COSEWIC
Assessment and Status Report

on the

Wood Turtle
Glyptemys insculpta

in Canada

THREATENED
2018

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

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

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Previous report(s):

COSEWIC. 2007. COSEWIC assessment and update status report on the Wood Turtle *Glyptemys insculpta* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 42 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

Brooks, R.J., Litzgus, J.D. 1996. COSEWIC status report on the Wood Turtle, *Clemmys insculpta*, in Canada. Committee on the Status of Endangered Wildlife in Canada. 1-64 pp.

Production note:
COSEWIC would like to acknowledge Geoffrey Hughes for writing the status report on Wood Turtle *Glyptemys insculpta* in Canada, prepared under contract with Environment and Climate Change Canada. This report was overseen by Tom Herman, Co-chair of the COSEWIC Amphibians and Reptiles Specialist Subcommittee (A&R SSC). Modifications to the status report after acceptance of the provisional report were overseen by Tom Herman, based on comments from jurisdictions, experts, A&R SSC, and COSEWIC members.

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Wood Turtle, *Glyptemys insculpta*, by Graham Forbes.

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COSEWIC
Assessment Summary

Assessment Summary – November 2018

Common name
Wood Turtle

Scientific name
Glyptemys insculpta

Status
Threatened

Reason for designation
This turtle is declining across much of its range, where it occurs in small, increasingly disjunct subpopulations, many of which are separated from each other by distances greater than the species can be expected to disperse. It has strong site fidelity, often returning to restricted nesting and overwintering areas for decades. Although it requires both aquatic and terrestrial habitats, it is more terrestrial than other freshwater turtles, making it vulnerable to road kill, land use practices, and collection for the pet trade. Its 'slow' life history, characterized by delayed maturation and extreme longevity, requires exceedingly high adult survival to maintain stable populations. Any chronic increase in adult or juvenile mortality, or a catastrophic adult mortality event, is destabilizing and unsustainable. Increased exposure to traffic on paved and unpaved roads, agricultural activity (particularly mowing and tilling), and expanding populations of subsidized predators, as well as changing regimes in watersheds, have increased mortality and placed subpopulations at risk.

Occurrence
Ontario, Québec, New Brunswick, Nova Scotia

Status history
Designated Special Concern in April 1996. Status re-examined and designated Threatened in November 2007. Status re-examined and confirmed in November 2018.

COSEWIC
Executive Summary

Wood Turtle
Glyptemys insculpta

Wildlife Species Description and Significance

Wood Turtle (*Glyptemys insculpta*) is a medium-sized freshwater turtle, with adults weighing about 1 kg and having a carapace (upper shell) length of 16 - 25 cm. The carapace ranges from greyish-brown to yellow and is broad and low. Each scute (scale-like section) has pyramidal concentric ridges (growth lines), giving the carapace a sculptured appearance; in older turtles, the ridges on the scutes may become worn smooth. The plastron (bottom shell) does not have a hinge, and is yellow with black blotches on the outer posterior corner of each scute. The plastron is flat in females and juveniles, and becomes concave in males as they reach maturity. Males are slightly larger than females, have a broader head, and longer, thicker tails. The skin is generally brown, but the legs and neck often have yellow, orange or reddish colouring.

Wood Turtle is popular as a pet, largely because of its attractive appearance, terrestrial habits, and non-aggressive response to people. The numerous threats facing Wood Turtles have made the species the focus of many research and conservation activities and given it a high profile as a Species at Risk.

Distribution

Wood Turtle is endemic to eastern North America and has a patchy distribution from Nova Scotia west through New Brunswick, Québec, and Ontario to Minnesota, south to Virginia and Maryland. In Canada, Wood Turtle occurs in Nova Scotia, New Brunswick, south-central Québec, and south-central Ontario, extending west to the southeastern shore of Lake Superior. Approximately 30% of the global distribution is in Canada. The range is discontinuous, and many subpopulations are isolated and small.

Habitat

Wood Turtle is semiaquatic and considerably more terrestrial than most freshwater turtles. It is strongly associated with meandering rivers and streams with moderate current and sand or gravel substrates. Wood Turtles overwinter underwater in streams, rivers, and occasionally ponds. During the active season (spring, summer, early fall), the turtles use riparian habitats and upland forests surrounding their home rivers; mosaics of forest and open-canopy areas are the most commonly used or preferred terrestrial habitats, and Wood Turtles are frequently referred to as an ‘edge species’. Wood Turtles primarily

forage in terrestrial or wetland habitats that occur within close proximity to the river/stream, including bogs, marshy pastures, oxbows, beaver ponds, shrubby cover, meadows, coniferous forests, mixed forests, hay and agricultural fields and pastures. Wood Turtles use the same areas each year and are capable of returning to these areas from several kilometres away; males tend to remain close to their home rivers during the active season, whereas females tend to move further inland.

Natural nesting habitat of Wood Turtle consists of sand or gravel-sand beaches or banks of streams that receive moderate to intense exposure to sun. Wood Turtles also nest in anthropogenic open-canopy sites such as gravel pits, road shoulders, and decommissioned railway beds.

Accurate quantitative data on the area of habitat available in the past and at present across the entire range are not available, but estimates using aerial photography show ~16% of current Wood Turtle habitat as low disturbance, with 29% being impacted by agriculture, 41% impacted by forestry, and 14% impacted by development (such as towns/cities and industry). More than 99% of Canadian Wood Turtle occurrences are on watercourses within 300 m of a road. These disturbances are likely deleterious to Wood Turtles, similar to impacts on other turtle species in Canada.

Biology

Wood Turtles hibernate from approximately October to April, and are generally active from May to September. During the active season, they may range up to 500 m from water and several kilometres upstream and downstream from their hibernation sites. Females nest between late May and early July. Rate of embryo development varies directly with ambient temperature and hatching occurs in late summer or early fall. Wood Turtles reach sexual maturity between 11 and 22 years of age; this range largely depends on latitude, with turtles farther north maturing later and at larger body sizes. Mating occurs throughout the active season but is most frequent during spring emergence and at the beginning of the overwintering period. Adult longevity in the wild can exceed 80 years, and a conservative estimated generation time is 35 years. The main predators of adults and juveniles are Raccoons, Coyotes, and foxes; these and other mammals also eat turtle eggs. Various mammals, fishes, and birds prey on hatchlings. Wood Turtles forage primarily in terrestrial habitats for berries, mushrooms, and a wide range of invertebrates.

Population Sizes and Trends

An overall estimate of total population size of Wood Turtle in Canada, based on estimates of varying precision from researchers across its Canadian range, is 13,650-31,790 adults. Wood Turtle subpopulations in areas with limited human access may be stable, but many subpopulations are declining where there is road access. The overall trend in Wood Turtle abundance over the past three generations (100+ years) is thought to be one of decline.

Limiting Factors and Threats

The most significant threats to Wood Turtles across the species' range are agriculture and transportation corridors. Agriculture causes direct mortality through machinery collisions and destruction of nests during tilling and affects the species indirectly through habitat loss and increases in subsidized predation. Transportation corridors cause direct mortality through vehicle collisions and affect the species indirectly through habitat fragmentation and increased human access to Wood Turtles and their habitats. Wood Turtles are also subjected to many other threats associated with human activities, such as changes in stream flow regimes, illegal collection, and invasive and problematic native species, including subsidized predators.

Like all turtles, Wood Turtles are limited by the low numbers of juveniles that survive to adulthood, and as a result, any adult mortality above the natural rate becomes a potential threat to the long-term viability of a subpopulation. Additionally, Wood Turtles tend to occur in dense concentrations, particularly after emergence in spring, during nesting, and during mating in fall, and poachers can potentially remove significant numbers from a subpopulation in a single event.

Protection, Status and Ranks

Globally, Wood Turtle is listed as Endangered by the International Union for Conservation of Nature, and is listed under Appendix II of CITES. Federally, Wood Turtle was assessed as Threatened by COSEWIC in 2007 and listed as such in Schedule 1 of the *Species at Risk Act* in 2010. Wood Turtle was up-listed from Threatened to Endangered under the Ontario *Endangered Species Act* in 2008; the species is also designated as a Specially Protected Reptile by the Ontario *Fish and Wildlife Conservation Act*. An Ontario recovery strategy was published in 2010, which was followed by the Government Response Statement later that year and a 'five-year review' in 2015. In Québec, the Wood Turtle is listed as "Vulnerable" under the "*Loi sur les espèces menacées ou vulnérables*" (RLRQ, c E-12.01) (Act respecting threatened or vulnerable species) (CQLR, c E-12.01) and is afforded protection under the "*Loi sur la conservation et la mise en valeur de la faun"* (RLRQ, c. C- 61.1) (Act respecting the conservation and development of wildlife) (CQLR, c. C-61.1). A Québec recovery strategy was published in 2005 and a new version is in preparation and should be published in 2019. In New Brunswick, Wood Turtles were listed as Threatened under the *Species at Risk Act* in 2013; New Brunswick's *Fish and Wildlife Act* also offers protection to all vertebrates, preventing collection and trade without a Ministry permit. In Nova Scotia, Wood Turtle was listed as Vulnerable in 2000 under the *Endangered Species Act*, and it was up-listed to Threatened in 2013.

In the United States, Wood Turtle is listed as Endangered in Iowa, as Threatened in Minnesota, Wisconsin, New Jersey and Virginia, and as Special Concern in Michigan, Connecticut, Maine, Massachusetts, New Hampshire, Vermont, Rhode Island, New York and West Virginia. In Pennsylvania and Maryland, Wood Turtle is not listed but is a protected nongame species. It is also known historically from Ohio and the District of Columbia, but is apparently extirpated from these jurisdictions. As of September 2018, the species' federal status in the United States is under review.

TECHNICAL SUMMARY

Glyptemys insculpta

Wood Turtle

Tortue des bois

Range of Occurrence in Canada: Ontario, Québec, New Brunswick, Nova Scotia

Demographic Information

Generation time = Age of first reproduction + 1/adult mortality (IUCN 2014 guidelines).	35 years
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes, inferred decline based on range–wide declines in IAO and observed direct mortality, and projected decline based on threats.
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Insufficient data to estimate.
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Insufficient baseline observation data over past 3 generations (105 years). Reduction suspected to be over 30% based on historical landscape change and the observed 24% reduction in IAO Canada-wide since historical times (see **Extent of Occurrence and Area of Occupancy** and **Fluctuations and Trends** sections in this document).
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Threats Calculator results indicate a suspected10-70% population reduction over 3 generations (100+ years) based on a high overall threat impact.
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Over 30% inferred and suspected reduction over 3 generations (100+ years) based on inferred minimum 24% reduction in past due to reduction in IAO nationally and suspected10-70% population reduction in future based on a high overall threat impact
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	a. partially b. yes c. no
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence	722,874 km^2 (931,462 km^2 including historical records)
Index of area of occupancy (IAO) (Always report 2x2 grid value).	3,728 km^2 (4,936 km^2 including historical records)

Is the population “severely fragmented” i.e. is >50% of its total area of occupancy is in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	Unlikely, although data are insufficient to assess across range.
Number of “locations” * (use plausible range to reflect uncertainty if appropriate)	Probably exceeds 300, using counts of element occurrence records (EOs) as proxies, because the threat of road mortality, in terms of long-term population viability, probably closely approaches the scale of most element occurrence records.
Is there an [observed, inferred, or projected] decline in extent of occurrence?	Observed (calculated) minimum 22% decline in EOO over past 3 generations.
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Observed (calculated) minimum 24% decline in IAO over past 3 generations; Inferred over 30% reduction based on historical landscape change and limited baseline observation data.
Is there an [observed, inferred, or projected] decline in number of subpopulations?	Observed decline: subpopulations throughout the species’ range have been extirpated.
Is there an [observed, inferred, or projected] decline in number of “locations”*?	Observed decline, based on loss of element occurrences across species’ range.
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Inferred decline: Roads (top recognized threat) occur within > 99% of Wood Turtle IAO squares. Forestry, agriculture, and development occur within 41%, 29%, and 14% of IAO squares respectively. Minimal human impacts occur in only 16% of IAO squares. The magnitude of these impacts is unknown, but declines in area, extent and quality are all inferred (see **Habitat Trends**).
Are there extreme fluctuations in number of subpopulations?	No.
Are there extreme fluctuations in number of “locations”1?	No.
Are there extreme fluctuations in extent of occurrence?	No.
Are there extreme fluctuations in index of area of occupancy?	No.

