COSEWIC
Assessment and Status Report

on the

Northern Dusky Salamander
Desmognathus fuscus

Carolinian population
Quebec / New Brunswick population

in Canada

Carolinian population - ENDANGERED
Quebec / New Brunswick population - NOT AT RISK
2012

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

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COSEWIC
Assessment Summary

Assessment Summary – May 2012

Common name
Northern Dusky Salamander - Carolinian population

Scientific name
Desmognathus fuscus

Status
Endangered

Reason for designation
This species is restricted to one small creek sustained by groundwater seepage on the steep slope of a gorge vulnerable to erosion, atmospheric deposition of pollutants and habitat acidification. The population is small and susceptible to ecological, demographic and genetic stochasticity.

Occurrence
Ontario

Status history
The species was considered a single unit and designated Not at Risk in April 1999. Split into two populations in May 2012. The Carolinian population was designated Endangered in May 2012.

Assessment Summary – May 2012

Common name
Northern Dusky Salamander - Quebec / New Brunswick population

Scientific name
Desmognathus fuscus

Status
Not at Risk

Reason for designation
The species remains widespread in Quebec and New Brunswick and, with additional search effort, many new sites have been discovered in recent years. Although there have been local extirpations and there are numerous ongoing threats, the species does not seem to be declining significantly, or at risk.

Occurrence
Quebec, New Brunswick

Status history
The species was considered a single unit and designated Not at Risk in April 1999. Split into two populations in May 2012. The Quebec / New Brunswick population was designated Not at Risk in May 2012.

COSEWIC
Executive Summary

Northern Dusky Salamander
Desmognathus fuscus

Carolinian population
Quebec / New Brunswick population

Wildlife Species Description and Significance

The Northern Dusky Salamander (*Desmognathus fuscus*) is a member of the family Plethodontidae (lungless salamanders). Adults are usually brownish with a light dorsal stripe that continues onto the first portion of the tail. The body is sparsely covered with dark spots that are concentrated on the sides and becomes white or grey on the underside. Old individuals tend to be uniformly dark brown or black. Younger life stages have five to eight pairs of dorsal blotches or spots. Both adults and larvae have larger hind legs than forelegs and a pale line extending from the eye to the rear of the jaw. The Northern Dusky Salamander is the most widespread representative of its genus in Canada.

Distribution

The Northern Dusky Salamander is distributed throughout the mountainous regions of eastern North America. The Canadian distribution accounts for about 5% of the global range and includes a small area in the Niagara Gorge in Ontario, three large areas in Quebec (the Adirondack Piedmont, the Appalachian uplift, and the north shore of the St. Lawrence River), and scattered areas in southern New Brunswick. Within its range, the Northern Dusky Salamander occurs discontinuously usually in high elevation, low-order streams, in forested habitat. There are two designatable units, the Carolinian DU in Ontario, and the Quebec/New Brunswick DU.

Habitat

The Northern Dusky Salamander inhabits the vicinity of springs, seepages, and small tributaries of clear headwater streams in forested habitats. The species takes refuge under protective cover (rocks, logs, moss or leaf litter) or in cool subterranean retreats near stream edges. It forages along the streamside, mostly in terrestrial habitat. Females usually nest in cryptic microhabitats near a stream's source where soil is saturated. Larvae are strictly aquatic and remain in interstitial spaces among rocks of the streambed during their development. In winter, larvae remain in shallow running water, whereas adults retreat to subterranean refuges with constant water flow. Habitat availability and quality are optimal in undisturbed watersheds with abundant forest cover.

Biology

The Northern Dusky Salamander has a biphasic life cycle that includes an aquatic larval stage of 7 to 16 months, followed by a semi-aquatic adult stage. Sexual maturity is attained at 3 to 4 years of age. Mating takes place in the spring or fall and females lay eggs annually in late spring and summer. Fecundity increases with body size, and clutch size varies geographically between 8 and 45 eggs. Females remain with their clutches until they hatch 45 to 60 days after oviposition. Maximum life span is about 10 years.

Northern Dusky Salamanders are particularly vulnerable to water loss, and are most active at night. The threat of desiccation makes the species a poor overland disperser. Movements occur primarily along the stream channel usually within a few metres of water's edge. Adult home range is small (0.1 m^2 - 3.6 m^2). The species consumes aquatic and terrestrial invertebrates opportunistically. It lacks defence mechanisms against predators, but is capable of tail breakage. Fish, snakes, crayfish, birds, small mammals and larger salamanders are the main predators of the Northern Dusky Salamander. Hybridization between Northern Dusky Salamanders and Allegheny Mountain Dusky Salamanders occurs infrequently.

Population Sizes and Trends

Although considerable sampling effort has been invested in some parts of the species' Canadian range, current data do not allow an accurate estimate of population sizes or trends. In Ontario, the species is confined to a single small location in the Niagara Gorge. Estimates suggest the Ontario population size is likely fewer than 250 adults. The species is widespread in Quebec and New Brunswick; however, local densities are usually low. In each province six new populations have been discovered in the past few years as a result of increased targeted searches. Accordingly, the extent of occurrence has slightly increased, reflecting greater search effort rather than population growth or the establishment of new populations. On the other hand, some populations seem to have disappeared.

Threats and Limiting Factors

Changes in water supply and quality due to human activities are the main threats to the Northern Dusky Salamander in Canada. Decreased groundwater supply to the species' habitat can be catastrophic to local populations. Artificial increase in discharged water volumes in some areas is also likely to disrupt salamander populations and reduce suitable microhabitats. Runoff water from urban, industrial and agricultural areas can contaminate groundwater and waterways. Heavy metal contamination from atmospheric deposition is likely responsible for the disappearance of the species in Acadia National Park in Maine. Stream acidification is also a concern to the species as nearly 40% of the mountain streams in the southern Appalachians show signs of acidification.

Timber harvesting, windfarms, and watershed urbanization reduce water supply, water quality and microhabitat availability. Siltation is one of the most adverse effects of timber harvesting because interstitial spaces used by salamanders for foraging, shelter, nesting, and overwintering are lost. At the watershed scale, urbanization has caused the disappearance of the Northern Dusky Salamander in Mount Saint-Hilaire National Park (Quebec) and other areas. Introduction of predatory fish, particularly Brook Trout, is a threat to the species.

Protection, Status, and Ranks

The Northern Dusky Salamander is listed as Endangered in Ontario and is protected under the *Endangered Species Act*, 2007. In Quebec, the species is likely to be designated Threatened or Vulnerable by the provincial government. Nonetheless, the provincial *Act respecting conservation and development of wildlife* (R.S.Q., c. C-61.1) prohibits collecting, buying, selling or keeping specimens in captivity. Article 22 of the provincial *Environment Quality Act* (R.S.Q., c. Q-2) offers protection against unregulated degradation of environmental quality. The Northern Dusky Salamander is designated as Sensitive in New Brunswick under the General Status of Species in Canada. It is protected under the New Brunswick *Fish and Wildlife Act*, which prohibits taking any wildlife into captivity, keeping wildlife in captivity, or selling, trading or purchasing any wildlife, without authorization from the Minister.

At the present time, nearly a quarter of Northern Dusky Salamander localities in Canada are secured in protected areas and by ownership agreements. More than 75% of the species' observations do not fall under any type of habitat protection.

TECHNICAL SUMMARY – Carolinian Population

Desmognathus fuscus
Northern Dusky Salamander — Salamandre sombre du Nord
Carolinian population — Population carolinienne
Range of occurrence in Canada: Niagara Gorge, Ontario

Demographic Information

Generation time *Following IUCN guidelines, generation time was estimated considering generation time is greater than the age at first breeding (i.e., average 4 years) and less than the age of the oldest breeding individual (10 years)*.	~6 years
Is there a continuing decline in number of mature individuals? *The number of mature individuals observed in the Niagara Gorge location is very low, but there are no data on trends.*	Unknown
Estimated percent of continuing decline in total number of mature individuals within 5 years.	Unknown
Estimated percent increase in total number of mature individuals over the last 10 years.	Unknown
Percent reduction in total number of mature individuals over the next 10 years.	Unknown
Percent reduction in total number of mature individuals over any 10 years period, over a time period including both the past and the future.	Unknown
Are the causes of the decline clearly reversible and understood and ceased?	NA
Are there extreme fluctuations in number of mature individuals?	Unknown, unlikely

Extent and Occupancy Information

Estimated extent of occurrence	4 km²
Index of area of occupancy (IAO)	4 km²
Is the total population severely fragmented?	No
Number of locations*	1
Is there a continuing decline in extent of occurrence?	No
Is there a continuing decline in index of area of occupancy?	No
Is there an observed continuing decline in number of populations?	No
Is there an observed continuing decline in number of locations*?	No
Is there an observed continuing decline in quality of habitat? *Slope failure already occurs along the gorge and has disrupted habitats near the sites where the species occurs. Effects of trampling by humans accelerates erosion and siltation*.	Yes
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each population)

Population	N Mature Individuals
Niagara Gorge	7 to 35 rough estimate

* See definition of location.

Quantitative Analysis

Probability of extinction in the wild is at least 20% within 20 years.	Unknown

Threats (actual or imminent, to populations or habitats)

- Changes in water supply
- Reduction of water quality (runoff water, sedimentation, contamination)
- Slope failure
- Urbanization of adjacent tableland (change in water quantity and quality, mudslides)
- Stochastic events, because the population is isolated and of a very small size.
- Trampling and disturbance by hikers, etc.

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? *US:* The Northern Dusky Salamander has a broad distribution throughout the eastern United States. Populations closest to the Niagara Gorge population (i.e., New York) are secure (S5).	
Is immigration known or possible? *The population is isolated by the large and fast flowing Niagara River and the nearest US population is 30 km away across the gorge and extensive urban areas. Please refer to* ***Dispersal and Migration*** *and* ***Rescue Effect*** *sections for details*.	No
Would immigrants be adapted to survive in Canada?	Likely
Is there sufficient habitat for immigrants in Canada? *The species' potential range in Ontario is very restricted, and suitable habitats already support the species. Please refer to* ***Canadian Range*** *section for details*.	No
Is rescue from outside populations likely?	No

Current Status

COSEWIC: Endangered (May, 2012)

Status and Reasons for Designation

Status:	**Alpha-numeric code:**
Endangered	B1ab(iii)+2ab(iii); D1
Reasons for designation: This species is restricted to one small creek sustained by groundwater seepage on the steep slope of a gorge vulnerable to erosion, atmospheric deposition of pollutants and habitat acidification. The population is small and susceptible to ecological, demographic and genetic stochasticity.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable, as there are no data on decline.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets B1ab(iii)+2ab(iii) with EO and IAO well under thresholds, a continuing decline in quality of habitat, and only one location.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable, as there is no evidence of continuing decline and abundance.
Criterion D (Very Small or Restricted Total Population): Meets Endangered D1 (< 250 adults).
Criterion E (Quantitative Analysis): Not done.

TECHNICAL SUMMARY – Quebec/New Brunswick Population

Desmognathus fuscus
Northern Dusky Salamander
Quebec/New Brunswick Population

Salamandre sombre du Nord
Population du Québec et du Nouveau-Brunswick

Range of occurrence in Canada: Quebec, New Brunswick

Demographic Information

Generation time *Following IUCN guidelines (2008), generation time was estimated considering generation time is greater than the age at first breeding (i.e., average 4 years) and less than the age of the oldest breeding individual (10 years)*.	~6 years
Is there a continuing decline in number of mature individuals? *The species' presence in some localities in Quebec and New Brunswick has not been confirmed in the last 20 to 50 years. One population has disappeared (i.e., Mount Saint-Hilaire, QC) and the persistence of two other populations is doubtful (Mount Brome and Mount Yamaska); perhaps a decline in number of mature individuals is possible*.	Yes
Estimated percent of continuing decline in total number of mature individuals within 5 years.	Unknown
Estimated percent increase in total number of mature individuals over the last 10 years, or 3 generations.	Unknown
Percent reduction in total number of mature individuals over the next 10 years.	Unknown
Percent reduction in total number of mature individuals over any 10 years period, over a time period including both the past and the future.	Unknown
Are the causes of the decline clearly reversible and understood and ceased?	No
Are there extreme fluctuations in number of mature individuals?	Unknown

Extent and Occupancy Information

Estimated extent of occurrence	69,800 km^2
Index of area of occupancy (IAO)	1412 km^2
Is the total population severely fragmented?	Unknown, possible perhaps
Number of locations*	Unknown, likely many but not calculated
Is there an observed continuing decline in extent of occurrence?	No, there is an increase from new targeted searches.
Is there a continuing decline in index of area of occupancy? *The IAO has probably decreased over the past decade because the species has not been observed in historical localities*.	Unknown, but likely

* See definition of location.

Is there an inferred continuing decline in number of populations? *The species' presence in some localities in Quebec and New Brunswick has not been confirmed in the last 20 to 50 years. One population has disappeared (i.e., Mount Saint-Hilaire, QC) and the persistence of two other populations is doubtful (Mount Brome and Mount Yamaska); perhaps a decline in number of populations is possible*.	Yes
Is there a projected continuing decline in number of locations*?	Possibly
Is there an observed continuing decline in extent and/or quality of habitat? *Urban developments (residential, leisure, windmill, etc.) are either ongoing or planned in many parts of the range, suggesting a reduction in the number of mature individuals in the next 10 years. Please refer to* ***Habitat Trends*** *and* ***Threats and Limiting Factors*** *sections for details*.	Yes
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each population)

Population	N Mature Individuals
Total	Unknown

Quantitative Analysis

Probability of extinction in the wild is at least 10% within 100 years.	Unknown

Threats (actual or imminent, to populations or habitats)

- Changes in groundwater supply (reduction) or surface water (increase)
- Water pumping, increased water consumption
- Reduction of water quality (runoff water, fertilizers, sedimentation, contamination)
- Habitat loss due to residential developments, recreational sites (campgrounds, ski stations, golf courts), agriculture, industries and windmill parks
- Urbanization (sedimentation, watershed urbanization and loss of habitat connectivity)
- Forest exploitation (removal of cover, shade) and road construction
- Atmospheric deposition of pollutants, and habitat acidification
- Stochastic events, because of the small size and isolation of some populations
- Brook Trout introduction (Appalachian Mountains)
- Hybridization (Covey Hill)

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? *US:* The Northern Dusky Salamander has a broad distribution throughout the eastern United States. The New York population which is closest to Covey Hill is secure (S5).	
Is immigration known or possible? *Please refer to* ***Dispersal and Migration*** *and* ***Rescue Effect*** *sections for details.*	Unknown
Would immigrants be adapted to survive in Canada?	Likely
Is there sufficient habitat for immigrants in Canada?	Probably
Is rescue from outside populations likely?	Unknown

* See definition of location.

Current Status

COSEWIC: Not at Risk (May, 2012)

Status and Reasons for Designation

Status: Not At Risk	**Alpha-numeric code:** Not applicable.
Reasons for designation: The species remains widespread in Quebec and New Brunswick and, with additional search effort, many new sites have been discovered in recent years. Although there have been local extirpations and there are numerous ongoing threats, the species does not seem to be declining significantly, or at risk.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): No overall decline detected.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Threatened B2 (IAO < 2000 $km^{2)}$, and b(iii) (declining habitat quality) but the number of locations is likely > 10.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable. Population size exceeds thresholds.
Criterion D (Very Small or Restricted Total Population): Not applicable. Population size exceeds thresholds.
Criterion E (Quantitative Analysis): Not done.

