pers. comm. 2020)

Strickland Entomological Museum, Department of Biology, University of Alberta, Edmonton, Alberta. (no BC records, Danny Shpeley pers. comm. 2020)

University of Calgary, Insects & Invertebrate Zoology Museum, Department of Biological Sciences, Calgary, Alberta. (no BC records, Swann pers. comm. 2020)

Victoria Natural History Society Invertebrate Alert (online database, https://www.vicnhs.bc.ca/?cat=8) (see Table 1, Tatum pers. comm. 2021)