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges) (grouped by province)	**N Mature Individuals**
Ontario Total	1,100-4,400
Québec Total	8,725-13,090
New Brunswick Total	1,825-7,300
Nova Scotia Total	2,000-7,000
Canada Total	**13,650-31,790**

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

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	Unknown for total population

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

Was a threats calculator completed for this species? Yes

Calculated overall threats impact High (high range) and High (low range).

i. Roads and railroads, including logging roads: medium.
ii. Annual and perennial non-timber crops, particularly mowing (which can directly kill adults) and tilling (which can destroy/expose nests): medium/low
iii. Problematic native species, esp. subsidized predators (foxes, Raccoons, skunks, corvids), particularly on nests and juveniles, but adults in some subpopulations as well: low
iv. Mining and quarrying for gravel: low.
v. Hunting and collecting terrestrial animals: low
vi. Recreational activities, particularly ATVs: low
vii. Housing and urban development, including cottages: low
viii. Other ecosystem modifications, esp. changing flow regimes in watersheds: low
ix. Livestock farming and ranching, due to trampling: low
x. Logging and wood harvesting (excluding logging roads): low.
xi. Storms and flooding, particularly through nest flooding: low

What additional limiting factors are relevant?

All turtles are limited by their “bet-hedging” life history strategy, wherein adults are long-lived with high lifetime reproductive output but low annual reproductive success, and few hatchlings survive to adulthood. Even slight increases in adult mortality above natural levels will cause long-term declines in a subpopulation.

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	USA: Declining in most states: listed as S3 in New York, New Hampshire and Vermont, and S4 in Maine.
Is immigration known or possible?	Possible in Québec and New Brunswick
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Yes
Are conditions deteriorating in Canada?	Yes
Are conditions for the source population deteriorating?	Yes
Is the Canadian population considered to be a sink?	No
Is rescue from outside populations likely?	Possible but unlikely on a large scale, due to declines in source populations, habitat patchiness, and limited dispersal capabilities.

Data Sensitive Species

Is this a data sensitive species? Yes

Current Status

COSEWIC Status History: Designated Special Concern in April 1996. Status re-examined and designated Threatened in November 2007. Status re-examined and confirmed in November 2018.
Author of the Technical Summary: Geoffrey Hughes and Amphibians & Reptiles Specialist Subcommittee
Additional Sources of Information:

Status and Reasons for Designation:

Status:	**Alpha-numeric codes:**
Threatened	A2cd+3cd+4cd
Reasons for designation: This turtle is declining across much of its range, where it occurs in small, increasingly disjunct subpopulations, many of which are separated from each other by distances greater than the species can be expected to disperse. It has strong site fidelity, often returning to restricted nesting and overwintering areas for decades. Although it requires both aquatic and terrestrial habitats, it is more terrestrial than other freshwater turtles, making it vulnerable to road kill, land use practices, and collection for the pet trade. Its 'slow' life history, characterized by delayed maturation and extreme longevity, requires exceedingly high adult survival to maintain stable populations. Any chronic increase in adult or juvenile mortality, or a catastrophic adult mortality event, is destabilizing and unsustainable. Increased exposure to traffic on paved and unpaved roads, agricultural activity (particularly mowing and tilling), and expanding populations of subsidized predators, as well as changing regimes in watersheds, have increased mortality and placed subpopulations at risk.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): A2. Suspected reduction in mature adults greater than 30% based on (c) decline in habitat quality over 3 generations (>100 years), and inferred minimum 24% reduction due to observed 24% reduction in IAO Canada-wide since 1997, and (d) exploitation in the form of road and agriculture-related mortality. A3. Threats Calculator results indicate a suspected10-70% population reduction based on a high overall threat impact (per Table 4 of Threats Calculator Guidelines), particularly due to (but not limited to) threats associated with roads, agriculture, subsidized predators, and changing flow regimes in watersheds. A4. Over 30% inferred and suspected reduction based on (c) decline in habitat quality over 3 generations (>100 years), and inferred minimum 24% reduction in past due to observed reduction in IAO nationally, and (d) past exploitation in the form of road and agriculture-related mortality, as well as a suspected 10-70% population reduction in future based on a high overall threat impact.
Criterion B (Small Distribution Range and Decline or Fluctuation): Does not meet criteria. EOO greatly exceeds and IAO exceeds threshold values.

Criterion C (Small and Declining Number of Mature Individuals): Does not meet criteria. Minimum population estimate (13,650) exceeds 10,000.
Criterion D (Very Small or Restricted Population): Does not meet criteria. The population is neither very small nor very restricted.
Criterion E (Quantitative Analysis): Does not apply. Data only available for a few small subpopulations.

PREFACE

Since the 2007 Report, (COSEWIC 2007), there has been considerable research on Wood Turtle throughout Canada. This new research has included studies on habitat use and spatial ecology (Greaves 2007; Wesley 2007; Paterson *et al*. 2012; White 2013; Thompson *et al*. 2018), thermal ecology and energetics (Dubois *et al*. 2008, 2009; Hughes 2016), assessment of the nest-site incubation conditions selected by female Wood Turtles (Hughes *et al*. 2009), growth rates (Marchand 2015), and spatial genetics studies (Amato *et al*. 2008; Fridgen *et al.* 2013). Surveys have been conducted throughout the species' range with focus on the northern range in Ontario and the eastern range in Québec. Larger population estimates relative to those in the 2007 Report reflect considerably expanded search effort rather than actual increases in population size. Since 2007, the species has been up-listed in all provinces except Québec, with Ontario up-listing to Endangered in 2008, and New Brunswick and Nova Scotia both up-listing to Threatened in 2013. A proposed federal recovery strategy was posted for review in 2016, but as of September 2018 it is yet to be finalized.

COSEWIC HISTORY

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

COSEWIC MANDATE

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

COSEWIC MEMBERSHIP

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

DEFINITIONS
(2018)

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

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

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

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

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

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

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Wood Turtle (*Glyptemys insculpta*) has had numerous taxonomic designations; the species authority is considered to be John Eaton Le Conte, who originally described it as *Testudo insculpta* in 1830. Leopold Fitzinger described the species as *Clemmys insculpta* in 1835, a designation that remained in general usage until 2001. Holman and Fritz (2001) and Feldman and Parham (2002) both suggested the splitting of *Clemmys* and grouped Wood Turtle and its closest living relative Bog Turtle (*Glyptemys muhlenbergii* Schoepf 1801) together; Holman and Fritz (2001) revived the name *Glyptemys* (Agassiz 1857) for these two congeners. One fossil species in the genus is known, *G. valentinensis*, from the middle Miocene of Nebraska; it is described as morphologically similar to *G. insculpta* and may be ancestral to it (Holman and Fritz 2001).

Morphological Description

Wood Turtle is a medium-sized freshwater turtle with adult carapace length ranging between 16 cm and 25 cm (Litzgus and Brooks 1996; Smith 2002). The greyish-brown to yellow carapace is broad and low, sometimes having dark or yellow markings. Each scute has pyramidal concentric ridges (growth lines), giving the carapace a sculptured appearance. The carapace is strongly keeled and is serrated at the posterior margin (Babcock 1971; Litzgus and Brooks 1996). In older turtles, the ridges on the scutes can be worn smooth to some degree. The plastron lacks a hinge and is yellow with variable black blotches on the outer posterior corners of each scute. The skin is generally brown, but the legs, neck, and chin often have yellow, orange, or reddish colouring (Ernst and Lovich 2009). The feet are slightly webbed with large claws. The irises of the eyes are yellow or brown, and the upper jaw forms a beak with two cusps on the maxilla, arched downwards over the slightly shorter lower jaw. Males are generally larger than females (Lovich *et al*. 1990). The plastron is flat in juveniles and adult females but becomes strongly concave in males as they reach sexual maturity. In adult females, the cloacal vent is located at the edge of the plastron, while in males it is located distal to the edge of the plastron along the length of the tail; males also have a longer, thicker tail than females.

Population Spatial Structure and Variability

All Canadian Wood Turtles are considered to belong to a single, nationwide population (COSEWIC 2007; Environment Canada 2016). The national population is subdivided into “local subpopulations”, each consisting of an interbreeding concentration of Wood Turtles within a single watershed (Environment Canada 2016). This terminology will be used throughout this report, and is consistent with that used in the draft federal Recovery Strategy. Subpopulations across the species’ range in Canada are in some cases delineated by element occurrences (EOs) as a proxy (see Population Sizes and Trends - Sampling Effort and Methods).

Amato *et al*. (2008) conducted a study of the phylogeography of Wood Turtles and sampled 117 turtles from 29 localities across the species' Canadian range. Twenty-one haplotypes were identified and there was little genetic variation, which is typical of turtles in general and the genus *Glyptemys* in particular (Avise *et al*. 1992; Rosenbaum *et al*. 2007). Nested clade analysis indicated a main postglacial dispersal up the east coast from a southern refugium to Nova Scotia, with subsequent westward dispersal (Amato *et al*. 2008). A BEAST analysis, using a Bayesian skyline plot, indicated the Wood Turtle population size had been growing rapidly over the last 12,000 years. One clade occurs along the eastern USA and Canada and west into the states south of the Great Lakes. A second clade occurs in Ontario and adjacent Québec west of the St. Lawrence, although some presence of the first clade was also found in this region.

Other genetic studies of six local subpopulations of Wood Turtles in Québec found them to be highly polymorphic; each subpopulation could be characterized using five microsatellite loci (Tessier and Lapointe 2002; Tessier *et al.* 2005). There was high variability within all local subpopulations indicating that putative past declines have not led to significantly reduced genetic variability, although the most genetically distinct subpopulations had the lowest diversity (Tessier *et al.* 2005).

Ultimately, it appears that there are at least three genetically different units within Québec: two on the north shore of the St. Lawrence River, and a single homogeneous group (of four subpopulations) south of the St. Lawrence River (Tessier *et al.* 2005). Additionally, the Bas-Saint-Laurent populations (at the eastern end of the Québec range near the New Brunswick border) are more closely linked to New Brunswick turtles than Québec turtles, and could be considered as a distinct conservation unit in Québec (Bouchard *et al*. 2013). Despite their small size, these subpopulations show high levels of heterozygosity (H_0 ranging from 0.561-0.886), and allelic diversity (an average of 10 alleles per locus per population) (Tessier *et al*. 2005). These data suggest that these Wood Turtles have genetic variation expected of a relatively abundant species, and that until "recently" (given the long generation times of the species) these populations existed in "long-term genetic neighbourhoods" comprising several thousand individuals, based on equilibrium considerations and the stepwise mutation model (Ohta and Kimura 1973). These conclusions further suggest that these subpopulations have undergone rapid, large declines, recent enough that they still show little genetic evidence of inbreeding despite their small sizes and relative isolation.

A study on Wood Turtle in Ontario isolated four subpopulations: one along the north shore of Lake Huron, two in eastern Ontario, and one in southern Ontario (Fridgen *et al*. 2013). The southern Ontario subpopulation showed "severe" signs of inbreeding (low heterozygosity), and the younger cohorts of Wood Turtles sampled from other subpopulations showed similar levels of inbreeding, indicating a looming genetic crisis for the species in Ontario (Fridgen *et al*. 2013).