PREFACE

Since the species' last assessment in 1999, a considerable increase in search effort led to more observations of the Northern Dusky Salamander in both New Brunswick and Quebec, confirming the species' persistence in some historical sites, and also in new localities. Accordingly, the species' extent of occurrence has slightly increased in both Quebec and New Brunswick. However, some populations have remained historical (have not been confirmed/observed for 20 to 50 years), and others have likely disappeared because of habitat destruction associated with human activities. In Ontario, although search efforts have increased, the Northern Dusky Salamander remains known only from a single, restricted location, where extensive threats and limiting factors are now better understood. In New Brunswick, there is no reason to believe there has been any real change in the extent of occurrence. Recent search efforts have been focused on expanding the known range, and attempts have not been made to confirm many historical populations in New Brunswick. However, the species faces expanding threats such as atmospheric deposition of pollutants, watershed urbanization and loss of network connectivity. Recent studies provide a better understanding of effects of these threats on the Northern Dusky Salamander and in the future may help clarify the species' situation in Canada. Recent studies on the genetic structure of *D. fuscus* in Quebec have allowed early inferences in regards to population distinctiveness. However, the levels of genetic differentiation within and among most populations remain unknown. Those that have been studied show a limited degree of divergence. Population sizes and trends remain unknown.

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
(2012)

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.

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

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

The Northern Dusky Salamander (*Desmognathus fuscus*; Rafinesque 1820*)* is a member of the family Plethodontidae, also referred to as lungless salamanders (Gray 1850). This highly diverse family is the largest among salamanders with 396 species (Frost 2010). The genus *Desmognathus*, or dusky salamanders, is part of the Plethodontinae subfamily and comprises 20 species (Frost 2010). Two representatives of this group are found in Canada: the Northern Dusky Salamander (*D. fuscus*), and the Allegheny Mountain Dusky Salamander (*Desmognathus ochrophaeus*).

The Northern Dusky Salamander was previously described as a polytypic species consisting of three subspecies *D. f. conanti* (southern form), *D. f. fuscus* (northern form) and *D. f. santeetlah* (Petranka 1998). Phylogenetic evidence based on mitochondrial DNA, allozyme variation and colour pattern later suggested *D. fuscus* is a monotypic species (Karlin and Guttman 1986, Titus and Larson 1996, Bonett 2002). Considerable molecular evidence now acknowledges *D. conanti* as a full species, distinct from *D. fuscus* (Kozak *et al.* 2005, Beamer and Lamb 2008). Nonetheless, although remaining very conservative morphologically, it appears that some populations of *D. fuscus* are also substantially genetically differentiated from each other (Titus and Larson 1996, Kozak *et al.* 2005, Beamer and Lamb 2008, Tilley *et al.* 2008).

Desmognathus fuscus hybridizes with *D. ochrophaeus* in several populations of Pennsylvania and Ohio (Karlin and Guttman 1981). This is also true in Canada, in the Covey Hill area of Quebec where they coexist (Sharbel and Bonin 1992, Sharbel *et al*. 1995, Boutin 2006). The infrequency of F1 hybrids in Quebec (*i.e*., heterozygous for all diagnostic loci) suggests low levels of hybridization and backcrossing between hybrids and parental species (Houck *et al*. 1988, Sharbel *et al*. 1995, Boutin 2006). In Quebec, backcrosses seem to occur exclusively with *D. ochrophaeus* (Sharbel *et al.* 1995).

Frost (2010) reports various scientific names previously given to this species such as: *Salamandra nigra*, *S. intermixta, S. picta* (Green 1818, 1825, Harlan 1825); *Triturus nebulosus* (Rafinesque 1820); *Triton niger* (Holbrook 1842); *Desmognathus fusca*, *D. nigra*, *D. phoca* (Cope 1859, Nash 1905, Dunn 1926); *Ambystoma frontale* (Gray 1850), *A. nigrum* and *Plethodon niger* (Hallowell 1856). English synonyms include Black Salamander (Green 1818); Painted Salamander (Verrill 1863), and Brown Triton (Hay 1892; see Frost 2010 for a review). In French, it is sometimes recognized as the “salamandre bistrée du Nord” (DeNoël 1999). The present accepted name is Northern Dusky Salamander (*Desmognathus fuscus*) or “salamandre sombre du Nord” in French (Bider and Matte 1994, Desroches and Rodrigue 2004, ITIS 2010).

Morphological Description

Dusky salamanders have a distinctive stout body, larger hind legs than forelegs, and a characteristic pale line extending from the eye to the rear of the jaw. The Northern Dusky Salamander has a keeled tail that is laterally compressed in its basal third, and a triangular shape in cross-section (Petranka 1998, Desroches and Rodrigue 2004). This medium-sized species reaches between 64 and 141 mm in total length (Desroches and Rodrigue 2004), with males attaining greater sizes than females (Organ 1961, Karlin and Pfingsten 1989). Adult males have papillose cloacal lips and a small mental gland at the tip of the chin. When sexually active, males develop enlarged glandular tissues on each side of the head. Females have smooth folded cloacal lips and lack a mental gland (Petranka 1998, Desroches and Rodrigue 2004).

Colouration of the Northern Dusky Salamander varies geographically and with age ranging from a uniform yellowish brown to a bold dorsal pattern (compare Figure 1 and cover photograph). In northern parts of the range, adults tend to have a relatively uniform, light, dorsal stripe that continues onto the first portion of the tail. The body is sparsely covered with dark spots that concentrate on the sides and become white or grey on the undersides. Old individuals tend to be uniformly dark brown or black, with white spotting on the sides, although some adults retain the dorsal patterns seen in younger stages (Petranka 1998).

Figure 1. Adult Northern Dusky Salamander from Carolinian DU. (Photograph by Anne Yagi).

Excluding melanistic individuals, the belly is cream with small grey spots (melanophores) creating a weakly reticulate or peppered pattern that becomes more obvious with age. Melanophores are also present on the dorsal lining of the mouth (Petranka 1998).

Hatchlings have prominent yolk reserves and whitish gills (Bishop 1941, 1943, Organ 1961, Krzysik 1980b). Their total length varies between 12 and 20 mm. Young larvae and many juveniles have five to eight pairs of dorsal blotches or spots between the front and rear limbs and continuing on the tail. In older larvae and juveniles, these blotches or spots will become partially fused or develop in a dorsal band. The sides show a dorsolateral stripe that can be wavy or straight and the back is either uniformly coloured or noticeably blotched with brown to reddish pigments (Petranka 1998).

The Northern Dusky Salamander is easily misidentified as the Allegheny Mountain Dusky Salamander (Figure 2). In Canada, both species co-occur only in Covey Hill (Quebec). A number of morphological features can help in identification (Conant 1975, Sharbel and Bonin 1992, Karlin and Guttman 1986, Desroches and Rodrigue 2004, Rocco *et al*. 2004, Davic 2005, Boutin 2006), and molecular tools have been developed for this purpose (Boutin 2006, Tessier and Bouthillier 2009).

Figure 2. Adult Allegheny Mountain Dusky Salamander *Desmognathus ochrophaeus*, photo by Frédérick Lelièvre, MRNF.

Colour variants, including albinos and amelanistic forms, have been observed in the US and Canada (Channell and Valentine 1972, Pendleburry 1973, Dyrkacz 1981, Karlin and Pfingsten 1989, COSEWIC 1999, Desroches and Rodrigue 2004, A. Boutin pers. obs.). These forms, similar to the Spring Salamander (*Gyrinophilus porphyriticus*), can be discriminated by the absence of reticulations on their body (Desroches and Rodrigue 2004).

Population Spatial Structure and Variability

Desmognathus fuscus shows high levels of intraspecific genetic variation in many parts of its range (Karlin and Guttman 1981, Tilley and Schwerdtfeger 1981, Titus and Larson 1996, Bonett 2002, Rissler and Taylor 2003, Kozak *et al*. 2005, Tilley *et al*. 2008). Local and regional differentiation has also been suggested by significant differences in life history, phenotype, and body size throughout the species' range (Danstedt 1975, 1979, Davic 1983, Tilley 1988, Jutterbock 1990). However, few studies have involved Canadian populations.

Kar Karlin and Guttman (1986) studied electrophoretic variation of 21 proteins in 16 *D. fuscus* populations, including one from Quebec. Their results reveal similarities between populations from Quebec, Maine, Pennsylvania and Ohio. However, genetic distances that separate Quebec populations from nearby Vermont populations are greater than those separating Quebec populations from Massachusetts or Pennsylvania (Karlin and Guttman 1986). Markle (2006) sequenced the Cyt b (370 bp) and the 12S rRNA (579 bp) mitochondrial DNA regions in 11 populations of *D. fuscus* (N=42) from Quebec. Although variation in the 12S rRNA sequence was low (between 0.0% and 0.11%) and had a maximum of only one base substitution, three mtDNA haplotypes were identified (Markle 2006). Two of the distinct haplotypes were found only on the north shore of the St. Lawrence, providing evidence that this river acts as a barrier to dispersal for the species and that some genetic drift is occurring (Markle 2006). The third haplotype was the only one found in all sampled sites south of the St. Lawrence River, and it also predominated north of the river.

Given separate lineages over small, sometimes overlapping ranges, it is acknowledged that other factors besides geographic distances promote intraspecific variability in the species (Beamer and Lamb 2008). Biotic interactions (Tilley 1997), dispersal barriers (Adams and Beachy 2001), physiographic provinces (Danstedt 1975), historical events (Rissler and Taylor 2003), urban fragmentation (Noël *et al*. 2007), and climatic gradients (Kozak and Wiens 2006) all affect small-scale genetic variation in plethodontid salamanders.

Designatable Units

The Canadian range of *D. fuscus* is disjunct, representing two designatable units belonging to several different COSEWIC Terrestrial Amphibians and Reptiles Faunal Provinces (COSEWIC 2010a). Two designatable units (DUs) are recognized: 1) the Carolinian population in Ontario, and (2) the "Quebec/New Brunswick" population in Quebec and New Brunswick (see Figure 4). These two DUs are completely isolated from one another, but it is unknown for how long they have been separated or whether they have differentiated genetically. Other than Markle (2006) and Markle *et al*. 2010, there are no genetic comparisons among Canadian locations.

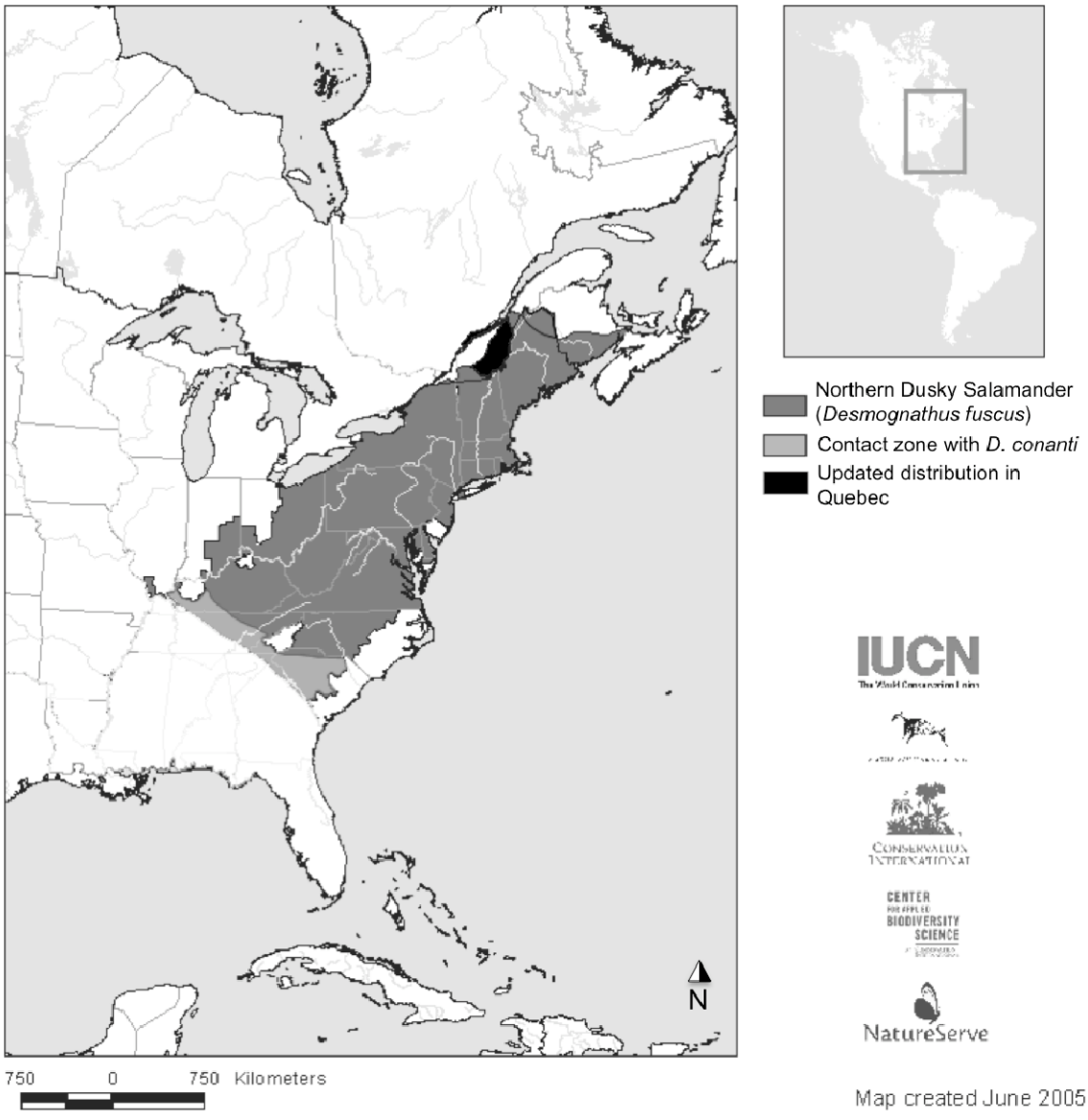

Figure 3. Global range of *D. fuscus* adapted from NatureServe (2010), including the contact zone with *D. conanti.*