Designatable Units

There are no clear distinctions in genetic structure (Tessier *et al*. 2005; Amato *et al*. 2008) based on either microsatellites or mitochondrial genes that can be associated with specific faunal provinces. Furthermore, there are no clear disjunctions among subpopulations and some span the boundaries of the Faunal Provinces (Figure 1). Therefore, separate designatable units based on discreteness and evolutionary significance criteria for assigning such units (see COSEWIC Operations and Procedures Manual, Appendix F5, Nov. 2017) do not appear defensible at this time.

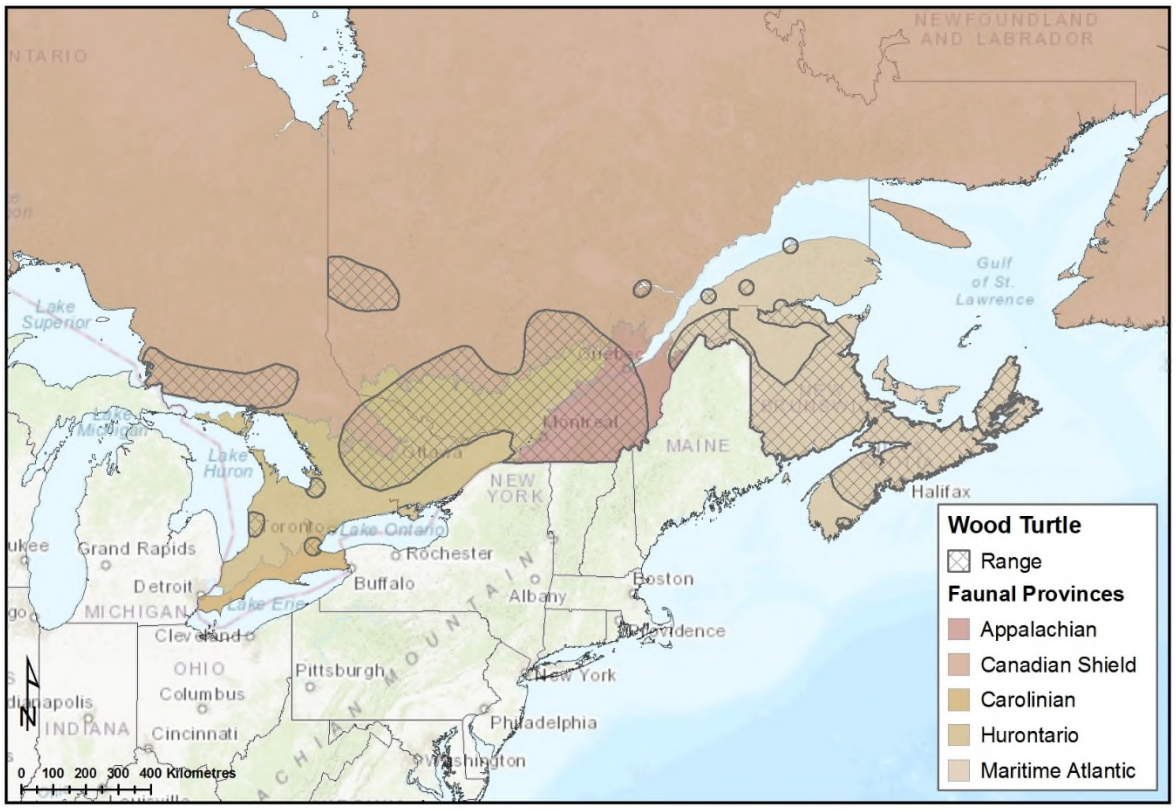

Figure 1. Wood Turtle range in Canada, in relation to COSEWIC Faunal Provinces for Terrestrial Amphibians and Reptiles in Canada.

Special Significance of the Species

Wood Turtle is unique among Canadian freshwater turtles in its highly terrestrial behaviour, attractive appearance, and docility, which in past have made it a popular pet. The species was tested in rodent mazes and performed comparably to rats (Tinklepaugh 1932). Turtles are important in Indigenous spiritual beliefs and ceremonies. To First Nations peoples, the turtle is a teacher, possessing a great wealth of knowledge. Turtles play an integral role in the Creation story, by allowing the Earth to be formed on its back. For this reason, some First Nations people traditionally called North America “Turtle Island” (Bell *et al*. 2010).

DISTRIBUTION

Global Range

Wood Turtle is endemic to eastern North America and has a discontinuous range from Nova Scotia west through New Brunswick, southern Québec and Ontario to Minnesota, south to Virginia and Maryland (Conant and Collins 1998; Ernst and Lovich 2009).

Canadian Range

In Canada, Wood Turtle occurs in Nova Scotia, New Brunswick, southern and eastern Québec, and south-central Ontario (Bider and Matte 1994; Conant and Collins 1998; Desroches and Rodrique 2004), with subpopulations in Ontario ranging north and west to western Algoma District in rivers draining into the east end of Lake Superior (Peiman and Brooks 2003; Knudsen 2004; Trottier 2004; Wesley *et al.* 2004; Figure 1). Approximately 30% of the species' global distribution is in Canada (Conant and Collins 1998; Ernst and Lovich 2009).

In Canada, the species' distribution is discontinuous throughout most of its range. Most Wood Turtle subpopulations are associated with watersheds that are widely separated. Wood Turtle is apparently dependent on rivers and streams with particular conditions; even within suitable watersheds local subpopulations are clustered in stream reaches. These subpopulations are isolated (Arvisais *et al.* 2002, 2004; Smith 2002; Seburn and Seburn 2004; Wesley *et al.* 2004, Tessier *et al*. 2005; Wesley and Brooks 2005), because turtles tend to move along streams and rarely move between streams even when they are only a few kilometres apart (e.g., Foscarini and Brooks 1997, but see Gravel *et al*. 2007). The observed genetic distinctness among nearby subpopulations is likely a reflection of low vagility.

Extent of Occurrence and Area of Occupancy

COSEWIC (2007) reported the extent of occurrence (EOO) as ~500,000 km^2, based on range maps in Ernst *et al*. (1994) and Conant and Collins (1998). For the present report, historical (pre-1997) EOO in Canada was calculated as 931,462 km^2, while recent (since 1997) EOO was calculated as 722,874 km^2, representing an apparent 22% decline in EOO, assuming that recent search effort has been adequate.

The index of area of occupancy (IAO) was calculated by generating 4 km^2 IAO squares from all known Wood Turtle occurrence records in Canada. Total IAO values by province, based on recent and historical records, are: Ontario - 932 km^2, including 240 km^2 exclusively historical (26% decline); Québec - 1596 km^2, including 216 km^2 exclusively historical (14% decline); New Brunswick - 1,476 km^2, including 224 km^2 exclusively historical (15% decline); Nova Scotia - 932 km^2, including 508 km^2 exclusively historical (55% decline). Total Canadian IAO is 4936 km^2, including 1,208 km^2 exclusively

historical, showing a 24% decline in occupancy. Extirpation of subpopulations in southern Ontario and southern Nova Scotia were most notable. This analysis assumes that all recent IAO squares also contained Wood Turtle historically, an assumption supported by the long generation time and strong site fidelity of the species. This estimate of decline is likely conservative due to historical landscape change, lack of historical data and limited historical search effort over much of the species' range. It is additionally conservative because most historical records are well under 100 years old, and the actual decline in IAO over a 3-generation period is more likely to exceed 30%.

Search Effort

Prior to 1990, there were very few studies on any aspect of Wood Turtle biology in Canada, but since the species was listed as Vulnerable (Special Concern) by COSEWIC in 1996, many studies have been initiated, and have filled gaps in knowledge of the species' abundance, demography, habitat requirements and distribution. A number of subpopulations have been studied using radio telemetry (e.g., Quinn and Tate 1991; Brooks and Brown 1992; Walde 1998; Compton 1999; Arvisais *et al*. 2002, 2004; Cameron *et al*. 2002; Compton *et al*. 2002; Smith 2002; Peiman and Brooks 2003; Saumure 2004; Dubois 2006; Wesley *et al*. 2004; Wesley 2006; Greaves and Litzgus 2009; Roy-McDougall 2010; Hughes 2016). Surveys of new and historical areas were conducted throughout the species' range, usually completed by walking (one to four people) alongside a river thought to provide good habitat, sometimes with one person walking or canoeing the river or stream.

In Ontario, systematic surveys were carried out across the province from the extreme southwest to western Algoma (Mitchell *et al.* 1997; Boyd and Brooks 1998; Cross *et al*. in press). Geographic Information Systems were used in some cases to focus search effort (Smith 2002). There are three localities in Ontario with ongoing study programs. One locality is in the Algoma and Sudbury Districts, with programs being operated by the OMNRF, Laurentian University, and Algoma Highlands Conservancy. At least four watersheds in these two districts have been studied intensively at differing times. Another locality is in central and eastern Ontario, where 5 watersheds have been studied to varying extents by researchers from the OMNRF, University of Guelph, and Laurentian University. Finally, an intensively managed subpopulation exists in southwestern Ontario, studied and managed by University of Guelph, MNRF, and the Huron Stewardship Council.

In Québec, surveys were conducted throughout most of the species' range in the province between 1998 and 2016. A total of 323 surveys on 150 river segments have occurred. The most recent search effect was focused on local subpopulations in the eastern part of the province north and south of the St. Lawrence River. Since 2010 the majority of survey effort in Québec has been planned based on a province-wide GIS analysis (Habitat suitability index), built for this purpose (Giguère *et al*. 2011). One subpopulation north of the St. Lawrence is intensively managed by the Ministry of Forests, Fauna, and Parks (*Le ministère des Forêts de la Faune et des Parcs*).

Historical surveys in the Maritime provinces have been poor, and searches for new Wood Turtle localities is ongoing (A. Downey pers. comm. 2016; H. Collins pers. comm. 2017). Several surveys and studies are ongoing in New Brunswick and Nova Scotia to document the extent of known subpopulations and identify new subpopulations. For example, one survey in New Brunswick used an Internet newsgroup to solicit reports of sightings (McAlpine and Gerreits 1999), while a second in Nova Scotia interviewed local residents (Adams 2002). Over the past decade, search activity in Nova Scotia, by both Department of Natural Resources staff as well as citizen science-based programs, has expanded substantially (Herman pers. comm. 2018).

HABITAT

Habitat Requirements

Wood Turtles are highly terrestrial for a freshwater emydid turtle, but are still greatly dependent on aquatic habitats (Bishop 1927; Breckenridge 1944; Lazell 1976; Thomas 1983). Wood Turtles are strongly associated with meandering, shallow rivers with sand, gravel, and/or cobble bottoms; these rivers are typically clear, with moderate current and frequent oxbows (DeGraaf and Rudis 1983; Hunter *et al.* 1992; Ernst *et al.* 1994; Adams 2003; Wesley 2006). Secondary tributaries (brooks) that feed these rivers may also support Wood Turtles; these tributaries can be used to access resource patches and may also provide subpopulation rescue when episodic events disrupt the subpopulation on the main river. Still water or slow water habitats, such as vernal pools, oxbows, marshes, and beaver ponds are also used, though less frequently than are riverine habitats.

Wood Turtles hibernate aquatically in streams and rivers (October to April, depending on location) (Harding and Bloomer 1979; Green and Pauley 1987; Farrell and Graham 1991; Hunter *et al.* 1992; Smith 2002; Arvisais *et al*. 2004; Trochu 2004, Wesley 2006; Greaves and Litzgus 2007; Ernst and Lovich 2009); in at least one locality they also hibernate in oxbows (White 2013). Wood Turtles may hibernate alone, communally with other members of the species or with other species of turtles (Breckenridge 1944; Harding and Bloomer 1979; White 2013). Overwintering sites are usually on the bottom of deep pools, often with fallen debris that provides structure and prevents dislodging during high flow events. Wood Turtles also use rivers during the active season for mating (Harding and Bloomer 1979; Ernst 1986; Farrell and Graham 1991), dispersal (Greaves 2007), and thermoregulation (Dubois 2006; Hughes 2016). Wood Turtles rarely move more than 300 m from water (Harding and Bloomer 1979; Quinn and Tate 1991; Kaufmann 1992; Saumure and Bider 1998; Ernst 2001b; Arvisais 2002; Arvisais *et al*. 2002; Compton *et al*. 2002; Smith 2002; Wesley 2006), but individuals have been recorded more than 900 m from their home river (Thompson *et al.* in press). Juveniles appear to remain closer to their home rivers than do adults, suggesting the juveniles rely on riverine habitats for protection.

Wood Turtles use terrestrial habitats for foraging, thermoregulation, and nesting; (Harding and Bloomer 1979; Kaufmann 1992a; Harding 1997; Smith 2002, Arvisais *et al.* 2002; Compton *et al.* 2002; Arvisais *et al.* 2004; Trochu 2004; Dubois 2006; Wesley 2006; Dubois *et al*. 2009). Natural Wood Turtle terrestrial habitat is most often reported as riparian forest, alder thickets/swale, and open shoreline habitat, although upland forest may be used as well (Daigle 1997; Cameron *et al.* 2002; Compton *et al.* 2002; Smith 2002; Adams 2003; Peiman and Brooks 2003; Arvisais *et al.* 2004; Trochu 2004; Wesley *et al.* 2004; Wesley 2006). Wood Turtles are frequently described as an “edge” species, and seem to prefer a mosaic of open and closed-canopy habitats that provide for a multitude of needs (Compton 2002; Dubois *et al*. 2009). Human-impacted land, such as agricultural fields and plantations, may also provide appropriate habitat, and Wood Turtles will use such sites when available. In fact, they have been described as ‘opportunistic’ regarding their terrestrial habitat choices (Quinn and Tate 1991; Saumure *et al*. 2007).

Naturally occurring nesting habitat includes sand or gravel-sand beaches and banks (Hunter *et al.* 1992; Walde 1998; Smith 2002; Hughes *et al*. 2009). However, similar to other terrestrial turtles in North America, Wood Turtles readily nest on gravel and dirt roads, gravel shoulders of paved roads, gravel pits, decommissioned railway beds and similar anthropogenic structures (Buhlmann and Osborn 2011; Litzgus pers. comm. 2016).

Habitat Trends

As part of the development of this status report, a province-by-province map of human impacts on Wood Turtle habitat was created using aerial photography and IAO squares. Each IAO square was assessed to determine the greatest impact on it; if more than one impact was observed, the impact type closest to the apparent Wood Turtle occurrence (streams) was counted; each IAO square was counted only once. This method can be subjective, and the varying quality of aerial photography available can make detecting impacts at some sites difficult, but it provides an attempt to quantify human impacts on Wood Turtle habitat. The magnitude of these human activities requires intensive on-the-ground assessment.

Each IAO square was assessed as being: (i) low impact (no obvious impacts based on aerial photography); (ii) agriculture; (iii) forestry (including plantation forest); and (iv) development (towns, cities, golf courses, industry, quarries). IAO squares with roads were counted separately from other human impacts. Because Wood Turtles rarely move more than 300 m from their home streams (Greaves 2007), each IAO square was assessed to determine if there were roads within 300 m of apparent Wood Turtle streams.

In Ontario, 4% of IAO squares were ‘low impact’. Of the higher impact activities, forestry occurred in 72%, agriculture occurred in 17%, and development occurred in 8% of IAO squares. Only three of 279 (1%) ‘recent’ IAO squares in Ontario did not have roads within 300m of the likely Wood Turtle watercourses.

In Québec, 23% of IAO squares were ‘low impact’. Of the higher impact activities, agriculture occurred in 36%, forestry occurred in 24%, and development occurred in 17% of the IAO squares. Only six of 327 (<2%) ‘recent’ IAO squares in Québec did not have roads within 300m of the likely Wood Turtle watercourses.

In New Brunswick, 24% of IAO squares were ‘low impact’. Of the higher impact activities, forestry occurred in 49%, agriculture occurred in 26%, and development occurred in 14% of the IAO squares. No ‘recent’ IAO squares (0 out of 1023) in New Brunswick lacked roads within 300 m of Wood Turtle watercourses.

In Nova Scotia, 24% of IAO squares were ‘low impact’. Of the higher impact activities, agriculture occurred in 31%, forestry occurred in 28%, and development occurred in 16% of IAO squares. Only one of 105 (<1%) ‘recent’ IAO squares in Nova Scotia did not have roads within 300 m of Wood Turtle watercourses.

Canada-wide, 16% of IAO squares contained ‘low impact’ activities whereas higher impacts (agriculture, forestry, development) occurred within 84% of IAO squares; Agriculture occurred within 29%, forestry within 41%, and development within 14%. Less than 1% of Wood Turtle IAO squares in Canada did not have a road within 300 m of the watercourse.

It is unclear what future landscape changes will occur throughout the range of Wood Turtle in Canada. However, if forestry and agriculture continue to intensify as they have, along with human population expansion, for most subpopulations the prognosis is not positive.

BIOLOGY

Life Cycle and Reproduction

Wood Turtles emerge from hibernation in late March to April. They mate throughout the active season (April to September), but most commonly in spring and fall (Kaufmann 1992b; Walde *et al*. 2003; Trochu 2004). Mating usually occurs in shallow water (DeGraaf and Rudis 1983), although Wood Turtles have occasionally been observed copulating on land (S. Gillingwater pers. comm. 2006 in COSEWIC 2007; Y. Dubois pers. comm. 2017). Females migrate to nesting areas and may stay in “staging” areas adjacent to nesting sites for several days to a few weeks before nesting (Walde *et al.* 2007). They dig nests in late May to early July (Bishop 1927; Thomas 1983; Schaffer 1991; Brooks *et al*. 1992; Kaufmann 1992b; Walde 1998; Smith 2002; Brooks *et al*. 2003; Trochu 2004). Nesting can occur throughout the day or night depending primarily on climatic conditions, but usually occurs in the evening (Walde 1998; R. Brooks pers. comm. 2005 in COSEWIC 2007). Female Wood Turtles lay only one clutch per year (Powell 1967; Farrell and Graham 1991; Brooks *et al*. 1992), although individual females may not nest every year (R. Brooks pers. comm. 2005 in COSEWIC 2007).

Sex determination in Wood Turtles is genetic rather than temperature-based as in many other turtles (Ernst 2001b). Montiel *et al*. (2016) showed that Wood Turtles have an XX/XY sex chromosome system, and estimated that this system evolved in the genus *Glyptemys* ~8-20 million years ago. However, temperature constraints on embryogenesis likely determine the northern limit of distribution of the species (Compton 1999).

Successful embryonic development and hatching require sufficiently warm temperatures, and eggs may not hatch in years when the summer temperatures are too low for incubation to be completed; eggs or hatchlings that fail to emerge in the fall do not survive the winter in the nest (Brooks *et al*. 1992; Compton 1999; Hughes *et al*. 2009). However, variable nest temperatures accelerate embryonic development in the lab (Compton 1999), and Hughes *et al*. (2009) found that females appear to select nest sites with variable incubation temperatures in the wild. Hatching occurs in late August to September or early October (Schaffer 1991; Smith 2002).

Females lay clutches of 1-20 eggs, with an average of 8-12 eggs (Powell 1967; Harding and Bloomer 1979; Brooks *et al*. 1992; Walde 1998; Peiman and Brooks 2003). Hatching success is often low due to cool summers or to nests being destroyed by predators (Brooks and Brown 1992; Brooks *et al*. 1992; Walde 1998; Cameron *et al*. 2002). Mortality of embryos is normally 20-80%, but can reach 100% (Brooks and Brown 1992; Brooks *et al*. 1992). In addition, Sarcophagid fly larvae may attack and kill embryos and newly hatched turtles in the nest (Smith 2002), but it is possible that the larvae more commonly only feed on dead embryos/hatchlings (Bolton 2007).

Hatchling Wood Turtles are difficult to find and study because of their small size and cryptic colouration (Peiman and Brooks 2003). In a recent study in central Ontario the period from first emergence from the nest to overwintering was characterized by low survivorship (11%), and smaller hatchlings had a higher survival rate than larger hatchlings (Paterson *et al*. 2014), perhaps due to predator avoidance (i.e., smaller hatchlings were harder to detect). The hatchlings spent most of their time in creeks, or on land hiding under cover (Paterson *et al*. 2012).

Sexual maturity is related to body size not age, and size at maturity is greater in northern subpopulations than in southern ones (Brooks *et al*. 1992; Daigle 1997; Cameron *et al*. 2002; Smith 2002; Peiman and Brooks 2003; Walde *et al*. 2003). In northern subpopulations, this size is reached between 11 and 22 years of age (Brooks *et al*. 1992; Walde *et al*. 2003; Marchand 2015).

Maximum ages for Wood Turtles in the wild are difficult to estimate due to the turtles' longevity and wear on the carapace, which prevents counts of growth lines in older turtles (Harding and Bloomer 1979). Growth slows dramatically after turtles reach maturity; after maturity, new growth lines become increasingly more difficult to detect. Nevertheless, some researchers have counted between 30 and 50 growth lines on some turtles (Cameron *et al*. 2002; D. Coulson pers. comm. 2004 in COSEWIC 2007). In a subpopulation of marked individuals in southeastern Pennsylvania, Ernst (2001a) recorded a marked female living at least 46 years. One female captured as an adult on

the New Jersey Turnpike has survived over 40 years in captivity (R. Brooks pers. comm. 2005 in COSEWIC 2007). Other records suggest that Wood Turtles survive beyond 80 years in the wild, with no evidence of reproductive senescence (Jones 2009). Generation time (GT) (average age of adults) has not been calculated in the literature, but an estimation based on published values for age at maturity (AM) and adult rates of mortality (MR) and using the IUCN formula would be:

$$GT = AM + (1/MR) = 15 + (1/0.05) = 35 \text{ years}$$

Physiology and Adaptability

There have been few investigations of the physiology of Wood Turtles, although there are recent studies of their thermal ecology (Tamplin 2006, 2009; Dubois *et al*. 2008, 2009; Hughes 2016). Tamplin (2006, 2009) investigated thermal preferences in hatchling and juvenile Wood Turtles, and found that they preferred a temperature of 27°C, and that older juveniles were better at distinguishing temperatures than younger ones. Dubois *et al*. (2008) reported a preferred temperature for digestion of (T_{set}) ~30°C. Dubois *et al*. (2009) found that free-living turtles were able to use basking to keep their metabolic activity up to 26% higher than if their body temperature was conforming to local air temperature. Hughes (2016) found that thermoregulation did not govern large scale (>20 m) movements for Wood Turtles, conforming with the findings of Compton *et al*. (2002), who found that small-scale habitat selection was determined by temperature, and that large-scale habitat selection was determined by foraging needs. During overwintering, body temperature is usually just above freezing (~0.5°C) (Greaves and Litzgus 2007; Hughes unpublished data).

Dispersal and Migration

Wood Turtles are philopatric, using the same general area (home range) both during a year and over many years; males are territorial and show dominance hierarchies (Thomas 1983; Lovich *et al*. 1990; Quinn and Tate 1991; Ross *et al.* 1991; Brooks and Brown 1992; Kauffman 1992b; Walde 1998; Arvisais *et al.* 2002; Cameron *et al.* 2002; Smith 2002; Peiman and Brooks 2003; Wesley *et al.* 2004). Home range sizes of 0.25 ha up to 70+ ha have been reported in Canada and the adjacent United States (Quinn and Tate 1991; Ross *et al.* 1991; Brooks and Brown 1992; Arvisais *et al*. 2002; Smith 2002; Trochu 2004; Greaves 2007). Greaves (2007) reported mean linear home ranges (home range peripheries in relation to the home river) of 1.6 km, with males having larger linear home ranges than females (excluding nesting movements).