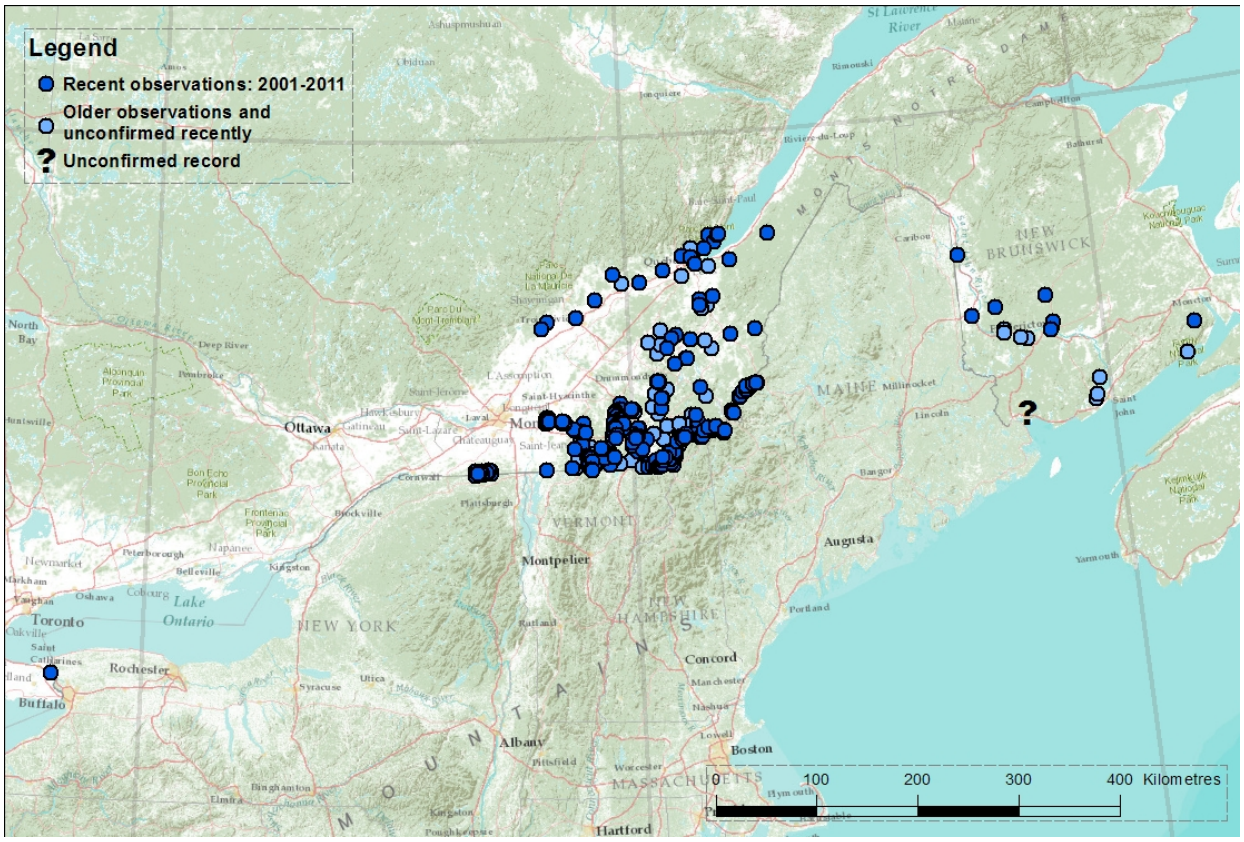

Figure 4. Canadian range of the Northern Dusky Salamander (*D. fuscus).*

The Niagara Gorge population lies within the Carolinian faunal province and consists of a single, small locality in Ontario. This population is over 420 km away from the next nearest Canadian population. The nearest US population is > 30 km southeast across the gorge and Niagara River, along the Niagara Escarpment in New York State (Bishop 1941, Kamstra 1990). This latter disjunction has significant barriers to dispersal and connectivity from heavily developed Buffalo and its suburbs along the Niagara river as well as from the river itself (COSEWIC 1999).

Populations in Quebec east of the St. Lawrence and in New Brunswick are undoubtedly connected through the New England states and, as such, they are considered a single designatable unit (Figures 4, 5, 6). Occurrences on the west/north shore of the St. Lawrence River have two unique haplotypes (Markle 2006) suggesting some isolation from populations south of the river. However the common Quebec haplotype south of the St. Lawrence is also present and predominant north of the St. Lawrence indicating genetic exchange across the river is ongoing (Markle 2006).

Special Significance

Dusky salamanders are highly diversified, making them particularly interesting for research in systematics, evolution and biogeography (Danstedt 1975, Rissler and Taylor 2003, Kozak *et al*. 2005). Dusky salamanders also offer exceptional opportunities for understanding speciation and reproductive isolation (Arnold *et al*. 1993). In this context, Canadian populations of Northern Dusky Salamander are of added interest because they constitute the northernmost limit of the species' range in North America. Furthermore, the species is the only widespread representative of the genus in the country, and some populations are genetically distinct (Markle 2006).

Stream salamanders are significant predators in riparian communities, especially headwater streams lacking predatory fish (Hairston 1949, Petranka and Murray 2001, Southerland *et al*. 2004), and play an important role in trophic transfer and energy flow (Burton and Likens 1975a, Davic 1983, Wyman 1998, Petranka and Murray 2001, Davic and Welsh 2004). Salamanders can be the dominant vertebrates within headwater-riparian forest ecosystems (Burton and Likens 1975a, b, Hairston 1987, Petranka and Murray 2001), and have a biomass greater than that reported for fish (Peterman *et al*. 2008), birds or small mammals (Burton and Likens 1975b, Petranka and Murray 2001, Peterman *et al*. 2008). Streamside salamanders are useful indicators of ecosystem health (Welsh and Ollivier 1998, Southerland *et al*. 2004), and the Northern Dusky Salamander is highly sensitive to forest disturbances (Petranka and Smith 2005, Moseley *et al*. 2008), stream pollution and siltation (Orser and Shure 1972).

DISTRIBUTION

Global Range

The Northern Dusky Salamander is distributed throughout the mountainous regions of eastern North America (Hairston 1987). Its range extends from southern New Brunswick and southeastern Quebec to southeastern Indiana, western Kentucky, eastern Tennessee, and northeastern Georgia with the exception of the coastal plain (Frost 2010, Figure 3). The species is distributed at elevations between sea level and 1600 m, and is absent from the highest mountains of the Appalachians (Great Smoky, Unicoi and Great Balsam mountains) and the southwestern portion of the Blue Ridge Mountains (COSEWIC 1999, NatureServe 2010).

The current global range of the Northern Dusky Salamander covers between 200 000 km^2 and 2 000 000 km^2 (adapted from NatureServe 2010) and is similar to previous range estimates (Petranka 1998, Conant and Collins 1991), though it has been refined over the years.

Canadian Range

In Canada, *D. fuscus* occurs in a small area of the Niagara Gorge (Ontario), in the Covey Hill area (Quebec), throughout the outskirts of the Appalachian Mountains of southern Quebec and southern New Brunswick, and along the west/north shore of the St. Lawrence (Figure 4). This distribution represents around 5% of the global range (COSEWIC 1999, NatureServe 2010).

In Ontario, the species occurs along the escarpment of the Niagara Gorge, downstream from Niagara Falls, near the Whirlpool (Figure 4). The entire population is contained in a narrow stream between the Niagara River at the bottom of the gorge, and the tableland along Niagara Parkway, both acting as dispersal barriers (Yagi and Tervo 2008). The species is found in seeps that originate from a single source. Because a single catastrophic event could wipe out the entire Ontario population, it should be regarded as a single location. Suitable habitats occur mainly along the Niagara escarpment and the species is unlikely to be found outside the Niagara area (W. Weller pers. comm. 2010).

In Quebec, *D. fuscus* reaches its western limit in Covey Hill at the northernmost edge of the Adirondack Mountains (Figure 5). At Covey Hill the species occurs within a small area (~ 200 km^2) surrounded by urbanized or agricultural lowlands. Hydrological discontinuities or inhospitable habitat could cause this population to be isolated from New York populations.

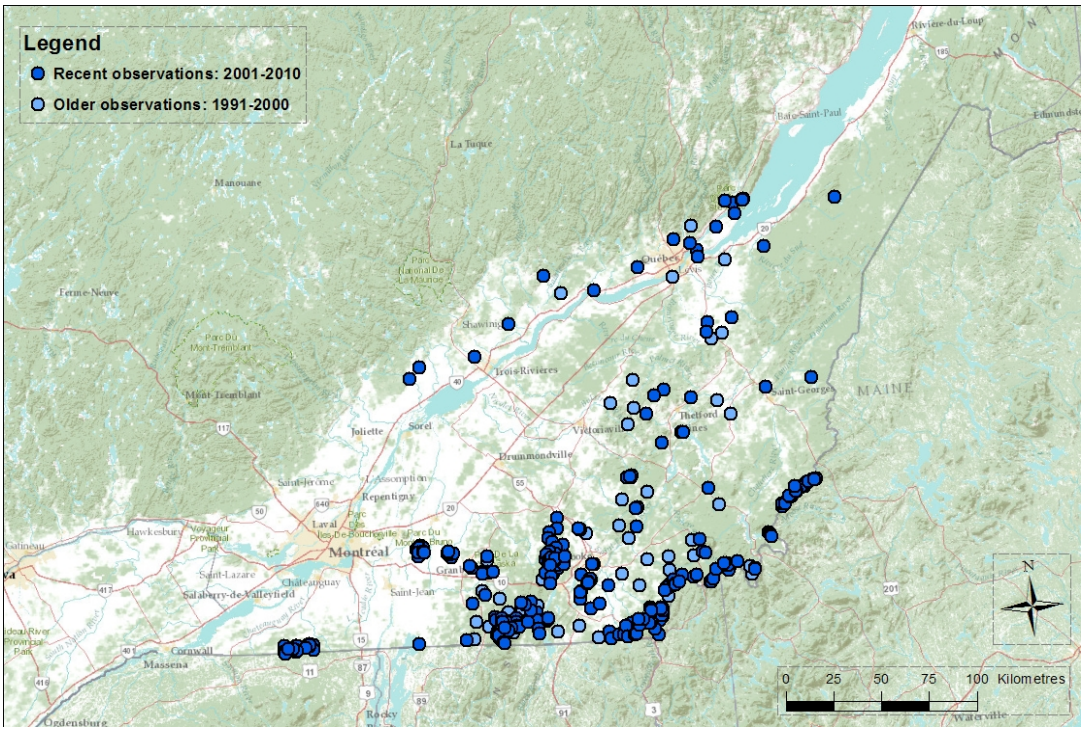

Figure 5. Quebec localities of the Northern Dusky Salamander (*D. fuscus).*

The species occurs throughout the Appalachian Mountains of Quebec, including Mounts Le Pinacle, Sutton, Echo, Foster, Orford, and Stoke. The range spreads out to the surroundings of Lakes Brome, Memphremagog, Massawippi, Magog and Brompton; and extends north of Mount Stoke, from Ham-Nord to Sainte-Justine. The remote topography of the Monteregian Hills (i.e., Mounts Saint-Hilaire, Rougemont, Yamaska, Shefford, Brome and Megantic) reduces the probability of immigration or emigration among these mountains (Figure 5).

In southeastern Quebec, the species is distributed along the US-Canada border from Hereford Hill to the lowlands of Sandy Bay Mountains (USA). Habitat suitability and connectivity between Quebec and neighbouring populations in Vermont, New Hampshire and Maine are unknown.

The species is also found along the south shore of the St. Lawrence River between the Chaudière River mouth (Charny) and Saint-Aubert, past Montmagny, which represents the northernmost record of the Northern Dusky Salamander in Canada (Figure 5). Along the west/north shore of the St. Lawrence River, the species occurs near the Saint-Maurice, Batiscan, Montmorency and Sainte-Anne rivers. Its presence has been confirmed between Louiseville and Saint-Ferréol-des-Neiges. Genetically distinct mitochondrial haplotypes have been identified near Charlesboug, Saint-Ferréol-des-Neiges and Trois-Rivières (Markle 2006).

In New Brunswick, the species' distribution is scattered, possibly reflecting a lower search effort rather than fragmentation. The Northern Dusky Salamander appears uncommon in southern and southeastern New Brunswick (McAlpine 2010a). The species is mainly found along the Saint John River valley, either near the river mouth (Grand Bay) or further north, between Perth-Andover and Fredericton (Figure 6). The northernmost confirmed records of the species in the province are in Perth-Andover (M. Sabine pers. comm. 2012). The species was also recently discovered in the Caledonia Gorge Protected Natural Area, south of Moncton in southeastern NB. This represents the easternmost record of the species in Canada. It also may be present near Bayside (Gorham and Bleakney 1983) and Twin Lakes, Charlotte County, in southwestern NB, and Fundy National Park, Albert County, in southeastern NB; these records are from reliable sources, but they have not been confirmed in recent years. Despite suitable habitats, the species is absent from Nova Scotia (Cook and Bleakney 1960, Gilhen 1984).

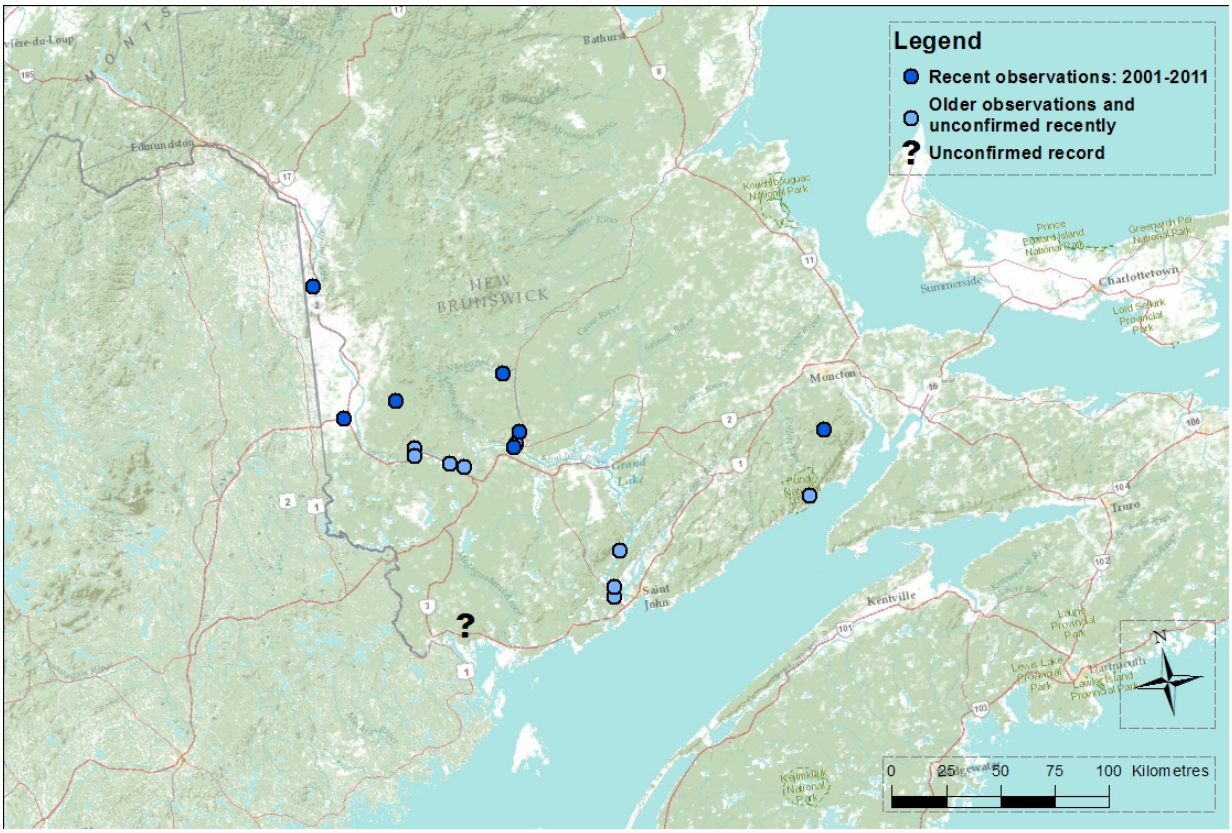

Figure 6. New Brunswick localities of the Northern Dusky Salamander (*D. fuscus)*.