Home range sizes vary in response to many factors, including age, sex, distance to nesting and hibernation sites, and habitat productivity (Daigle 1997). Size of home ranges varies greatly both among study sites and among individual turtles within sites; males tend toward larger but linear home ranges, as they defend territories along their home rivers, while females have broader home ranges as they tend to move away from rivers in summer (Thompson *et al.* 2018). The amount and quality of available habitat also affect home range size.

Wood Turtles can home reliably over 2 km, and there are accounts of them homing distances up to 8 km (Harding and Bloomer 1979). Straight-line distances travelled have been recorded up to 8.3 km in one year (Daigle 1997; Adams 2002; Cameron *et al.* 2002; Smith 2002; Wesley *et al.* 2004), and 23 km over 5 years (Brooks and Brown 1992).

Interspecific Interactions

Wood Turtles are opportunistic omnivores at all stages of life (Bishop 1927; Breckenridge 1944; Harding and Bloomer 1979; DeGraaf and Rudis 1983; Schaffer 1991; Walde *et al.* 2003). Important foods include berries, green plants, soft-bodied invertebrates (particularly worms and slugs), amphibian larvae, and carrion (Harding and Bloomer 1979; Ernst *et al*. 1994). Mushrooms have also been identified as a particularly important food source (Harding and Bloomer 1979; Ernst *et al*. 1994). Wood Turtles exhibit a unique “worm stomping” behaviour (Brooks *et al.* 2003). They alternately stamp their forefeet and plastron on the substrate and then consume earthworms that come to the surface. Why, or even whether, earthworms come to the surface is not clear. An alternative hypothesis for this behaviour is that the turtles scuffle and bounce to flush small invertebrates from the litter on the forest floor and in doing so may uncover worms (Kaufmann 1989).

The main predators of adult Wood Turtles are Raccoon (*Procyon lotor*), Striped Skunk (*Mephitis mephitis*), Coyote (*Canis latrans*), Mink (*Mustela vison*), River Otter (*Lutra Canadensis*), Red Fox (*Vulpes vulpes*), and Common Raven (*Corvus corax*) (Peiman and Brooks 2003; Bourgeois *et al.* 2004; Ernst and Lovich 2009). Predators will consume turtles or amputate limbs and tails (Saumure and Bider 1998; Cameron *et al.* 2002; Smith 2002; Peiman and Brooks 2003; Litzgus pers. comm. 2016; Mullin pers. comm. 2016). Large fish such as Largemouth Bass (*Micropterus salmoides*) (Breckenridge 1944) and Northern Pike (*Esox lucius*) and birds such as Great Blue Heron (*Ardea herodias*) will prey on hatchlings (Seburn 1996). Raccoons, skunks and foxes dig up and eat eggs (Brooks *et al.* 1992), resulting in high levels of nest failure.

Major predation events have been observed in several localities. For example, Raccoons killed seven of 37 (19%) female Wood Turtles on a Québec nesting site in 2004 (D. Masse pers. comm. 2005 in COSEWIC 2007). During the spring survey in 2005, eight additional dead females were found near the main nesting site. These females were marked and had nested at the site in previous years. It is estimated that predators killed 40% of the nesting females at this site over a relatively short period (Adams *et al.* 2007). In New Brunswick 47 of 57 individual Wood Turtles showed signs of attempted predation over a three-year period (2005-2007); the mortality rate was 15% (Gravel *et al.* 2007). Common Ravens have been observed preying on adult Wood Turtles in New Brunswick (D. McCullum pers. comm. 2016); the birds flip the turtle on its back and attack the leg pockets. At least 48 Wood Turtles within one subpopulation have been killed in this way. Wood Turtles are more susceptible to major predation events where predators are subsidized by human activities, particularly agriculture.

There has been at least one account of Wood Turtles and Blanding's Turtles (*Emydoidea blandingii*) mating and at least one account of Wood-Blanding's hybrids from a semi-captive study population; genetic analysis of one of the hatchlings showed it to be the offspring of a female Wood Turtle and a male Blanding's Turtle (Harding and Davis 1999). Wild hybrids between Wood Turtles and Blanding's Turtles are not known, and the typical habitats for the two species are sufficiently different that interactions in the wild would be rare.

Wood Turtles display "anting behaviour" (use of ants to remove epibionts) (McCurdy and Herman 1997; Hughes *et al*. 2016), and remain still while being cleaned by Blacknose Dace (*Rhinichthyes* spp.) (Kaufmann 1991). There are many accounts of Wood Turtles with leeches, *Placobdella parasitica* and *P. ornata*, on their legs, necks and carapaces (Brewster and Brewster 1986; Farrell and Graham 1991; Saumure and Bider 1996; Smith 2002), but it is not clear how these ectoparasites affect the Wood Turtle (Kaufmann 1991). Other parasites of the Wood Turtle include trematodes, an acanthocephalan, caddisfly larvae (an epibiont), and the flesh fly, *Sarcophagus* spp., which may parasitize both eggs and hatchlings (Walde 1998; Smith 2002).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Accurate estimates of population size of Wood Turtle in Canada cannot be made because size estimates are only available for a small number of local subpopulations. However, a rough estimate of population size for Canada has been calculated by summing estimates derived for each local subpopulation delineated by element occurrence (EO) when available or by watershed unit. Where possible, recent (<10 years old) estimates of subpopulation size were acquired directly from researchers. Alternatively, when sufficient surveys had been conducted and EOs had been characterized expert opinion was used to estimate the subpopulation. Finally, when only observational data were available, subpopulations were estimated with standardized minimum and maximum values of 25 and 100 individuals/local subpopulation (based in part on size distributions of known subpopulations) to generate minimum and maximum population size respectively.

The Natural Heritage Information Centre in Ontario and the Québec Conservation Data Centre (CDC) have created element occurrence (EO) layers using Wood Turtle observations to roughly delineate Wood Turtle subpopulations in these provinces. Points close to each other are grouped within the same EO. Points that are farther than 5 km along riverine corridors, 3 km in intermediate habitat, 1 km across continuous upland habitat, or separated by barriers (e.g., busy highway, obstructions, cliffs, etc.) are assigned to different EOs (NatureServe 2018). An EO rank was assigned to each EO to estimate viability when sufficient data exist. EO layers are not available for the Maritime provinces, but an estimated number of EOs was calculated and reported in the proposed Recovery Strategy for Wood Turtle in Canada (Environment Canada 2016).

Several studies have reported density estimates for Wood Turtle; however, these could not be applied here because the proportions of streams/rivers used by Wood Turtles within each area are unknown. Experience indicates that even in rivers with apparently good habitat throughout their length, Wood Turtles are usually patchily distributed, with much of the river unoccupied except by transients (R. Brooks pers. comm. 2005 in COSEWIC 2007; Wesley 2006; Hughes pers. obs.). For such patchy subpopulations, extrapolating estimates evenly across an entire river can severely overestimate true subpopulation size. For example, virtually all sightings of Wood Turtles along a 20 km stretch of a major river in central Ontario occurred at two sites, one 1.2 km and the other 0.4 km in length. Extrapolation from these sites over the 20 km surveyed would have given an estimate of over 2000 adults, when the real subpopulation of adults was likely fewer than 150 (R. Brooks pers. comm. 2005 in COSEWIC 2007). Such extrapolation has been avoided in this report when possible.

Abundance

Subpopulations in Ontario

There are three major clusters of extant Wood Turtle subpopulations in Ontario: one along the north shore of Lake Huron, one in eastern and central Ontario, and one in southern Ontario. The Wood Turtle population in Ontario is estimated to be ~1100 adults (Environment Canada 2016). Alternatively, using the number of EOs to calculate an estimate produces a similar estimate. There are 44 EOs in Ontario considered to be extant, thus multiplying this number by low (25 adults) and high (100 adults) estimates for abundance give a range of 1100-4400 adult Wood Turtles.

Subpopulations in Québec

Subpopulation estimates were made for 50 EOs (subpopulations) in Québec. In Québec, EO were derived from considerable survey effort conducted over the last 20 years. Population estimates derived from mark recapture data were available for three subpopulations. For the remaining 47 EOs subpopulation estimates were based on expert opinion considering the number of observations within each EO, the quality of the habitat within the EO, and the size of the EO (Yohann Dubois pers. comm. 2005). Estimates should be considered a conservative minimum subpopulation size for each EO. The total minimum population of adult Wood Turtle for Québec was estimated as 8,725 mature individuals. To provide a range of population estimates comparable with the other regions, the estimate was arbitrarily increased by 50% based on expert opinion to an upper estimate of 13,087. At the provincial level, data from Quebec are more precise and accurate than those in the rest of the Canadian range, due to more intensive and extensive sampling.

Subpopulations in New Brunswick

An estimated population size for New Brunswick was calculated using the Wood Turtle management units from New Brunswick to define subpopulations. The number of extant management units (73) multiplied by low (25 adults) and high (100 adults) estimates for abundance give a range of 1,825-7,300 adult Wood Turtles. A best estimate was calculated by assigning 100 adults to management units with ≥ 10 observations (21 sites), and 25 adults to management units with < 10 observations (52 sites), which gave an estimate of (21x100)+(52x25) = 3,400 adult Wood Turtles.

An alternate method to estimate the provincial population would be to use the number of defined EOs and a high and low population estimate. There are 101 EOs in New Brunswick (Environment Canada 2016), thus multiplying this number by low (25 adults) and high (100 adults) estimates for abundance gives a range of 2,525-10,100 adult Wood Turtles. Search effort in some areas of the province has been limited to date; additional effort may expand estimates in future.

Subpopulations in Nova Scotia

No recent population size estimates were made directly available for Nova Scotia subpopulations, so an estimate was taken from the proposed Recovery Strategy for the Wood Turtle in Canada (Environment Canada 2016). The Wood Turtle population in Nova Scotia is estimated to be 2,000-7,000 adults (Environment Canada 2016). This estimate is comparable to one that would be calculated using the number of EOs. There are 122 EOs in Nova Scotia (Environment Canada 2016), thus multiplying this number by low (25 adults) and high (100 adults) estimates for abundance gives a range of 3,050-12,200 adult Wood Turtles.

Total Canadian Population Estimate

Combining the provincial minimum estimates and maximum estimates yields a range of 13,650-31,790 individual adult Wood Turtles throughout Canada. However, this range must be interpreted with caution given the limited available data used for the calculation, assumptions made, and that very few subpopulations have been estimated with certainty.

Fluctuations and Trends

Across Canada there have been a few studies of sufficient length to estimate changes in subpopulation size.

In Ontario, one population has been subjected to yearly monitoring, including capture-mark-recapture population estimates, since 2005. These estimates show a steady decline in the wild adult population. However, a headstarting project has resulted in an increase in the total number of adult turtles (Litzgus pers. comm. 2018) (but see **Limiting Factors**). This population is noted for a high rate of adult mortality from

subsidized predators (J. Mullen pers. comm. 2016) and has shown severe signs of inbreeding (Fridgen *et al*. 2013). Subpopulations in eastern and central Ontario are considered to be in decline (L. Trute pers. comm. 2017). Subpopulations along the north shore of Lake Huron are considered likely stable by researchers, although no quantifiable projections have been made.

In Québec, there are three subpopulations with multi-year population estimates showing different trends: 1) showing a 50% decline between 1997 and 2002 (Daigle *et al*. 2005) and a stable population between 2002 and 2013, 2) showing a slight decline that is within the confidence intervals of the population estimates, and 3) showing a slight increase within the confidence intervals of the population estimate. However, sampling duration in all three is well under a single generation. Trend information is not available for other subpopulations in Québec because only presence-absence surveys have been conducted.

In New Brunswick relatively large populations of Wood Turtle remain in two regions of the province. However, three sites within these areas experienced mass mortality events in 2016 that have resulted in approximately 110 documented mortalities, primarily adults (Browne pers. comm. 2018). Ravens were identified as the agent at one site; the cause remains unknown at the other two sites, but the limited information available is consistent with predation. Insufficient data exist to assess trends in population sizes in New Brunswick; however, anecdotal information suggests that declines have occurred in some regions.

No long-term population data are available to estimate trends in subpopulation sizes in Nova Scotia. Personnel in Nova Scotia Department of Natural Resources, Nova Scotia Museum of Natural History and Acadia University have reported that several of the small subpopulations (and possibly the largest subpopulation) in the province have apparently declined in the past 30 years (Herman pers. comm. 2018). The current distribution of clusters of high and low density subpopulations is due to urban settlement and land use practices/disturbances that have fragmented the linear continuity of subpopulations along the primary waterway, and degraded capillary waterways that might support additional subpopulations or harbour hibernacula.

Since there are too few long-term data on patterns of abundance to assess directly decline in total number of mature individuals, the report relies on changes in IAO (and secondarily EOO) to infer declines in abundance. The use of IAO, EOO, or element occurrences as a proxy to measure population trends and sizes is potentially biased by changes in patterns and intensity of search effort over time. Although not all historical sites have been re-visited, there has been an enormous increase in sampling in the past 20 years by resource agencies and citizen science groups, in part as a result of recovery efforts and initiatives across the species' range in Canada; under these circumstances the use of these proxies is probably justified. In fact, rather than recent (1997 to date) records underestimating IAO since all historical sites might not have been re-visited, it is far more likely that historical (pre-1997) records of IAO woefully underestimated actual historical IAO.

Rescue Effect

There are five current and three historical Wood Turtle subpopulations in Québec that are part of watersheds that extend into the US. There are also several border-crossing watersheds between Maine and New Brunswick. However, most Wood Turtle populations in the United States, including those in Maine, New Hampshire and Vermont, are apparently declining (NatureServe 2016), and there is likely only limited exchange of individuals across the border.

THREATS AND LIMITING FACTORS

Threats

The threats calculator identified an overall High threat level for the Wood Turtle in Canada (Appendix I). This ranking indicates that the species is expected to decline by 10-70% over the next 100 years (approx. 3 generations) based on ongoing threats over the next 10 years. The sheer diversity of threats is compelling. Agriculture and transportation corridors, particularly roads, were identified as the greatest threats to the species. Other threats identified by the threats calculator were: residential and commercial development (low impact threat), energy production and mining (low impact threat), biological resource use (low impact threat), human intrusions and disturbance (low impact threat), natural system modifications (low impact threat), invasive and other problematic species/genes (low impact threat), and climate change and severe weather (low impact threat) (Appendix I). The analysis of activities within IAO squares (see **Habitat Trends**) supports the Threats Calculator results. It revealed that Canada-wide, only 16% of IAO squares contained only 'low impact' activities. In contrast higher impacts – forestry, agriculture and development – occurred within 84% of IAO squares. Less than 1% of Wood Turtle IAO squares in Canada did not have a road within 300 m of the watercourse.

Transportation and service corridors

Transportation and service corridors – roads in particular – were ranked by the threats calculator as a medium-level threat and were identified as the most significant threat to the Wood Turtle in Canada (Appendix 1). Turtles are slow-moving on land and typically hide in their shells rather than flee from danger, making them especially vulnerable to vehicle collisions. Given the long-lived life history of freshwater turtles (see **Limiting Factors**), rates of annual adult mortality as low as 1-5% can result in population decline and extirpation (Congdon *et al.* 1993 [Blanding's Turtle]; Compton 1999 [Wood Turtle]; Enneson and Litzgus 2008 [Spotted Turtle *Clemmys guttata*]). Annual mortality rates on roads likely exceed these thresholds in many parts of North America, particularly in areas with high road densities and/or adjacent to roads with high traffic volumes (e.g., Gibbs and Shriver 2002; Beaudry *et al.* 2008). There is a general lack of data on the scope or severity of the threat posed by smaller roads, such as logging roads and secondary highways. However, secondary or tertiary roads that occur within close

proximity to and/or follow watercourses were also identified as a potentially significant threat to subpopulations during the threats calculator assessment, and Wood Turtle mortality has been documented on a variety forestry roads with differing characteristics (size, speed, etc.) in Ontario (L. Trute unpublished data; J. Crowley pers. comm. 2018). Gravel road embankments attract nesting female turtles, putting them at higher risk of collision as they search for nesting sites. This increased risk to females can result in skewed sex ratios, further impairing the population's ability to cope with ongoing mortality (Steen and Gibbs 2002; Aresco 2005; Gibbs and Steen 2005, 2006). Further, roads and water crossings may also act as ecological traps for the nests and hatchlings due to the associated vehicular traffic and road maintenance activities (e.g., grading of the road shoulder during the incubation period). Generally, roads can also act as a vector for the spread of invasive species and pathogens, provide access for illegal collection and result in direct and indirect habitat loss and fragmentation (Forman *et al.* 2000; Trombulak and Frissell 2000) – all of which are threats to Wood Turtle subpopulations (see below).

Agriculture and Aquaculture

The ongoing conversion of natural areas into agricultural land (crop fields, pasture, etc.) has resulted in widespread destruction, degradation and fragmentation of Wood Turtle habitat across the species' Canadian range (see **Habitat Trends**). Of the 357 watersheds within New Brunswick, 73% have agricultural land within 200 m of the streams/rivers. Within the watersheds in which Wood Turtles have been documented, 94% are within close proximity to agriculture (NB ERD unpublished data). In addition to the direct impacts to habitat, agricultural practices can result in significant and unsustainable mortality rates (Saumure *et al.* 2007; R. White unpublished data). For example, six of the 30 turtles that were tracked during a 2-year telemetry study in Québec were killed by farming machinery, and the authors concluded that agricultural activities reduced annual adult survival by 10-13% and annual juvenile survival by up to 18% (Saumure *et al.* 2007). Most of the surviving individuals in this subpopulation showed evidence of non-fatal injuries from farming machinery. Such high levels of annual mortality are not sustainable, and reduced numbers of captures in subsequent years indicate that this subpopulation is rapidly declining and will become locally extirpated without intervention. Agricultural areas may also create ecological traps for nesting females, which are attracted to open-canopy areas with exposed soil. Nests in agricultural areas are at risk of destruction or disturbance from a variety of activities, including tilling and trampling by cattle. Further, egg development in agricultural sites may be compromised by shading from crop growth (Mui *et al.* 2016). Agriculture was identified as a low-to-medium threat by the threats calculator.

Biological Resource Use

Illegal Collection

Wood Turtle is listed under CITES Appendix II, and the collection of Wood Turtles from the wild is illegal in all Canadian provinces. However, there is still a high demand for Wood Turtles in the commercial pet trade (Crowley pers. comm. 2018), and illegal

collection has been attributed to the decline of several Wood Turtle subpopulations across their North American range (Lazell 1976; Harding and Bloomer 1979; Garber and Burger 1995; Litzgus and Brooks 1996; Galois and Bonin 1999). Wood Turtles are particularly vulnerable to collection in early spring when they bask in high concentrations along watercourses. Thus, it is possible for poachers to remove large numbers of Wood Turtles over a short time, resulting in significant and often permanent declines in the subpopulation. In one case, poachers removed over 50% of the adult turtles from a subpopulation in southwestern Ontario, resulting in a high likelihood of local extirpation over the short-term (reference suppressed as sensitive information). Only through intensive conservation intervention, including headstarting for over a decade, is this subpopulation beginning to recover (R. White pers. comm. 2018). Their curious, calm demeanor, terrestrial nature and colourful appearance make Wood Turtles attractive pets, and opportunistic collection by members of the public may also pose a serious risk to populations in areas with a high volume of human use (Garber and Burger 1995). Although illegal collection can be detrimental to subpopulations, with the potential for a single collection event to render a subpopulation non-viable, it is unlikely to affect a large portion of the Canadian population over the next 10 years, and was ranked as a low overall threat by the threats calculator.

Forestry

There is a paucity of information on the effects of forestry activities on Wood Turtles. The large scale-removal of forest cover (e.g., clear cutting) likely reduces habitat suitability for Wood Turtles, at least in the short term (Arvisais 2000; J. Crowley pers. comm. 2018). However, several studies have demonstrated that Wood Turtles readily use regenerating stands several years post-harvest (Arvisais 2000; Tingley and Herman 2008), suggesting that the effects of some harvest activities may be relatively short-lived. Forestry activities that occur within Wood Turtle habitat during the active season also have the potential to result in the direct mortality of turtles. This species is particularly susceptible to being struck and killed by heavy machinery (e.g., skidders) during forestry operations due to their preference for forested areas during the summer months, as well as their limited ability to evade heavy machinery. Ontario, Québec and Nova Scotia have developed guidance for forestry activities in Wood Turtle habitat, such as restricting activities during certain times of year (Environment Canada 2016). Although these practices help to reduce the likelihood of forestry-related impacts to Wood Turtles and their habitat, they do not completely eliminate this threat (J. Crowley pers. comm. 2018). Forestry roads, which can be pervasive throughout Wood Turtle habitat (J. Crowley pers. comm. 2018), also result in direct mortality to Wood Turtles (see **Transportation and Service Corridors**). Logging and wood harvesting were ranked as a low overall threat by the threats calculator.

Invasive and Other Problematic Species

Problematic native species

Predators of turtles and their eggs, such as Raccoon, Coyote, Striped Skunk, Red Fox, American Crow (*Corvus brachyrhynchos*), and Common Raven (*Corvus corax*), can occur at unnaturally high densities in human-altered landscapes, owing to increased access to food and other resources (Rosatte 2000; Phillips and Murray 2005). In areas with high densities of subsidized predators, nest predation rates can approach 100%, effectively eliminating recruitment (S. Gillingwater unpublished data). Several studies have documented high and potentially unsustainable rates of nest predation in Canadian Wood Turtle populations (Brooks *et al.* 1991; Greaves 2007). Subsidized predators can also exert high predation pressure on hatchlings, juveniles and adults, and unusually high incidences of predation of adult Wood Turtles have been documented in multiple subpopulations across Canada (McCullum 2015; Environment Canada 2016; R. White unpublished data). For example, at a site in southern Ontario with a heavily subsidized Raccoon population, Raccoon predation resulted in the mortality of over 40 Wood Turtles (hatchlings, juveniles and adults) over a 2-year period (R. White unpublished data). This threat was ranked as having a low impact by the threats calculator.

Problematic species/diseases of unknown origin

Although few significant disease threats have been reported in Wood Turtle in Canada to date, there is growing concern that these may become a problem. Necrotic shell disease and ranavirus have been reported from one Ontario subpopulation; in 2018 the first case of herpes virus was documented in the same subpopulation (Litzgus pers. comm. 2018).

Residential and commercial development

Residential and commercial development can pose a significant threat to freshwater turtle populations, including the Wood Turtle, by directly removing the species' habitat, as well as degrading and fragmenting shoreline and riparian areas on which Wood Turtles depend. However, the majority of Wood Turtle subpopulations in Canada occur in relatively remote areas or rural agricultural regions where residential and commercial development is limited. Consequently, this threat was ranked by the threats calculator as having a low impact.