Additional search efforts should be oriented toward the northern part of the species' distribution in Quebec, between Scott and Saint-Aubert. Also, a large area of apparently suitable habitat, east of Thetford Mines, has never been searched (S. Rioux pers. comm. 2009). In New Brunswick, although the species seems to be limited to the lower Saint John River and Fundy coast (D. McAlpine pers. comm. 2011), further investigations are needed to complete, and possibly expand, the species' range.

Information available in 2010 suggests an extent of occurrence (EOO) of 93,500 km^2 (Figure 4), of which the Carolinian population (Niagara Gorge) accounts for 4 km^2, and the Quebec/New Brunswick population accounts for 69,800 km². The total EOO value in Canada was calculated using a minimum convex polygon (COSEWIC 2010b) around all extant occurrences (Figure 4). The size of the total EOO has slightly increased over the past 10 years because of the discovery of new occurrences on the north shore of the St. Lawrence River and in remote areas in New Brunswick (Figures 5, 6).

The index of area of occupancy (IAO) is 1416 km^2, calculated by superimposing a grid with 2 km x 2 km cells over the species' occupied range. Because *D. fuscus* is a poor overland disperser and its movements are mainly through stream networks and riparian habitats, IAO was determined along streams where it occurs. Grids connecting two extant occurrences of the species along a stream were kept in calculations, except in the presence of dispersal barriers (e.g., roads, lakes, open field).

Search Effort

In Ontario, the Northern Dusky Salamander was discovered in the Niagara Gorge in 1989 (Kamstra 1991) and near an historical site reported by Bishop (1943). Since then, cover board surveys and standard searches have added observations in the known site, all within an area of 0.0015 km^2 (A. Yagi, *unpublished data*, W. Weller pers. comm. 2010). Search effort along the Niagara Gorge is restricted by its steep, dangerous topography. Suitable habitats have been searched in Niagara-on-the-Lake, St. Catharines, Grimsby and north of the Sir Adam Beck II Generating Station (6 person-hours) but the searches were unsuccessful (W. Weller pers. comm. 2010).

In Quebec, considerable search effort has been dedicated to the Northern Dusky Salamander subsequent to its discovery in 1928 (AARQ 2010). From the late 1950s to the late 1970s, the species was searched for mainly in the Appalachian area of Quebec and in the Maritimes (Bleakney 1958, Cook and Bleakney 1960, Denman 1963, Pendlebury 1973, Weller 1977). The Adirondack foothills and areas near Quebec City were more thoroughly studied in the following years (Bonin 1991, Bider and Matte 1994). Since 2000, over 800 new observations in southern Quebec have better delineated of the species' range (Frenette 2007). Of these, nearly 350 are in Covey Hill and 40 on the north shore of the St. Lawrence (AARQ 2010, CDPNQ 2010, A. Boutin unpublished data). Markle (2006) has searched for the Northern Dusky Salamander in 58 localities of Quebec and Labrador with a total effort of 100-150 h (Markle 2006). The Northern Dusky Salamander was found in 11 of the sampled sites, all south of l'Île d'Orléans, suggesting the species' absence in streams of northern Quebec (Appendix 2, Markle 2006).

In Quebec, systematic searches of stream sections were conducted in three areas of Covey Hill between 2002 and 2004 with a total effort of 154 person-days (Table 1, Jutras 2003, Boutin 2006, Frenette 2007). In the Appalachian Mountains, Appalachian Corridor Appalachien (ACA) and *Envirotel* have surveyed along the Sutton Mountain Range since 2001 (Table 1). Streams of Mount Stoke, near Lake Massawippi and along the hydrological basin of the Saumon River have also been investigated (Table 1, Desroches and Picard 2001, Frenette 2007). Numerous field surveys also took place on seven Monteregian Hills between 1997 and 2004 (Ouellet *et al*. 2005). Combined methods were used to locate stream salamanders: daily active search, nighttime visual encounters, pit traps, drift nets, and deviating fences. The results suggest the species is absent from Mount-Royal and Mounts Saint-Bruno and Saint-Grégoire (Ouellet *et al*. 2004, Ouellet *et al*. 2005, Noël *et al*. 2007 Appendix 2). Extensive fieldwork in Mount Saint-Hilaire *Biosphere Reserve* between 1997 and 2002 suggests the species has

disappeared from that area, along with three other amphibians (Ouellet *et al*. 2005, Appendix 2A). Active searches of salamanders have been completed in forest patches of Montréal and nearby islands (Noël-Boissonneault 2009, N. Tessier and Éco-Nature *unpublished data*), all suggesting the species' absence in Montréal (Table 1, Appendix 2).

Table 1. Search effort provided for some stream salamander surveys completed in Quebec between 2000 and 2010.

DU (Area)	Locality	Year(s)	Effort*	Area searched◊	Source
Great Lakes/ St. Lawrence (Covey Hill)	Covey Hill	2002-03	90	399 stream sections†	MRNF, UM, NCC
	Covey Hill	2004	64	63 stream sections†	A. Boutin *unpublished data*
Appalachian / Atlantic Coast South of St. Lawrence River, QC	Sutton Mountain Range	2001-05	261	Sutton Mountain Range and surroundings	ACA, Envirotel
	Mount Stokes	2001	15	7 streams of Mounts Stokes	MRNF, Frenette 2007
	Lake Massawipi	2001	-	Few streams near Lake Massawipi	MRNF, Frenette 2007
	Mount Brome	2004	-	A stream section of 4.7 km long	*Aqua-Berge Inc.* Frenette 2007
	Lake Megantic, Mount Megantic	2010	33.3	354 stream sections† in 10 areas from the Vermont border to ~50 km northeast of Lake Megantic	C. Laurendeau pers. comm.
	Mille Îles River	2006-10	28	Along the shores of the river and on 16 islands	S. Noël-Boissonneault, N. Tessier, Éco-Nature *unpublished data*
Appalachian / Atlantic Coast North of St. Lawrence River, QC	Capitale-Nationale region	2002	48.9	121 stations within the study area	Pouliot *et al*. 2007
	Portneuf	2010	4.3	Streams sections† near Saint-Alban, Saint-Ubalde and Grandes-Piles	C. Laurendeau pers. comm.

* Effort in person-days
◊ Area searched using an active search method (i.e., overturning all possible cover items)
† Stream section of 25 m long and extending up to 2 m from water's edge

Considerable search effort was expended around Quebec City, after the species' presence was confirmed in 1987. The species was found on Île d'Orléans and in 16 new localities near Quebec City (Desroches and Pouliot 2005, Pouliot and Vallières 2007, Pouliot *et al*. 2007). All the islands from the St. Lawrence estuary were searched between 1992 and 2003 without success (Fortin *et al*. 2004). The species is also thought to be absent on l'Île aux Coudres (Pouliot *et al*. 2007).

A number of additional salamander surveys have been conducted in specific areas of Quebec. Although the search effort is not available, a herpetological survey of a 467 ha forest in the Monteregian Plain between 2002 and 2004 failed to locate the species (Galois and Ouellet 2005). A total of 70 wetlands from Estrie have also been investigated, and the species was present in two of them (Frizzle 2001).

In 2010, habitat was searched along the eastern limit of the species' range as well as near Portneuf on the north shore of the St. Lawrence (C. Laurendeau, pers. comm., Table 1). Over 90 new occurrences of *D. fuscus* were found and the species' persistence was confirmed in known sites (C. Laurendeau, pers. comm. 2009).

The available data on the distribution of *D. fuscus* in New Brunswick comes mainly from fieldwork completed between 1954 and 1974 (ACCDC 2010, NBM 2010). Many observations of *D. fuscus* in New Brunswick are considered historical (NBM 2010). However, there is no reason to believe that the species has disappeared from these areas (D. McAlpine pers. comm. 2011). In 2010-2011, searches for Northern Dusky Salamander in New Brunswick focused on expanding the known range, rather than confirming historical locations. Two historical locations were confirmed and six new locations were discovered, including significant range expansions to the north and east of the province.

HABITAT

Habitat Requirements

The Northern Dusky Salamander inhabits springs, seepages, small tributaries of clear headwater streams of forested habitats and immediately adjacent moist terrestrial habitats (Hairston 1949, Organ 1961, Krzysik 1979, Petranka 1998, Pasachnik and Ruthig 2004). In Canada, it is mostly associated with mountain streams that drain topographic heights (Pendlebury 1973, Weller 1977, Bonin 1991). It has a predilection for small intermittent springs and seepages as opposed to fast flowing streams (Organ 1961, COSEWIC 1999, Rutherford *et al*. 2004). *Desmognathus fuscus* occupancy is higher in streams connected to other first-order streams than in those flowing directly into larger streams and rivers (Grant *et al*. 2009). In Covey Hill, more individuals were found in intermittent streams (n=394) than in permanent streams (n=94) (Rutherford *et al*. 2004, A. Boutin *unpublished data*). Substrate preference is not obvious (Keen 1982, Boutin 2006); substrates are used as long as they have high moisture (Grover 2000). The species is found in substrates of medium coarseness (i.e., gravel, small rocks; Krzysik 1979, Keen 1982), but also occur in streams with organic and muddy bottoms (Bonin 1991), in which it burrows (Orser and Shure 1972).

Metamorphosed individuals breathe through their skin and are critically sensitive to water loss by evaporation (Spotila 1972, Spotila and Berman 1976, Feder 1983, Feder and Burggren 1985). During daytime and low moisture conditions, the species remains hidden under protective cover objects (rocks, logs, moss or leaf litter) or in cool subterranean retreats (12-25 cm deep) near the stream edge (Spotila 1972, Ashton 1975, Keen 1984, Grover 2000). Availability of these refuges is essential to the species (Orser and Shure 1972) as they provide protection against dessication and predators, as well as feeding and brooding habitats (Hom 1988, Jaeger *et al*. 1995, Petranka 1998). Furthermore, the availability of these retreats can regulate distribution, abundance and composition of salamander communities (Southerland 1986c, Grover

1996). At night, *D. fuscus* emerges from these moist retreats to forage on the forest floor sometimes up the stream bank, away from water (Burton and Likens 1975a, Burton 1976, Organ 1961, Orser and Shure 1972, Grover 2000). *D. fuscus* feeds opportunistically on available prey along the streamside predominantly in the terrestrial habitat (Grover 2000, Mynatt and Miller 2002), but requires nearby aquatic habitats for respiration and hydration; thus, both are essential to the species (Pasachnik and Ruthig 2004).

Females usually nest in sandy or muddy substrates of high-gradient, shallow (< 5 cm) headwater streams that have small watersheds (< 70 ha) (Snodgrass *et al.* 2007). Eggs are laid in cryptic microhabitats adjacent to streams, between 1 and 88 cm from the water's edge (n=85) (Petranka 1998, Snodgrass *et al.* 2007). They are attached under rocks, moss or logs along stream banks, seeps or nearby habitats where the soil is saturated with water (Organ 1961, Juterbock 1986, Hom 1987, Grover 2000). Larval development requires cool flowing water and may be affected by stream dessication and acidification (Green and Peloquin 2008).

The Northern Dusky Salamander winters in habitats protected from freezing, either on the stream bottom or buried in refuges with gravel substrate and continuous water flow (Ashton 1975, Ashton and Ashton 1978, Desroches and Rodrigue 2004). Larvae remain in shallow, running water during winter (Desroches and Rodrigue 2004). Abundant rocky substrate on the streambed and banks probably prevents young individuals from freezing (Bider and Matte 1994). Maintenance of water flow to these streams is important to ensure the availability of wintering habitat for the species.

Forest cover is generally essential to the species. Vegetation cover keeps water cool, well oxygenated, and maintains moisture and temperature levels adequate for salamander survival (Shealy 1975, Krzysik 1979). Forest also plays a role in water quality and refuge availability as it lessens local sources of siltation (Hawkins *et al*. 1983, Waters 1995, Shannon 2000). Moreover, it limits solar radiation and dessication, (Thorson and Svihla 1943). Vegetation contributes to soil moisture and prey abundance, promoting better foraging conditions (Petranka 1998, Grover 2000).

At the landscape scale, connectivity between aquatic habitats is important to maintain dispersal and gene flow (Schalk and Luhring 2010); restricted movements between streams may cause population isolation (Tilley and Scherdtfeger 1981).

Temporary waterways formed during heavy rains may provide dispersal opportunities between otherwise terrestrially isolated wetlands (Schalk and Luhring 2010). Because *D. fuscus* tends to move upstream to brood and to winter in springs that do not freeze (Ashton 1976, Snodgrass *et al.* 2007), access to good quality headwater streams is also essential to the species.

Habitat Trends

The Niagara area has undergone considerable development in the past centuries, resulting in little remaining habitat for the Northern Dusky Salamander. Except for the steep banks of the Niagara River, the surrounding landscape is highly urbanized and fragmented. The Ontario population is within an unexploited forest stand managed by the Ontario Parks Commission (Yagi and Tervo 2008). However, storm water runoff and drainage water from the tableland (roads, parking lots, golf courses) are discharged along the gorge causing mudslides and inflow of poor quality water (Yagi and Tervo 2008). Storm water runoff increases bank instability and thus poses a risk to habitat maintenance. Furthermore, the water supplying the only extant occurrence of the species comes from a single source and the groundwater recharge area is not yet known (Yagi and Tervo 2008). For this reason, a single stochastic event such as a toxic chemical spill or groundwater contamination could critically jeopardize habitat quality in Niagara.

On the upper portion of Covey Hill, the soil type discouraged early agricultural development in areas occupied by the species. Also, probably because of the topography, Covey Hill has not been subjected to substantial timber harvesting; hence, the area retains old forest stands, unique in the province (Laroque *et al*. 2006). Nevertheless, the hill is now isolated in a highly fragmented landscape where agriculture, tourism developments, and increasing water needs remain important pressures on the habitat (Laroque *et al*. 2006, Frenette 2008).

Over the past 20 years, residential development and recreational infrastructures (i.e., skiing stations, golf courses) have significantly increased in the Appalachian region of Quebec (COSEWIC 1999) Therefore, habitat loss, alteration and fragmentation have occurred at various degrees in these localities. After an environmental impact assessment conducted in 2004, work to enlarge the Bromont ski station was begun in areas where the species is abundant (Frenette 2007, M. Frenette pers. comm. 2009).

In the centre of the Appalachian Mountain area of Quebec, the construction of windmill parks threatens Northern Dusky Salamander habitat. Windmill construction requires the alteration and construction of access roads and transmission lines that reduce the habitat quality/quantity because of increased runoff, erosion, siltation and damage to riparian vegetation.

Along the St. Lawrence Valley, numerous residential developments are ongoing, especially near Quebec City. Housing units are being constructed, namely in Lac Beauport, Stoneham, along the Montmorency River and on l'Île d'Orléans (Construction McKinley 2010, Construction Première-Classe 2010, Quai de Beauchatel 2010, Ville de Lévis 2010), areas where genetically distinct populations of *D. fuscus* are found. Although it is hard to determine whether these developments are directly reducing the Northern Dusky Salamander's habitat; they are located within watersheds where the species occurs and all require the construction of access roads.

Since the 19th century, the loss of cold spring habitat, mainly through forestry operations, remains the main threat to the Northern Dusky Salamander habitat in New Brunswick (D. McAlpine pers. comm. 2011). Current forest management practices are increasingly converting natural mixed forests to conifer plantations (Erdle and Pollard 2002). The adverse impact of logging activities (clear-cutting, stream siltation, conifer plantations) probably affected the species throughout the years.

BIOLOGY

Little is known about the species' biology in Canada. Accordingly, this section relies heavily on available information from nearby US populations.

Life Cycle and Reproduction

The Northern Dusky Salamander has a biphasic life cycle that includes an aquatic larval stage followed by a semi-terrestrial adult stage strongly associated with the aquatic habitat (Petranka 1998). Duration of the larval period varies between 7 and 16 months throughout the global range (Organ 1961, Tilley 1968, Danstedt 1975, Petranka 1998, Bruce 2005). Hatchlings grow faster, transform sooner and reach greater sizes at metamorphosis in southern as compared to northern populations (Juterbock 1990). In New York and Maryland, larvae complete their development in 8 to 10 months and 9 to 12 months respectively, during which they feed on small prey such as copepods, chironomid larvae and plecopteran nymphs (Bishop 1941, Danstedt 1975, Petranka 1998). They metamorphose in May or June, within a year after hatching (Bishop 1941, Danstedt 1975). Metamorphs range from 9 to 20 mm snout-vent length (SVL) (Petranka 1998).

Sexual maturity is attained at 38 to 44 mm SVL in many populations (Organ 1961, Spight 1967, Hall 1977, Juterbock 1978, Danstedt 1979, Davic 1983). Males are sexually mature at 2 or 3 years of age (Spight 1967, Danstedt 1975, 1979), although in higher elevations in Virginia, they mature at 3.5 years of age (Organ 1961). Females require an additional year to reach maturity and they produce a first clutch when 5 years old (Organ 1961). Considering the first breeding occurs at an average age of 4 years, and that the oldest breeding individuals in the wild can reach 10 years (Danstedt 1975, Desroches and Rodrigue 2004), generation time for the Northern Dusky Salamander could be about 6-7 years.

Mating takes place on land, in spring or fall in New York and Virginia (Bishop 1941, Organ 1961). Individuals engage in a complex courtship that lasts 1 to 2 h, in which the female ultimately recovers the spermatophore deposited by the male (Petranka 1998). Females lay eggs annually in late spring or early summer (Bishop 1941, Organ 1961, Hom 1987, Petranka 1998). Date of oviposition varies geographically, but also annually within *D. fuscus* populations (Hom 1987, Petranka 1998).

Fecundity increases with body size (Tilley 1968, Hom 1987, Petranka 1998). Throughout its range, clutches of between 8 and 45 eggs have been reported, with mean egg diameter of 3 to 4.5 mm (Bishop 1941, Jones 1986, Hom 1987, Juterbock 1987, Petranka 1998).

Females remain with their clutches until they hatch, 45 to 60 days after oviposition (Bishop 1941, Krzysik 1980b, Juterbock 1986, Hom 1987). Hatching occurs in late summer and early fall, (Bishop 1941, Organ 1961, Juterbock 1986, Hom 1987, Petranka 1998). Guarding females do not leave the nest cavity; they prey upon intruders and occasionally consume shed skin and infected eggs (Tilley 1970, Forester 1979, Krzysik 1980a). Brooding behaviour includes protection of the eggs from desiccation and against beetles or conspecific predators, agitation of the clutch by gular movements to prevent yolk deposition (layering) and oophagy to reduce fungal infections (Forester 1979). This behaviour is known to increase reproductive success in dusky salamanders because mortality of unattended clutches approaches 100% (Dennis 1962, Hom 1987, Forester 1979, Juterbock 1987). Nest failure is fairly high and varies year to year, likely caused by predation (Hom 1987). Reproductive success (i.e., the percentage of nests in which at least one embryo survives to hatching) is variable but low, ranging from 24% to 49% in Tennessee (Hom 1987).

Demographic attributes of Canadian populations have not been estimated. *Desmognathus* tend toward a Type I survivorship curve (*i.e*., high survival in early and middle life stages and low survivorship in later life), with substantial interpopulation variation in survival (Organ 1961, Danstedt 1975). Within populations survival rates are generally greater for males than for females and juveniles (Danstedt 1975). The average annual survival rate of males and non-brooding females in early years of life is 0.62; this value decreases to 0.40 in the first years following sexual maturity (Organ 1961). Maximum life span of the species is about 10 years (Danstedt 1975, Desroches and Rodrigue 2004).

Physiology and Adaptability

Salamanders from the Plethodontidae family are lungless; adults breathe through their thin and highly vascularized permeable skin (Whitford and Hutchison 1967, Feder 1976, Feder and Burggren 1985). To allow gas exchange, the skin needs to remain moist at all times; yet it is ineffective in restricting water loss by evaporation (Spight 1967, 1968, Spotila 1972, Spotila and Berman 1976, Feder and Burggren 1985). Hence, *D. fuscus* has no physiological control over desiccation or its rates of heating and cooling (Moore and Sievert 2001), and any movement out of its wet retreat involves water loss (Heatwole 1983).

To limit desiccation *D. fuscus* remains in refuges and reduces daily activities to periods of high moisture and low temperatures (Hairston 1949, Spotila 1972, Huheey and Brandon 1973, Shealy 1975, Grover 2000). At night, it ventures on the forest floor to forage and to reproduce when the temperature is low and humidity is high (Shealy 1975). The species uses microhabitats that are consistently cooler than the air

temperature (4°C), and it will move toward springs and seepages (up to 14°C cooler) as the stream temperature rises above 22°C (Ashton 1975). The Northern Dusky Salamander is mostly active at relative air humidity of 90% and when air temperatures range between 14°C and 23°C (Ashton 1975). To rehydrate *D. fuscus* must return to moist habitat or water, where its permeable skin allows water uptake (Shoemaker *et al*. 1992, Moore and Sievert 2001). Larvae are sensitive to low pH values; pH values less than 3.95 can be lethal, although some mortality can occur at pH levels below 4.2. Adults show tolerance to pH levels as low as 3.5 (Kucken *et al*. 1994, Green and Peloquin 2008).

Unlike birds, mammals, and turtles that store mercury in feathers, hair or carapace, amphibians cannot store mercury in body parts away from vital organs (Bank *et al*. 2007), and *Desmognathus fuscus* is sensitive to heavy metal contamination.

Dusky salamanders lack obvious chemical defences against predators and are known to be fully palatable (Brodie *et al.* 1979, Petranka 1998). However, the Northern Dusky Salamander is capable of autotomy at any point of the entire length of the tail. Once cleaved, the autotomized portion vigorously undulates to draw the predator's attention. The regenerated tail will reach a size close to the lost portion and will eventually become fully functional (Mufti and Simpson 2005). Tail breakage is suggested to be an indicator of predation pressure (Danstedt 1975). Wake and Dresner (1967) reports 33% of 239 *D. fuscus* he observed had stumped tails, whereas in Covey Hill, 23% of adults showed recent tail breakage (A. Boutin *unpublished data*).

The species is highly vulnerable to predation, competition and habitat alteration throughout its life stages (Burton 1976, Southerland 1986d). The particular secretiveness of vulnerable stages (brooding females, eggs and hatchlings) and their tendency to burrow and hide in refuges may allow them to circumvent some of these threats. *Desmognathus fuscus* can likely reduce predation and competition risk by adjusting its periods of activity, by using different refuges or by modifying its feeding behaviour (Jaeger 1971b, Fraser 1976, Krzysik 1979, Roudebush and Taylor 1987, Grover 2000, Boutin 2006). Foraging during rainy nights reduces dehydration and predation risk, while increasing foraging success (Jaeger 1972, Burton 1976, Fraser 1976, Keen 1982, Jaeger *et al*. 1995).

The species is considered a feeding generalist that consumes available prey of an adequate size (Burton 1976, Sites 1978). Whereas larvae feed mostly on aquatic invertebrates, adult diet consists predominantly (60 to 85%) of terrestrial prey such as arthropods and earthworms, with a variable proportion of aquatic invertebrates that reflects the diversity and seasonally abundant invertebrate fauna (Ashton 1975, Burton 1976, Sites 1978, Mynatt and Miller 2002).

Dispersal and Migration

In plethodontids, first-year larvae have limited swimming capabilities (Bruce 1986, Müller 1954), therefore they have a high propensity for drift (i.e., downstream passive movement), especially at low temperatures (Bruce 1986, Marvin 2003) or during high water flow events (Bruce 1986, Lancaster *et al.* 1996, Elliott 2002). However, recent research on stream salamander dispersal revealed that both adults and larvae move significantly more frequently and over longer distances upstream than downstream (Lowe 2003, Lowe *et al*. 2006a, Cecala *et al*. 2009). Dispersal of stream salamanders occurs primarily along the stream channel (within-network movement) following a model of simple diffusion (Lowe 2003, Lowe *et al*. 2006b). Downstream movements (drift) are rather infrequent and occur over small spatial scales (Lowe 2003, Cecala *et al*. 2009). These findings refute the common hypothesis that downstream movement or drift is important in salamander dispersal.

Nonbreeding adults are relatively sedentary and are usually found between 15 and 90 cm from water's edge (Krzysik 1979), or at most within 5 m of open water (Pendlebury 1973, Petranka 1998). Over 2 years, most adults remain within a 15 m stretch of stream (Hom 1987). Specimens can return to their home range after being displaced 30 m (Barthalamus and Bellis 1969).

Females exhibit an upstream bias in movements to reach high gradient headwater streams for brooding (Snodgrass *et al.* 2007). It seems they move as far upstream as possible to select a nesting site near the terminus of these streams (Snodgrass *et al.* 2007). This behaviour may minimize the exposure of eggs and larva to predatory fish, high current velocities and deteriorating water quality (Forester 1977, Bruce 1986). Brooding females are secretive and can move into the rock layers below the stream to depths greater than 1 m (Ashton 1975). *Desmognathus fuscus* also tends to move upstream ahead of winter to reach springs that do not freeze (Ashton 1976).

Adult home range is small and varies between $0.1m^2$ and $3.6m^2$ in summer (Ashton 1975). Females exhibit fidelity to a short (15 m) section of the stream segment, at least during spring and summer (Hom 1987).

Because the species is considered a poor overland disperser, genetic exchange between isolated populations seems feasible only through stream network connectivity. Episodes of heavy rainfall can create temporary streams that can allow the species to colonize new wetlands. Grover and Wilbur (2002) found *D. fuscus* colonize successively and persist in artificial seeps created 3 m and 15 m from streams.

Interspecific Interactions

Predation is likely responsible for high nest failure in Northern Dusky Salamanders (Hom 1987). Carabid beetles, crayfish, the Northern Watersnake (*Nerodia sipedon*), Eastern Gartersnake (*Thamnophis sirtalis*) and Ring-necked Snake (*Diadophis punctatus*) also consume salamanders and their eggs (Uhler *et al.* 1939, Hom 1987, Whiteman and Wissinger 1991, Desroches and Rodrigue 2004). The Northern Dusky Salamander is undoubtedly prey to birds and small mammals such as shrews, rodents, raccoons and skunks (Bishop 1941, Krzysik 1980a, Petranka 1998).

The Spring Salamander preys upon smaller salamanders (Bishop 1941, Bruce 1979, Petranka 1998) and including *D. fuscus* (Danstedt 1975). Brook Trout (*Salvelinus fontinalis*) is an important predator of salamanders (Lowe *et al*. 2004, Barr and Babbitt 2007). Fish are capable of influencing larval densities of streamside salamanders (Petranka 1983, Sih *et al*. 1992, Barr and Babbitt 2002, Lowe and Bolger 2002). Survival of larval Spring Salamanders is reduced by over 50% in the presence of fingerling Brook Trout (Resetarits 1995).

Desmognathus fuscus can defend its eggs against conspecifics and carabid beetles but not against larger species (Forester 1979, Hom 1987). Larger individuals occasionally cannibalize larvae and juveniles (Carr 1940, Hamilton 1943).

The ecology of *D. fuscus* is greatly influenced by interspecific interactions with other salamanders (Means 1975, Keen 1982, Boutin 2006). In sympatry, salamanders segregate along a moisture gradient that minimizes niche overlap (Hairston 1987, Grover 2000, Grover and Wilbur 2002, Petranka and Smith 2005). In stream salamander communities, the Spring Salamander is usually the most aquatic species as well as a strong competitor and predator (Forester 1979, Petranka 1998). It successfully displaces *D. fuscus* toward dryer, less optimal microhabitats (Grover 2000). In return, *D. fuscus* is able to displace the Red-backed Salamander (*Plethodon cinereus*) and *D. ochrophaeus* toward drier habitats (Krysik 1979, Grover and Wilbur 2002).

Although *D. fuscus* and *D. ochrophaeus* are completely sexually incompatible in some localities where they both co-occur (Verrell 1990, 1994), in others they hybridize. Hybrids have been detected in several contact zones in Ohio, Pennsylvania and Quebec (Karlin and Guttman 1981,1986, Houck *et al*. 1988, Sharbel *et al*. 1995). In Quebec, the phenomenon is infrequent (Karlin and Guttman 1981, Sharbel *et al*. 1995). The absence of F1 hybrids suggests low levels of hybridization and backcrossing with *D. ochrophaeus* is apparent in most hybrids (Sharbel *et al.* 1995, Boutin 2006).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Considerable sampling effort has been provided in some parts of the Canadian range, yet it is difficult, if not impossible, to determine whether populations are declining or not based on available data.

In Ontario, sampling effort has mainly focused on determining the species' presence along seepages of the Niagara Gorge. However, 13 individuals were marked in 2005, in an attempt to evaluate population size, but only three were recaptured (A. Yagi, *unpublished data*).

In Quebec, fieldwork has mainly focused on determining the species' presence/absence in numerous parts of the range and in previously unexplored areas. Still, very limited data are available on local abundances. Although numbers of individuals are recorded in many localities, the total area searched and the effort expended are not always available (AARQ 2010). Therefore, it is hard to compare populations or to make assumptions on local densities.

In New Brunswick, many historical records exist on *D. fuscus* (reviewed by McAlpine 1997) of which two sites were confirmed in recent years. In addition, six new sites have been discovered within the last two years. Recent search effort has focused on determining presence/absence and extending the known range of Northern Dusky Salamander in New Brunswick, and not on estimating local abundances or confirming historical locations (M. Sabine pers. comm. 2011).

Abundance

The number of Northern Dusky Salamanders in Canada is unknown. In Ontario, the species is considered rare because of its very restricted range. There was an attempt to estimate the Ontario population size in 2005. Preliminary results provided a rough estimate of between 7 and 35 mature individuals (A. Yagi *unpublished data*). The mark-recapture study has not been repeated.