Energy Production and Mining

Quarries (i.e., gravel and sand pits) can result in large-scale damage or destruction of Wood Turtle habitat through the direct removal of foraging and shelter habitat. Quarries may result in the creation of new nesting habitat, and Wood Turtles are known to nest in gravel and sand pits (e.g., Walde *et al.* 2007). However, when active, these quarries can create sink habitats for nesting females and their nests, which are at risk of mortality from heavy equipment. Although quarries can have a significant impact when they occur within

Wood Turtle habitat, this threat will only affect a small portion of Wood Turtle subpopulations across Canada and, thus, was ranked by the threats calculator as having a low impact.

Natural systems modification

The large-scale modification of terrestrial habitat surrounding Wood Turtle streams, particularly through conversion to agricultural land uses or clear-cutting, can result in increased frequency and severity of flood events. Repeated flooding events can displace large portions of Wood Turtle subpopulations and increase mortality rates of displaced individuals (Jones and Sievert 2009). Winter flooding can cause the mortality of overwintering Wood Turtles (Norden 1999), while flooding during the active season can also result in the direct mortality of turtles, particularly hatchlings and juveniles, which can get trapped under water in debris. Wood Turtles nest within close proximity to streams, often using gravel and sand bars within the riparian zone (see **Habitat Requirements**), making their nests especially vulnerable to mortality from flooding (Compton 1999). The modification of terrestrial and riparian habitats surrounding streams, particularly the removal of forest cover, can lead to increased erosion and sedimentation of streams, degradation of water quality, and changes to stream temperature, chemistry, and biotic communities (Lenat 1984; Campbell and Doeg 1989; Davies and Nelson 1994). Wood Turtle subpopulations may be susceptible to many of these changes, particularly those that reduce the suitability of overwintering sites. This threat was ranked as low in the threats calculator.

Climate change and severe weather

As climate continues to warm, Canada is experiencing higher seasonal and daily temperatures, increases in the frequency and intensity of extreme weather events, changes to levels of precipitation, stream flow, and sea level, and several other atmospheric and hydrological changes (Warren and Lemmen 2014). Some of these changes are likely to negatively affect Wood Turtle subpopulations, particularly as these trends continue and extremes become more frequent. For example, flooding events can displace Wood Turtles, result in direct mortality of adults and juveniles, and reduce recruitment by flooding nesting habitat (see **Natural systems modification**). Reductions in stream flow, resulting from drought or reduced precipitation in some regions, may also affect the suitability of streams to support Wood Turtle subpopulations over the long-term. This threat was ranked by the threats calculator as having a low impact.

Human intrusion and disturbance

Increasing popularity of off-road vehicles (ATVs/trucks) and in particular their use along and through watercourses creates potential for disturbance to Wood Turtles throughout the year, particularly during nesting and hibernation. This is in part due to increased accessibility via growing networks of forestry roads, and is an issue across all jurisdictions. This threat was ranked by the threats calculator as having a low impact.

Limiting Factors

Like most turtles, Wood Turtles are long-lived and vulnerable to acute and chronic increases in mortality of adults or older juveniles. Modelling studies suggest that a chronic annual increase in adult mortality rate as low as 1% can lead to extirpation of a population of Wood Turtles (Compton 1999). A southern Ontario Wood Turtle subpopulation experienced an acute poaching event in the mid-1990s that removed approximately 50% of the turtles (reference suppressed as sensitive information). PVA modelling using VORTEX indicates that without headstarting there was a 100% probability of extinction in 50 years (Mullin *et al.* n.d.). The subpopulation has been subjected to intensive intervention using a headstarting program since 2003. If the headstarting program ceased immediately (in 2018), or even 50 years after the start of the program (in 2053), there is still a 100% probability of extinction after 50 years (Mullin *et al.* n.d.). In addition, in 2017 and 2018, subsidized predation has increased mortality rates of wild adult and headstarted turtles, further impacting this already heavily managed subpopulation, and requiring implementation of a predator removal program (Litzgus pers. comm. 2018). In other turtle species with similar age of maturity and reproductive output, increases of 3-5% in annual rates of adult mortality can result in population declines (Enneson and Litzgus 2008, Spotted Turtle; Congdon *et al.* 1993, Blanding's Turtle).

Female Wood Turtles reproduce at most once per year, and lack the ability for compensatory recruitment if subpopulations decline (Brooks *et al.* 1991, 1992). Nesting success and survival of hatchlings over their first year are extremely low (usually between 0 - 30%) (Ernst and Lovich 2009). Over their entire lifespan, female Wood Turtles are likely to produce only a few offspring that survive to maturity.

Headstarting of hatchlings is underway in Ontario and Québec, but it will take several years for headstarting turtles to affect population trends (M. Malhiot pers. comm. 2004 in COSEWIC 2007; D. Mullin pers. comm. 2016). Headstarting programs on freshwater turtles, including Wood Turtles and Blanding's Turtles, are also underway in the United States; evaluations of these programs conclude that unless adult mortality is curbed, headstarting juveniles is ineffective as a conservation tool (Heppel *et al*. 1996; Spinks *et al.* 2003). Turtles have evolved in circumstances in which subpopulations experience high juvenile mortality but low adult mortality, and introducing large numbers of juveniles can only bolster a subpopulation if causes of adult mortality are rectified (Heppel *et al.* 1996; Spinks *et al.* 2003). Further, headstarted juveniles may be less vigorous, less acclimated to harsh wild conditions, or more accustomed to humans than their wild-born counterparts (Bolten *et al*. 1990; Spinks *et al*. 2003).

Number of Locations

"Location" is defined by COSEWIC as a geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the taxon present. The size of the location depends on the area covered by the threatening event and may include part of one or many subpopulations (see COSEWIC 2016 for full definition).

Transportation and service corridors – roads in particular – were identified as the most significant threat to Wood Turtle in Canada. While roads and the risks associated with them are ubiquitous across most of the species' range in Canada, as a threatening event, their impact on individuals/subpopulations is more local. The extent of that impact, in terms of long-term population viability, probably closely approaches the scale of most element occurrence records (EOs); counts of EOs were therefore used as a proxy for number of locations: 44(ON), 97(QC), 101(NB) and 122 (NS).

PROTECTION, STATUS, AND RANKS

Legal Protection and Status

Internationally, Wood Turtle is listed in Part 1 of the Schedule to the Wild Animal and Plant Trade Regulations, made under the Wild Animal and Plant Protection and Regulation of International and Interprovincial Trade Act (S.C. 1992, c. 52) (WAPPRIITA), which controls the trade of species listed under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES); this treaty requires an export permit for international trade in Wood Turtles.

Wood Turtle is listed as Threatened under the federal *Species at Risk Act* (SARA). SARA provides protection for individuals of threatened and endangered species, as well the areas that are identified as 'critical habitat' for those species. Critical habitat protection is generally only enforced on federal lands (e.g., military bases, national parks), although the federal government does have the ability to enforce critical habitat protection on provincial/private lands, if necessary. The SARA listing also necessitates the completion of a federal Recovery Strategy, which is currently being drafted. An Action Plan for the recovery of the species will be posted in or before 2021.

Wood Turtle is listed as Endangered on the Species at Risk in Ontario List under the Ontario *Endangered Species Act*, 2007 (ESA 2007). ESA provides protection for threatened and endangered species, as well as the habitat on which they depend, on all Crown and private land, but not on federal lands. Wood Turtle is also listed as a specially protected reptile under the Ontario *Fish and Wildlife Conservation Act*, which prohibits hunting, possessing, selling, purchasing, and taking of any listed such reptile for educational or scientific purposes except under the authority of a licence and subject to the regulations. Forestry activities within regulated habitat is regulate by the *Crown Forest Sustainability Act*. An Ontario recovery strategy was published in 2010, which was followed by the Government Response Statement later that year and a 'five-year review' in 2015.

In Québec, the Wood Turtle is listed as "Vulnerable" under the "*Loi sur les espèces menacées ou vulnérables*" (RLRQ, c E-12.01) (LEMV) (Act respecting threatened or vulnerable species) (CQLR, c E-12.01) (MRNF 2011) and is afforded protection under the "*Loi sur la conservation et la mise en valeur de la faune*" (RLRQ, c. C- 61.1) (LCMVF) (Act respecting the conservation and development of wildlife) (CQLR, c. C-61.1). Under

article 26 of the LCMVF, it is illegal to disturb, destroy, or damage the eggs or nest of an animal. It is also prohibited to capture, hunt, and/or keep in captivity any species of turtles that are native to Québec. The aquatic habitat of Wood Turtles in Québec is also indirectly protected by Article 128.6 of this same act (LCMVF). Because the Wood Turtle is an also an aquatic species, the "*Loi sur la qualité de l'environnement*" (RLRQ, c. Q-2) (Environment Quality Act) (CQLR, c. Q-2) generally, and more specifically through the "*Politique de protection des rives, du littoral et des plaines inondables*" (RLRQ, c. Q-2, a. 2.1) (Protection Policy for Lakeshores, Riverbanks, Littoral Zones and Floodplains) (CQLR, c. Q-2, a. 2.1), protects this species' aquatic habitat.

The Wood Turtle was listed as Threatened under the New Brunswick *Species at Risk Act* in 2013. The New Brunswick *Species at Risk Act* prohibits the killing, harming, harassment, collection, or sale of listed species and the protection of survival habitat. New Brunswick's *Fish and Wildlife Act* prohibits the collection, possession, and trade in all native vertebrate species. Forestry in New Brunswick is regulated by the *Crown Lands and Forests Act* on Crown lands. The New Brunswick *Clean Water Act* regulates activities within 30m of a watercourse, which helps protect the species' habitat.

In Nova Scotia the Wood Turtle is listed as Threatened under the Nova Scotia *Endangered Species Act,* which prohibits killing or disturbing species at risk, destroying or disturbing residences, and destroying or disturbing core habitat. Forestry in Nova Scotia is regulated by the *Forests Act*.

Non-Legal Status and Ranks

Internationally, Wood Turtle is considered Endangered (declining) by the International Union for the Conservation of Nature (IUCN). Its Global Rank is G3 (vulnerable). In the United States, the Wood Turtle is listed as N3 (vulnerable), and occurs (or occurred) in 19 states, where it ranges in rank from SH (presumed eliminated: 1 state + D.C.), S1 (critically imperilled: 1 state), S2 (imperilled: 6 states), S3 (vulnerable: 8 states), and S4 (apparently secure: 3 states) (Table 1). Note: these values include uncertainty ranges (e.g., S2S3).

Table 1. Global, national, and sub-national ranks of the Wood Turtle.

Region	Sub-region	Rank*
Global	---	G3
Canada	---	N3
	Ontario	S2
	Québec	S3
	New Brunswick	S3
	Nova Scotia	S3
United States	---	N3
	Connecticut	S3

Region	Sub-region	Rank*
	District of Columbia	SH
	Iowa	S1
	Maine	S4
	Maryland	S4
	Massachusetts	S3
	Michigan	S2S3
	Minnesota	S2
	New Hampshire	S3
	New Jersey	S2
	New York	S3
	Pennsylvania	S3S4
	Ohio	SH
	Rhode Island	S2
	Vermont	S3
	Virginia	S2
	West Virginia	S2
	Wisconsin	S3

*G- Global; N- National; S- Sub-national
1– Critically Imperilled; 2– Imperilled; 3- Vulnerable; 4- Apparently Secure; 5- Secure

Wood Turtle's Canadian ranking is N3 (vulnerable), and its sub-national ranks in the provinces are S2 (imperilled: Ontario) and S3 (vulnerable: Québec, New Brunswick and Nova Scotia) (Table 1).

Habitat Protection/Ownership

Approximately 2% of Wood Turtle habitat is located inside national parks and ~8% is located inside provincial parks, nationwide.

Approximately 2% of Wood Turtle occupancy is located inside Canadian Forces bases [CFB Petawawa, CFB Valcartier, and CFB Gagetown]. Public access to military bases is restricted in most cases, but the public can access portions of some bases with approval. Military bases are federal lands and all provisions of SARA apply. The Canadian Forces have strict regulations and protocols for the protection of Species at Risk on their properties, and personnel typically avoid any activities that might harm or kill Wood Turtles or damage their habitat.