In Covey Hill (Quebec), time-constrained searches of 1 h covering a stream section of 25 m in length, extending up to 2 m from the water's edge, yielded a maximum of 11 adults in one site or 0.07 adults/m^2 (A. Boutin *unpublished data*). Maximum catches in the Megantic area using the same protocol provided 10 individuals (C. Laurendeau *unpublished data*). Burton and Likens (1975b) estimated densities of 0.04 individuals/m^2 in streams of New Hampshire. In more southern parts of the range, populations usually reach higher densities: 0.43-1.42 salamanders/m^2 in North Carolina and 0.75-0.78 salamanders/m^2 in Pennsylvania (Spight 1967, Hall 1997). Based on available observations, small intermittent springs and seepage areas support greater densities (Weller 1977, COSEWIC 1999, Boutin 2006, Markle 2006). Throughout the species' range, the 11 sites sampled by Markle (2006) for at least 20 min. per site

yielded between 1 and 18 individuals (mean = 8.6 individuals); however, the distance over which specimens were captured is unavailable. Although the species is not usually found in large numbers in Canada (usually ≤ 10 AARQ 2010), as many as 117 metamorphosed individuals were observed in one stream of Mount Orford, suggesting the species can be locally abundant (AARQ 2010).

The species has always been considered “rare” in New Brunswick (McAlpine 1997), a maximum of 7 adults and 3 juveniles have been reported in a single site (ACCDC 2010, NBM 2010). The species seems extremely rare in Fundy National Park (Clay and Brownlie 1996). One new site in 2011 yielded 15 Northern Dusky Salamanders after 2 people searched one hour (M. Sabine pers. comm. 2011).

Fluctuations and Trends

Fluctuations and trends for Canadian populations are unknown. Because the species has only been discovered recently in Ontario, little is known about fluctuations and trends of the population. In Quebec, a comparison of historical and current records available in 2010 show that populations in some areas have persisted for as long as 80 years after initial discovery (AARQ 2010). The numerous searches made in the past decade led to discovery of six new populations and a small increase of extent of occurrence, likely reflecting greater search effort rather than population growth or the establishment of new populations. On the other hand, some Quebec populations of *D. fuscus* currently remain historical suggesting the species has disappeared from some areas. It has likely disappeared from Mount St-Hilaire since the early 1960s (Weller 1977, Ouellet *et al*. 2005, AARQ 2010). On Mount Yamaska, the species was last observed in 2007 (Coté and Cormier 2007; AARQ 2010), but habitat loss has occurred on the mountain (S. Rioux pers. comm. 2009). As for Mount Brome, the species was observed in 1997, in an area now exploited by the ski station (Frenette 2007). Salamander surveys on Mounts Royal, Saint-Bruno and Saint-Gregoire, all in the Monteregian Hills, failed to locate the species (Ouellet *et al*. 2004, Galois and Ouellet 2005, AARQ 2010).

In New Brunswick, historical populations likely reflect the lack of recent surveys. Based on records from 1997, *D. fuscus* did not appear to have declined (McAlpine 1997). Records from 2010-2011 have expanded the species’ range in the province, suggesting the species could be more widely distributed, although with a scattered distribution.

Rescue Effect

Throughout its US range, *D. fuscus* is mostly secure (NatureServe 2010). Adjacent to Canada, populations in New York, Vermont, New Hampshire and Maine are considered secure, but local extinctions have been reported in Maine, in Acadia National Park (Bank *et al*. 2006). Based on the species' poor dispersal ability, it is unlikely that individuals can overcome the distance and physical barriers that separate most Canadian populations. The Niagara Gorge population is over 30 km away from the nearest US population in New York State, and separated by important geographical barriers such as the Niagara River (Bishop 1941, Kamstra 1990, COSEWIC 1999). In New York State, agriculture, forest harvesting and access roads have modified the habitat adjacent to Covey Hill and reduced habitat connectivity. In the Appalachian Mountain area of Quebec, it is only along the southeastern limit of the range that Vermont, New Hampshire and Maine populations could offer a rescue potential, provided that the species has persisted there and that suitable habitat ensures connectivity between populations. In New Brunswick, some populations are a mere 5 km from Maine.

THREATS AND LIMITING FACTORS

Human activities (urbanization, logging, road construction) that affect water supply and quality, as well as microhabitat quality and availability, are the major threats to *D. fuscus* in Canada. Some threats are particularly severe on small remote populations as they increase the risk of extirpation due to stochastic events. Watershed urbanization may also be detrimental to local populations, as it increases runoff water and stream siltation, and reduces network connectivity. Development of wind farms in Quebec (Figure 7) threatens dusky salamanders particularly from the impacts of construction of access roads and new transmission corridors. In Ontario, impacts from human activities such as trampling riparian habitat, discarding garbage into the gorge (millions of people visit the Niagara Gorge annually), changing the water table from the hydroelectric tunnel project and storm water runoff (which causes mudslides), and pollution of the groundwater and the stream itself (see Stewardship Guide and Yagi and Tervo 2008, Markle *et al*. 2010).

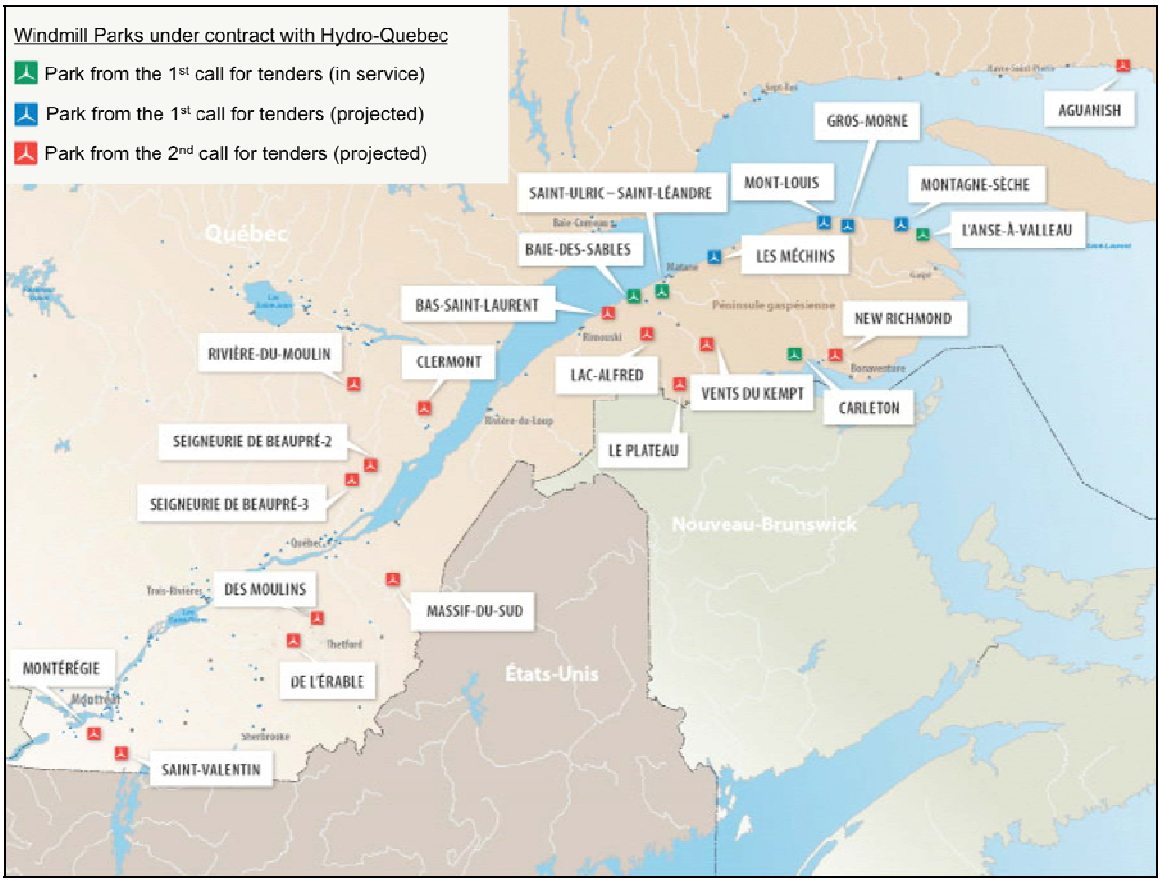

Figure 7. Windmill parks planned in Quebec as of 2009. Some are currently under review, whereas others are now operating (Éoliennes de l'Érable Inc. 2009)

Because they are small and have reduced water flow, high elevation streams tend to be less permanent, which naturally limits habitat available for larvae and metamorphs of semi-aquatic salamanders (Petranka and Smith 2005). Globally, low order headwater streams inhabited by the Northern Dusky Salamander are the first aquatic habitats affected by development and pollution (Wilson and Dorcas 2003). These streams do not appear on 1: 20 000 scale maps or on air photographs thus they may be overlooked in environment assessment projects (Snodgrass *et al*. 2007, Peterman *et al*. 2008), especially when drought renders such streams barely visible. Furthermore, headwater streams are more susceptible to degradation than other ecosystems (Power *et al*. 1988) partly because they are small and depend heavily on local watershed conditions (Bank *et al*. 2006). They also have little acid-neutralizing capacity and may fluctuate beyond acidity levels tolerated by some salamander species (Green and Peloquin 2008).

Underground water reserves feed seeps and springs inhabited by *D. fuscus* in the Niagara Gorge (Yagi and Tervo 2008) and Covey Hill populations (Barrington *et al.* 1993) and are undoubtedly indispensable to the species elsewhere in the Canadian range. In Ontario, the groundwater supplying the *D. fuscus* location originates from a single source and its recharge area is unknown (Yagi and Tervo 2008). Therefore, any

major developments along the adjacent uplands could be detrimental, as they would change the quality and quantity of water discharged in the area. Bank instability caused by large volumes of runoff water has disrupted salamander populations and reduced availability of suitable microhabitats (Orser and Shure 1972, Riley *et al*. 2005). This threat is imminent as slope failure already occurs along the Niagara Gorge and has altered habitats near the sites where *D. fuscus* is found.

In the Adirondack Piedmont, a large peat bog at the top of Covey Hill supplies the water table of the whole Covey Hill area (Barrington *et al*. 1993). Further development of the hill or the destruction of the bog would likely change groundwater levels. In that area, there is considerable consumption of groundwater for orchards, agriculture, private residences, and a campsite facility, but these activities do not represent a threat to groundwater levels yet (COSEWIC 2007). However, groundwater exploitation for commercial and industrial use is now stronger than ever in Quebec (Bonin 2000). Exploitation for bottled water has been previously tabled in the Covey Hill area but was withdrawn after local opposition (J. Bonin pers. comm. 2010). Current regulations do not protect the species' habitat from the effects of water exploitation, and in parts of the species' range groundwater is shared with the United States (COSEWIC 2007).

Alteration of water quality is as threatening to the species as the reduction of water supply to its habitat (Jutras 2003). Water pollution can affect the species through underground water and connecting streams and is a threat throughout the Canadian range. The situation is further complicated as water sources feeding most of the species' habitats in Canada remain unknown. In Covey Hill, high levels of pesticides and fertilizers used in adjacent agricultural lands and golf courses could be a source of groundwater contamination (COSEWIC 2007).

Low order headwater streams used by *D. fuscus* are among the ecosystems most susceptible to degradation (Power *et al*. 1988). They are subject to atmospheric deposition of pollutants (Fitzgerald *et al*. 1991, Bank *et al*. 2006) and have poor acid-neutralizing capacity (Green and Peloquin 2008). Moreover, plethodontid salamanders are sensitive to heavy metal contamination (Bank *et al*. 2007) as well as soil and water acidification (Roudebush 1988, Wyman 1988, Kucken *et al*. 1994). In streams showing metal contamination and acidification, Kucken *et al*. (1994) noticed a reduction of 50% in populations of the closely related *D. ochrophaeus*. Atmospheric deposition is the primary source of mercury (Hg) in surface waters from the northern US (Fitzgerald *et al*. 1991). This pollutant accumulated, possibly from upwind sources, in Acadia National Park in Maine where *D. fuscus* is dramatically declining (Bank *et al*. 2006). High concentrations of Hg, reaching levels that are critical for fish conservation, were measured in *E. bislineata* from that area (USEPA 1997, Bank *et al*. 2006). Although the sensitivity of *D. fuscus* to such pollutants has not been evaluated, Bank *et al*. (2006) suggest heavy metal contamination is the primary explanation for the species' disappearance in the protected study area. Pollution by atmospheric deposition is also responsible for the acidification of nearly 40% of the mountain streams in the southern Appalachians (United States). This acidification has severely affected stream water chemistry in the area, and analyses predict it will continue to increase (Sullivan *et al*.

2004). The levels of stream acidification in Canada are unknown but should be regarded as a serious threat throughout the species' range. The negative effect of water acidification on a large *Desmognathus* species was demonstrated and could be especially lethal to the smaller *D. fuscus* (Green and Peloquin 2008). Because young life stages of *D. fuscus* are strictly aquatic, eggs and larvae may be particularly vulnerable to adverse effects of such water conditions.

Studies have reported the adverse and possibly severe effects of timber harvesting on salamanders (Corn and Bury 1989, Petranka 1994, Gibbs 1998). Knapp *et al.* (2003) found that gravid females of *D. ochrophaeus* weighed less in cut treatments. As body weight is directly correlated with clutch size, deforestation can have negative outcomes on reproductive success and survivorship. Canopy removal affects moisture and temperature conditions crucial for plethodontid survival, but also reduces water quality (Shealy 1975, Krzysik 1979, Jung *et al*. 2000). Plethodontids are particularly sensitive to the edge effects associated with warmer and dryer habitats caused by timber harvesting and road construction (Petranka and Smith 2005). One of the most adverse effects of timber harvesting is the filling-in of the interstitial spaces used by salamanders for foraging, shelter, nesting, and overwintering through substrate embedment (siltation) (Hawkins *et al*. 1983, Waters 1995, Shannon 2000). Sedimentation is a persistent threat to the integrity of small stream ecosystems (Lowe *et al*. 2004), and can greatly reduce salamander abundance (Welsh and Olliver 1998, Lowe and Bolger 2002, Lowe *et al*. 2004). As interstices between rocks become embedded, protective cover from predators is reduced or eliminated (Lowe and Bolger 2002, Lowe *et al*. 2004). This can expose larvae to stronger currents, and decrease prey availability (Smith and Grossman 2003). As retreats are depleted, competition and predation pressures may increase and cause community shifts (Krzysik 1979, Southerland 1986 a, b, c, Roudebush and Taylor 1987). Furthermore, *D. fuscus* avoids nesting in streams receiving runoff from residential areas as they likely suffer more erosion (Snodgrass *et al*. 2007). Increase in organic matter (i.e., erosion leading to siltation) is believed to reduce oxygen levels, vital to larvae (Bider and Matte 1994). Recruitment may also be impaired if sediments are deposited on eggs (Bruce 1978).

Deforestation is ongoing in Quebec where residential and recreational developments are increasing; in New Brunswick, it remains the main threat to the species (D. McAlpine pers. comm. 2011). Because intermittent streams inhabited by *D. fuscus* are mostly located on private lands they are not protected from forest operations (Jutras 2003).

D. fuscus is known to have lower occupancy probabilities in streams within urbanized regions compared to relatively undeveloped areas (Grant *et al*. 2009). Urban developments have impacts on hydrology, geomorphology as well as stream ecosystem function and structure (Grant *et al*. 2009). It also increases the chances of episodic extinctions (Price *et al*. 2006). Watershed urbanization increases runoff from paved surfaces and instability of surrounding soils (Welsh and Olliver 1998, Lowe and Bolger 2002, Lowe *et al.* 2004). Furthermore, in highly disturbed watersheds, maintaining riparian buffers may not lessen the impacts of upland watershed development on

sensitive salamanders (Wilson and Dorcas 2003). Thus they may be ineffective in protecting local salamander populations (Wilson and Dorcas 2003). In Canada, *D. fuscus* as well as three other amphibian species have disappeared from Mount Saint-Hilaire National Park because of extensive developments (Ouellet *et al*. 2005).

Stream salamanders are particularly sensitive to large-scale (*i.e*., landscape) habitat alterations that change spatial configuration of stream networks and reduce their connectivity (Welsh and Ollivier 1998, Lowe and Bolger 2002, Grant *et al*. 2009). Flood control regimes and roads have important implications for metapopulation viability in salamanders because they alter watershed connectivity (Schalk and Luhring 2010). In areas of heavy urban or agricultural land use, small streams are lost and stream networks become simplified over time (Dunne and Leopold 1978, Sophocleous 2000), which is detrimental to *D. fuscus*, a poor overland disperser requiring first order headwater streams (Snodgrass *et al.* 2007, Peterman *et al.* 2008). Loss of stream connectivity reduces the likelihood of recolonization by overland movements (Fagan *et al*. 2009) that can greatly reduce isolation and risk of extirpation (Lowe 2002).

In the past, the Quebec provincial government has introduced Brook Trout and other salmonid species to headwater streams, above the natural barriers that normally limit their access to these headwaters (W. Bertacchi, pers. comm. 2011). These introductions have occurred in large numbers in the Estrie region in tributaries of the Missisquoi River and near Mount Orford where the Northern Dusky Salamander is present. Although the guidelines have now been revised, fish introduction still occurs in Quebec and represents a threat to stream salamanders (W. Bertacchi, pers. comm. 2011). Introduction of predatory fish into streams or upstream lakes is likely to deplete populations of the Northern Dusky Salamander (Resetarits 1991, 1995, Jutras 2003). The negative effects of predation significantly increase when interstitial refuges become scarce (Lowe *et al.* 2004). Artificial dams created along urbanized streams may also reduce salamander abundance through increased predation by fish (Lowe and Bolger 2002, Lowe *et al*. 2004).

PROTECTION, STATUS, AND RANKS

Legal Protection and Status

The Northern Dusky Salamander is assessed Endangered in Ontario by the Committee on the Status of Species at Risk in Ontario (COSSARO) and listed as Endangered by the Ministry of Natural Resources (NHIC 2010). It is protected under the Ontario *Endangered Species Act* (E.S.A.), 2007. The natural heritage component of the Provincial Policy Statement under the *Planning Act* provides for protection of significant habitat of species listed in regulation under the E.S.A. The *Fish and Wildlife Conservation Act* makes it illegal to hunt, trap, keep, sell or purchase live specimens without a government permit.

In Quebec, the species is not designated. It is currently on a list of species likely to be designated Threatened or Vulnerable by the provincial government (MRNF 2010). Nonetheless, the species is protected by the provincial *Act respecting conservation and development of wildlife* (R.S.Q., c. C-61.1) that prohibits collecting, buying, selling or keeping specimens in captivity.

The New Brunswick *Fish and Wildlife Act* prohibits taking any wildlife into captivity, keeping wildlife in captivity, or selling, trading or purchasing any wildlife, without authorization from the Minister.

Non-Legal Status and Ranks

At the federal level, the Northern Dusky Salamander was assessed as a single DU and Not at Risk by COSEWIC (1999).

Globally, the species is ranked G5 (last reviewed 2003) by NatureServe indicating it is widespread and globally secure (NatureServe 2010). In the United States it is also nationally secure (N5), whereas in Canada it is considered vulnerable to apparently secure (N3-N4). In Quebec and New Brunswick, the Northern Dusky Salamander is ranked S3, meaning it is vulnerable in each province, and it is ranked critically imperiled (S1) in Ontario (NatureServe 2010). The IUCN Red List considers the species Least Concern (IUCN 2010), and it does not appear on the Convention on International Trade in Endangered Species (CITES). Under the General Status of Species in Canada, the Northern Dusky Salamander is designated as being “at Risk” in Ontario, and “Sensitive” in Quebec, New Brunswick and Canada (http://www.wildspecies.ca).

Habitat Protection and Ownership

Currently, about 25% of the Northern Dusky Salamander’s area of occupancy in Canada is in protected areas (Nature Conservancy of Canada (NCC) 2011). In Ontario, the area in which *D. fuscus* occurs is owned and managed by the Niagara Parks Commission. Although sites are difficult to access, hikers still do venture into the species’ habitat and cause damage to riparian areas (Yagi and Tervo 2008). In Quebec, protection measures for stream salamanders, regarding silvicultural practices on public provincial lands, have been recently adopted and implemented (MRNF 2008a). However, most of the Northern Dusky Salamander’s range in Quebec is located on private lands. Landowners have been encouraged to apply these protection measures on a voluntary basis (D. Banville, J. Jutras pers. comm. 2011). Article 22 of the provincial *Environment Quality Act* (R.S.Q., c. Q-2) offers protection against unregulated degradation of environmental quality. A certificate of authorization from the minister must be obtained prior to undertaking any construction or industrial activity that negatively affects a river, a lake, a pond, a marsh, or a peat bog.

In Quebec, NCC bought 1.24 km^2 of land as part of its Covey Hill Natural Laboratory initiative, protecting half of the hilltop bog that feeds the streams of the hill (Laroque *et al*. 2006). The protection of the bog does not guarantee the ecological and hydrological integrity of the habitat because it is very sensitive to external disturbances (Pellerin and Lavoie 2003). South of the US border, in New York State, a similar area, "The Gulf Unique Area", is protected and represents 2.16 km^2 (Laroque *et al*. 2006).

In the Appalachian Mountains, the species' habitat is protected in Quebec National Parks, which fall under provincial jurisdiction, including: Mount Orford Park (54.90 km^2), Mount Saint-Bruno Park (12.89 km^2), and Mount Megantic Park (54.86 km^2). In Haut-Saint-François County, the Ecological Reserve of Samuel-Brisson was created, providing protection for 7.9 km^2 of habitat adjacent to Mount Megantic. Records confirmed the species' presence at Mount Yamaska National Park (12.89 km^2) until 2007 (Coté and Cormier 2007, AARQ 2010); however, very little suitable habitat remains inside the park's limits at this time (S. Rioux pers. comm. 2009).

The Mount Sutton Range, protected by NCC in partnership with the forest company Domtar Inc. is the largest private protected area in Quebec, currently covering 63.94 km^2 (Frenette 2007, NCC 2008). Ultimately, NCC wishes to protect a total of 101.17 km^2 in the centre of these mountains and establish a surrounding buffer zone of 303.51 km^2 (NCC 2008). To do so, NCC is collaborating with private landowners, the Appalachian Corridor Appalachien (ACA) Land Trust, the Ruiter Valley Land Trust, and local organizations. The south slope of Mount Sutton is under provincial protection, as part of the Ruiter Valley Ecological Reserve (1.17 km^2), which the Northern Dusky Salamander inhabits.

As a non-profit conservation organization, ACA works to preserve wildlife habitats along the Appalachians. Since 2001, conservation plans for stream salamanders have been produced for landowners and conservation agreements have been signed with them (Frenette 2007). Since 2000, the Société de conservation du corridor naturel de la rivière aux Saumons has also been active in the conservation of a region north of Mount Orford. This non-profit organization has bought over 0.65 km^2 of land and oversees the management of an additional 1.27 km^2 of habitat used by the Northern Dusky Salamander (Frenette 2007). The Société de Conservation et d'aménagement du bassin de la rivière Châteauguay promotes public awareness on private properties in the hydrological basin of the Chateauguay River (Frenette 2007). Collectively, these initiatives might help the species' situation on private land.

Mount Saint-Hilaire is a 4-km^2 Migratory Bird Sanctuary of which 0.13 km^2 are aquatic habitats (CWS 2008). On this mount, the Northern Dusky Salamander habitat is protected through the Gault Nature Reserve, owned and managed by McGill University (S. Giguère pers. comm. 2010). However, the species seems to have disappeared from this area (Ouellet *et al*. 2005).

The establishment of the *Réserve écologique de la Serpentine-de-Coleraine* in 2003 may help protect the species potential habitat near Thetford Mines. It comprises two of the three Coleraine Mounts over 3.96 km^2 (MDDEP 2008a). However, as opposed to other nature reserves on private land, public access is allowed in this reserve.

At a smaller scale, measures to mitigate adverse effects of silvicultural operations to stream salamanders (including *D. fuscus*) have been developed in public forests (MRNF 2008a). A riparian area is protected over 60 m on either side of an observation point and over a distance of 500 m downstream and upstream, along the hydrological network concerned. The guidelines prohibit construction of logging roads and the installation of bridges or culverts in riparian zones. Depending on their severity, some forest operations affecting less than 50% of the cover are allowed in the last 20 m of the protected zone (MRNF 2008a). If species observations are not along a stream (*e.g.,* springs, seepage areas), the protection zone is considered as a circle of 150-m diameter around the occurrence. *D. fuscus* localities from Mount Megantic, Notre-Dame-des-Bois and Lake Megantic are on public land where these silvicultural measures apply. This may help protect the species' habitat and attenuate threats in these government-managed areas.

In New Brunswick, one locality of *D. fuscus* is found within the protected area of Fundy National Park, managed by Parks Canada. An additional site is located within the Caledonia Gorge Protected Natural Area, where industrial, commercial, agricultural uses and development are prohibited under the New Brunswick *Protected Natural Areas Act*. Another site is located within the Odell Park where wildlife is protected under the New Brunswick *Fish and Wildlife Act*.

Most of the species' range in Canada is located on private lands, which do not fall under any type of protection. As much as 75% of the species' area of occupancy remains in unprotected habitat. However, initiatives to protect the species' habitat have increased over the past decade. In this regard, and assuming that essential habitats and good quality water supplies are maintained, the species' long-term survival is possible.

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BIOGRAPHICAL SUMMARY OF REPORT WRITER

Anaïs Boutin obtained her Master's degree in biology at l'Université de Montréal in 2006. Her thesis focused on determining the habitat selection of a community of stream salamanders from Covey Hill (Quebec) comprising five species and *Desmognathus fuscus* x *D. ochrophaeus* hybrids. Her work also focused on the development of molecular methods for identifying these hybrids and their parental species. She is a member of the National Recovery Team for the Mountain Dusky Salamander and of the Ontario Dusky Salamander recovery team and acts as a coordinator for the Quebec Stream Salamander Recovery Team. She remains involved in the conservation of endangered wildlife and works as a biologist under the Habitat Stewardship Program for Species at Risk.

COLLECTIONS EXAMINED

No collections were examined for this update of the status report on the Northern Dusky Salamander (*Desmognathus fuscus*) in Canada.

DATA SOURCES

This report is based on available data in 2010, provided from:

Atlantic Canada Conservation Data Center (ACCDC)

Atlas des Amphibiens et des Reptiles du Québec (AARQ)

Centre de données sur le patrimoine naturel du Québec (CDPNQ)

Natural Heritage Information Centre of Ontario (NHIC)

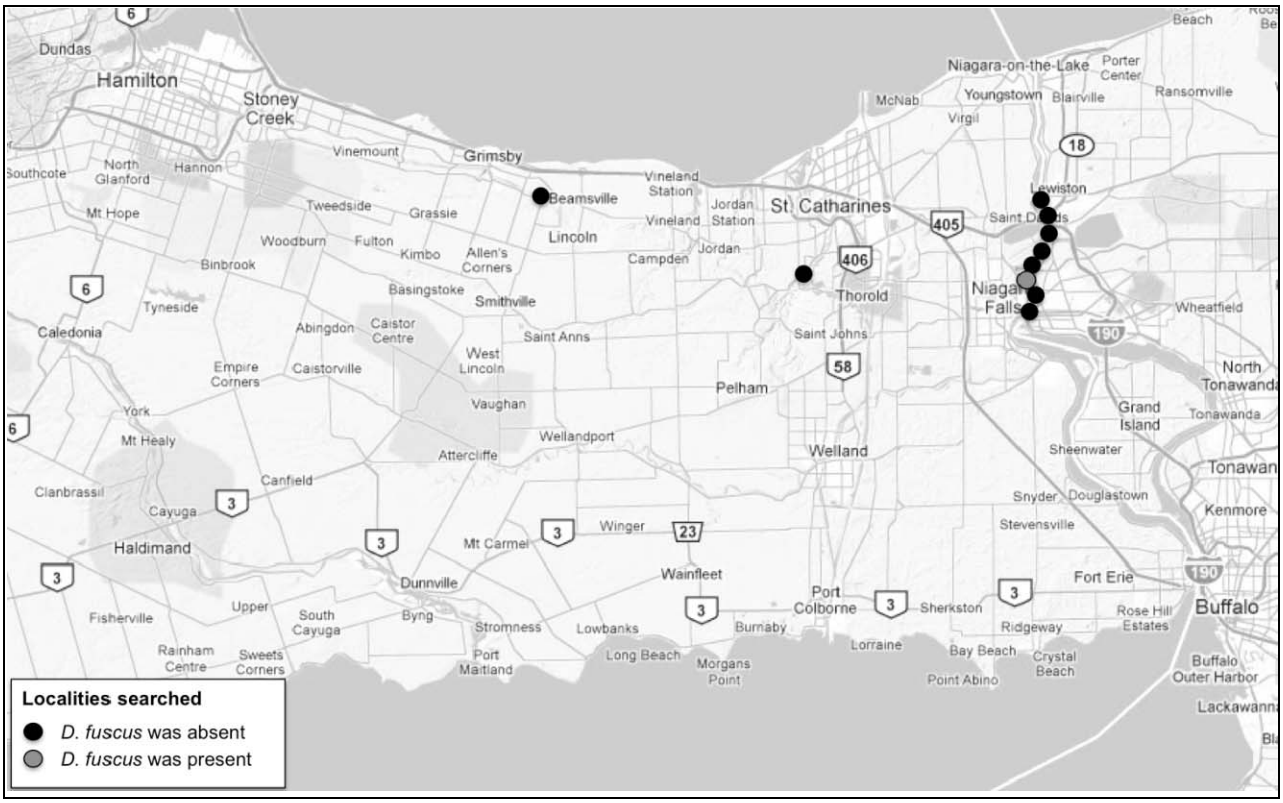
New Brunswick Museum (NBM)

Ontario Ministry of Natural Resources (MNR)

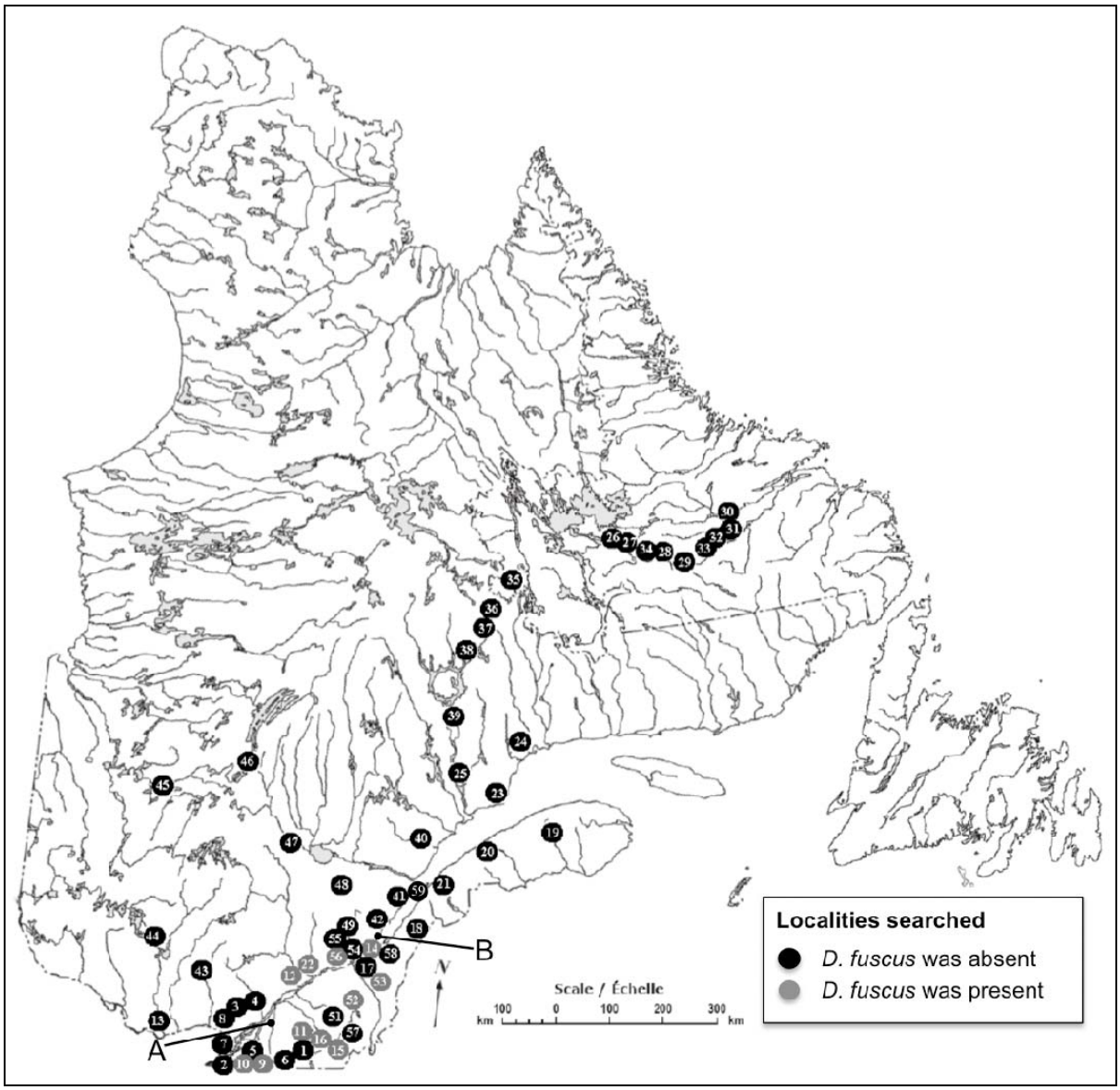
Anaïs Boutin, unpublished data

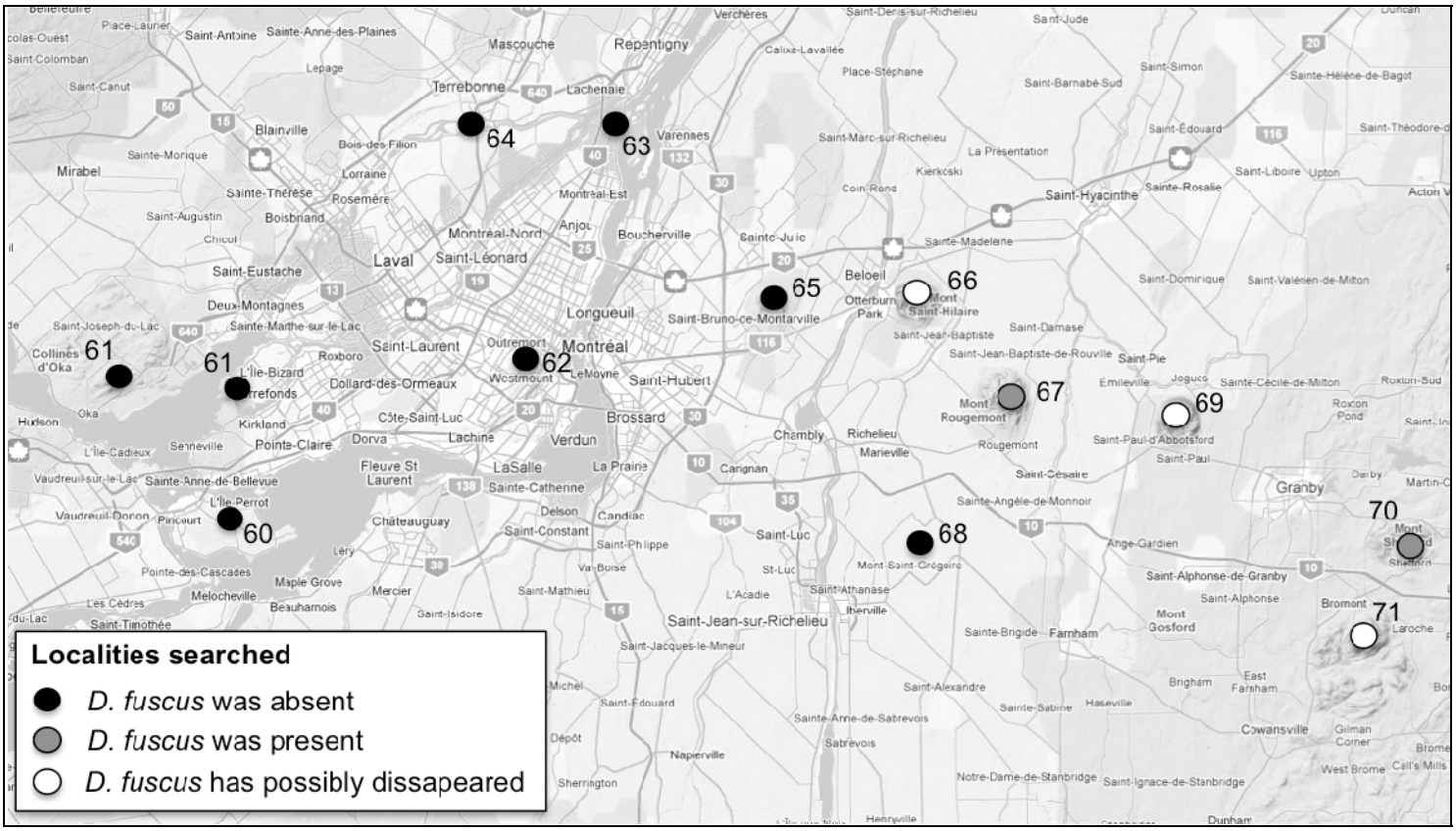
Ann Yagi, unpublished data

Appendix 1. Localities in the Niagara area (Ontario) that were searched for Northern Dusky Salamanders.

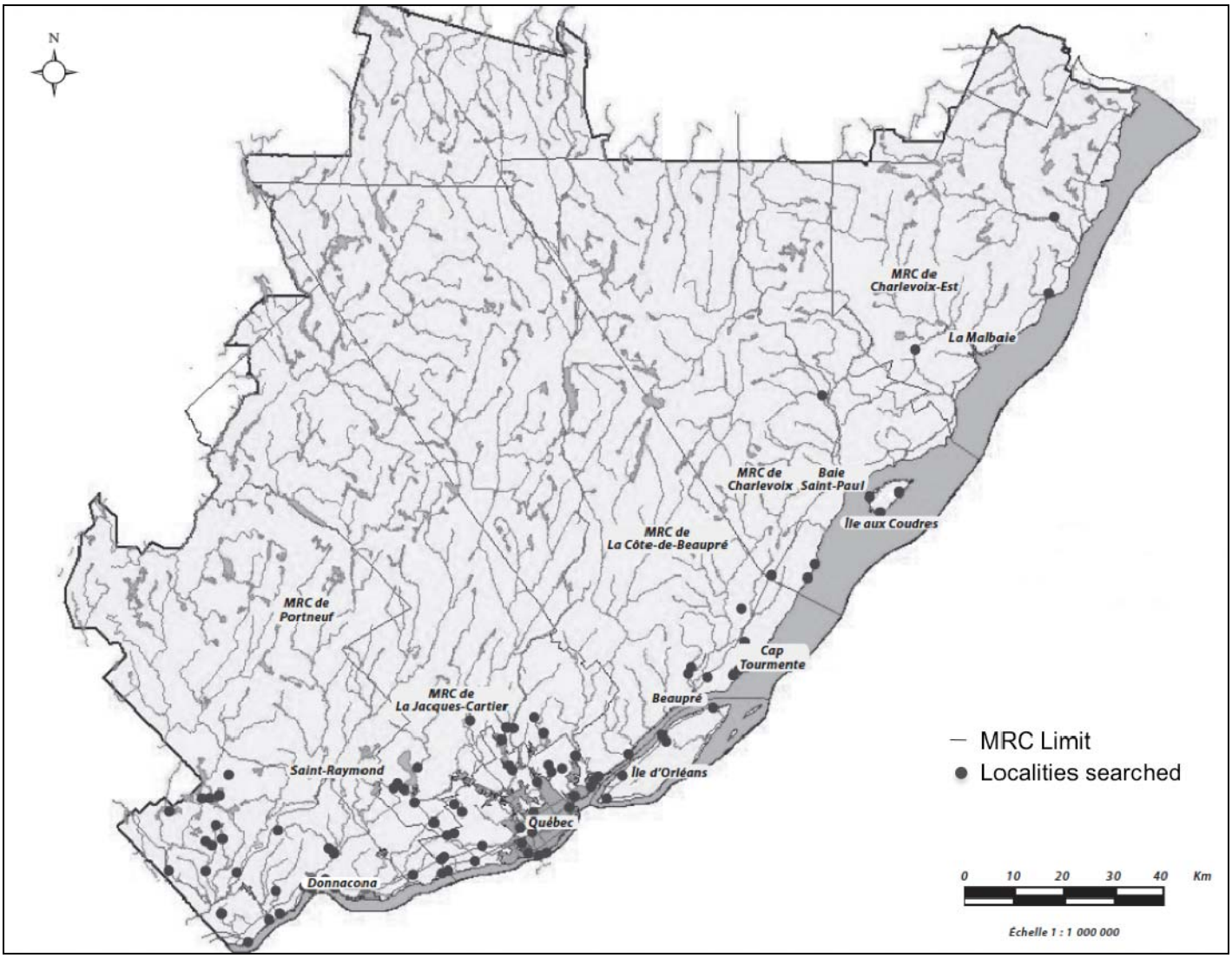


Appendix 2. Localities from Quebec and Labrador that were searched for Northern Dusky Salamanders by Markle (2006) and Pouliot *et al*. (2007). Please refer to A) for localities near Montréal and on the Monteregian Hills and, to B) for the Capitale-Nationale Region on the North Shore of the St. Lawrence River.





A) Localities searched in the Montréal area and on Monteregian Hills by Ouellet *et al*. (2005), Noël-Boissonneault (2009), N. Tessier and Éco-Nature *unpublished data*.



B) Localities searched in the Capitale-Nationale Region by Ouellet *et al*. (2005).

Appendix 3. Details of the localities that were searched for Northern Dusky Salamanders in Quebec.

1	Bromont, Qc	37	86 km South of Labrador City, Qc
2	Huntington, Qc	38	172 km South of Labrador City, Qc “Blough River”
3	Shawbridge, Qc	39	Manic 5, Qc
4	Sainte-Calixte, Qc	40	Forestville, Qc
5	Russeltown, Qc	41	27 km South of Baie St. Catherine, Qc
6	St. Armand, Qc	42	Baie St. Paul, Qc
7	Rigaud, Qc	43	Bayard, Qc
8	Brownsburg, Qc	44	48.6 North of Grand Remous, Qc
9	Havelock, Qc	45	7 km North of Waswanipi, Qc
10	Franklin, Qc	46	20 km North of Chabougamau, Qc
11	Mt. Shefford, Qc	47	South border of Reserve Faunique Ashuapmushhuan
12	Trois-Rivières (Saint-Narcisse), Qc	48	40.5 km South of Herbertville Hwy 169, Qc “Rivière Wine”
13	Gatineau, Qc	49	Réserve faunique des Laurentides, Qc
14	Île d’Orléans, Qc	51	Asbestos, Qc
15	Compton, Qc	52	Thetford Mines, Qc
16	Mt. Orford, Qc	53	Frampton, Qc
17	Beaumont, Qc	54	“Parc de la chute” Montmorency, Qc
18	Lac de L’Est, Qc	55	Charlesbourg, Qc
19	Gaspesie National Park, Qc	56	Charlesbourg, Qc
20	St. Damase, Qc	57	Scotstown, Qc
21	Trois-Pistoles, Qc	58	Beaumont, Qc
22	St. Alban, Qc	59	Île aux coudres, Qc
23	Godbout, Qc	60	Île Perrot, Qc
24	Sept-Isles, Qc (Réserve faunique de Port-Cartier)	61	Île Bizard, Qc
25	North of Baie Comeau, Qc (Hwy 389)	62	Pointe-aux-Prairies, Qc
26	29 km East of Churchill Falls, Labrador	63	Rivière des Mille Îles, Qc
27	34 km East of Churchill Falls, “Ozzie’s Brook” Labrador	64	Collines d’Oka
28	147 km East of Churchill Falls, Labrador	65	Mont-Royal, Qc
29	149 km East of Churchill Falls, Labrador	66	Mt. St. Bruno, Qc
30	North West River, Labrador	67	Mt. St. Hilaire, Qc
31	“Lower Brooke” 29 km West of Happy Valley Goose Bay, Labrador	68	Mt. Rougement, Qc
32	38 km West of HVGB, Labrador “Upper Brook”	69	Mt. St. Grégoire, Qc
33	54 km West of HVGB, Labrador “Edward’s Brook”	70	Mt. Yamaska, Qc
34	195 km West of HVGB, Labrador “East Wilson river”	71	Mt. Shefford, Qc
35	13 km NE of Labrador City, Nfld and Labrador	72	Mt. Brome, Qc
36	64 km South of Labrador City, Qc		

Markle 2006 (**1 to 58**); Pouliot et al. 2007 (**59**); Noël-Boissonneault 2009 (**60 to 62**); S. Noël-Boissonneault, N.Tessier, Éco-Nature, *unpublished data* (**63**), Ouellet *et al*. 2005 (**64 to 71**); Gallois and Ouellet 2000 (**69**); S. Rioux pers. comm. (**70**); Frenette 2007 (**72**).