A limited amount of habitat is located inside conservation properties owned by the Nature Conservancy of Canada. These NCC properties are primarily located in Ontario and Québec; one additional property with known Wood Turtle sightings is located in New Brunswick. Additionally, several Protected Natural Areas on New Brunswick Crown Land contain Wood Turtle habitat, and at least one Nova Scotia Nature Trust property protects Wood Turtle habitat in Nova Scotia. Collectively, these protected habitats probably represent less than 1% of the total habitat.

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BIOGRAPHICAL SUMMARY OF REPORT WRITER

Geoffrey Hughes completed his Honour's Bachelor of Science at Laurentian University in 2007, with a specialization in Wildlife and Habitat Ecology; he wrote his undergraduate thesis on the nest-site selection of Wood Turtles in northern Ontario. He also received a Graduate Diploma in Science Communication from Laurentian University in 2008. Geoffrey then spent the next eight years working for research projects and performing science outreach for universities, not-for-profits, and environmental consulting firms, primarily with SAR reptiles in Ontario. In 2014, he began a Master's thesis on the thermal ecology of Wood Turtles, working on the same population that he studied for his undergraduate thesis, graduating in 2016.

Appendix 1 - Threats Calculator.

Species or Ecosystem Scientific Name	*Glyptemys insculpta*
Element ID	180751
Elcode	
Date (Ctrl + ";" for today's date):	2017-04-13
Assessor(s):	Kristiina Ovaska (facilitator), Geoffrey Hughes (status report writer); provincial jurisdictions: Mary Sabine (NB), Maureen Toner (NB), Gabrielle Fortin (QC), Lauren Trute (ON), Alison Lake (ON), Jim Trottier (ON), Paul Gelok (ON), Jenn Hoare (ON); federal jurisdictions: Eric Tremblay (PC), Daniel Gallant (PC), Deanna McCullum (DND), Sylvain Giguère (CWS), Jean-Louis Provencher (PC); Other: Rachel White (Huron Stewardship Council); Amphibians and Reptiles SSC: Tom Herman (Co-chair), Connie Browne, Joe Crowley, Chris Edge, Jackie Litzgus; COSEWIC Secretariat: Bev McBride
References:	Draft COSEWIC status report (Jan2017)

Overall Threat Impact Calculation Help:

Threat Impact		**Level 1 Threat Impact Counts** high range	low range
A	Very High	0	0
B	High	0	0
C	Medium	2	1
D	Low	7	8
Calculated Overall Threat Impact:		High	High

Assigned Overall Threat Impact:	**B = High**
Impact Adjustment Reasons:	
Overall Threat Comments	Assumptions: Generation time 35 years. Assessments, particularly for i) Agriculture (annual & perennial non-timber crops), ii) Roads, and iii) Problematic native species are considered by some reviewers to be overly conservative.

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	Residential & commercial development	D	Low	Small (1-10%)	Serious (31-70%)	High (Continuing)	
1.1	Housing & urban areas	D	Low	Small (1-10%)	Serious (31-70%)	High (Continuing)	This assessment includes cottages. The threat was perceived to be negligible in ON, but small-to-restricted in QC, NB and NS. WOTU live primarily in remote or agricultural areas.
1.2	Commercial & industrial areas		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	Wood Turtles live primarily in remote or agricultural areas. The threat was considered to be negligible in ON and QU, negligible-small in NS, and small in NB.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
1.3	Tourism & recreation areas		Negligible	Negligible (<1%)	Moderate - Slight (1-30%)	High (Continuing)	Several subpopulations found in public-access parks; boating activities potentially reveal locations as well as resulting in incidental collection (captured in 6.1).
2	Agriculture & aquaculture	CD	Medium - Low	Large - Restricted (11-70%)	Moderate (11-30%)	High (Continuing)	
2.1	Annual & perennial non-timber crops		Medium - Low	Large - Restricted (11-70%)	Moderate (11-30%)	High (Continuing)	This category includes preparation and mowing of fields, which can be a source of habitat loss and casualty for Wood Turtle. There was variability in the extent to which subpopulations overlap agricultural areas, but the risk was perceived as significant in all jurisdictions. Many subpopulations in southern Ontario, Québec, southern New Brunswick and Nova Scotia are in contact with agriculture; conflicts in some NB and NS subpopulations arise from mowing adjacent to riparian areas.
2.2	Wood & pulp plantations						
2.3	Livestock farming & ranching	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	Cropland agriculture is more of an issue; limited riparian disturbance by livestock in some NS and NB subpopulations, which may trample nests and destabilize streambanks.
2.4	Marine & freshwater aquaculture						No conflicts reported to date.
3	Energy production & mining	D	Low	Small (1-10%)	Serious - Moderate (11-70%)	High (Continuing)	
3.1	Oil & gas drilling						
3.2	Mining & quarrying	D	Low	Small (1-10%)	Serious - Moderate (11-70%)	High (Continuing)	Gravel quarries a common source of conflict in Ontario. Some active extraction pits are used by nesting females. This is a primary threat in some northern Ontario sites and a local threat in NB and NS.
3.3	Renewable energy						Wind turbines generally rare in Wood Turtle habitat; only one windfarm development (Algoma Highlands) reported as potential threat.
4	Transportation & service corridors	C	Medium	Pervasive (71-100%)	Moderate (11-30%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
4.1	Roads & railroads	C	Medium	Pervasive (71-100%)	Moderate (11-30%)	High (Continuing)	This includes both roadkill and habitat loss. Subpopulations in remote areas are less vulnerable than those in more populated areas. While participants on the call did not reach consensus on the impact, it was observed, and there are data to support, that forestry access roads are more problematic than secondary highways in Ontario (particularly eastern and central ON). Secondary highways in NB and NS that parallel watercourses are problematic. Some participants noted concern that the threat level is higher in some locations than is indicated by the severity score. There was agreement that more data and analysis on mortality on forest and other access roads would be helpful. Adult females experience a higher impact from roads than other demographic groups, due to nesting migrations and use of road surfaces and shoulders for nesting.
4.2	Utility & service lines		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Vegetation management beneath hydro lines was identified as a limited issue in ON and QU.
4.3	Shipping lanes						
4.4	Flight paths						
5	Biological resource use	D	Low	Large (31-70%)	Slight (1-10%)	High (Continuing)	
5.1	Hunting & collecting terrestrial animals	D	Low	Large (31-70%)	Slight (1-10%)	High (Continuing)	Commercial poaching for illicit pet trade is identified as a threat to the species throughout the range, but the Incidence is likely lower than that of local collection for casual pets. Evidence from turtles captured in studies across the species range (e.g., holes through shells) indicates that they had previously been kept as pets. Large-scale commercial collection is an event of low probability but high consequence. This threat is likely to increase with increasing road density in remote areas and increasing recreational activity, including boating, which elevates risk of collection (Garber and Burger (1995).
5.2	Gathering terrestrial plants						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
5.3	Logging & wood harvesting	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	This excludes the impact of forestry roads (captured in 4.1), which probably have more of an impact than harvesting, due to low frequency of harvesting and seasonal restrictions on harvesting activity. Forest harvesting and Wood Turtle often coincide in northern ON, NS, and NB. The scope and severity are mostly due to habitat loss, not to harvesting activities directly. There was some uncertainty around the severity of those impacts depending on the extent of clearcutting and the extraction methods employed.
5.4	Fishing & harvesting aquatic resources						Unlikely as a direct source of conflict, but may lead to incidental encounters which may result in turtles being collected.
6	Human intrusions & disturbance	D	Low	Large (31-70%)	Slight (1-10%)	High (Continuing)	
6.1	Recreational activities	D	Low	Large (31-70%)	Slight (1-10%)	High (Continuing)	This includes fording of rivers by off-road vehicles (ATVs/trucks). ATV use is an issue across all jurisdictions, including southern and eastern ON (e.g., Algonquin Park). ATVers are the primary users of forestry roads.
6.2	War, civil unrest & military exercises		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	Wood Turtles occur on CFB Gagetown (NB), Petawawa (ON), and possibly Val Cartier (QC). At CFB Gagetown, base personnel are very aware of the species and avoid damaging habitat as much as possible; an array of effective mitigation measures is in place to minimize any disturbance.
6.3	Work & other activities		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	Handling associated with scientific research.
7	Natural system modifications	D	Low	Restricted - Small (1-30%)	Moderate - Slight (1-30%)	High (Continuing)	
7.1	Fire & fire suppression		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	
7.2	Dams & water management/ use		Unknown	Small (1-10%)	Unknown	High (Continuing)	Potential impacts due to Wood Turtle being a riverine species; some Wood Turtle watersheds do have dams and impoundments.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
7.3	Other ecosystem modifications	D	Low	Restricted - Small (1-30%)	Moderate - Slight (1-30%)	High (Continuing)	Adjacent land uses (particularly those involving extensive land clearing) impact the flow regimes in rivers, particularly increasing the frequency and severity of flooding events. Significant flow impacts exist in two watersheds containing the largest populations in Nova Scotia, which are influenced primarily by agriculture and secondarily by forestry. Remote Wood Turtle habitat is often popular for growing cannabis, but the impact on the species is unknown.
8	Invasive & other problematic species & genes	D	Low	Large (31-70%)	Slight (1-10%)	High (Continuing)	
8.1	Invasive non-native/alien species/ diseases						
8.2	Problematic native species/ diseases	D	Low	Large (31-70%)	Slight (1-10%)	High (Continuing)	Subsidized predators (Raccoons, Red Foxes, skunks, Common Ravens) are common predators of individuals and nests, and are potentially a high impact threat.
8.3	Introduced genetic material						Species is known to hybridize with Blanding's Turtle in captivity, but this is unreported in wild populations.
8.4	Problematic species/diseases of unknown origin						Few significant disease threats reported in Wood Turtle to date; one subpopulation has reported necrotic shell disease, herpes and ranaviruses (Litzgus pers. comm. 2018)
8.5	Viral/prion-induced diseases						"
8.6	Diseases of unknown cause						"
9	Pollution		Unknown	Large (31-70%)	Unknown	High (Continuing)	
9.1	Domestic & urban waste water		Unknown	Small (1-10%)	Unknown	High (Continuing)	Potential issue, as Wood Turtle is riverine and effluents may be released into streams; no specific instances reported to date.
9.2	Industrial & military effluents						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
9.3	Agricultural & forestry effluents		Unknown	Large (31-70%)	Unknown	High (Continuing)	Agriculture is the most likely source of effluents, but no specific instances reported to date. Sedimentation from bridge construction, forestry activities and river fording (by off-road vehicles and livestock) may be locally significant, particularly for overwintering turtles.
9.4	Garbage & solid waste						May not be an issue for remote subpopulations, but subpopulations in more human-dense areas may have litter in the watershed; specific impact is unknown
9.5	Air-borne pollutants						Potential issue with precipitation-borne pollutants working their way into the ecosystem; Sudbury population probably best case study
9.6	Excess energy						
10	Geological events						
10.1	Volcanoes						
10.2	Earthquakes/ tsunamis						
10.3	Avalanches/ landslides						
11	Climate change & severe weather	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	
11.1	Habitat shifting & alteration						
11.2	Droughts						Wood Turtle highly dependent on rivers for hibernation; droughts would be high impact; may negatively impact Wood Turtle summer food resources.
11.3	Temperature extremes						Genetic sex determination means Wood Turtle less likely to be impacted than other turtle species.
11.4	Storms & flooding	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	[This is additional to 7.3]. Floods could potentially destroy nests in subpopulations that nest close to river; frequent floods could reduce recruitment significantly and disrupt water flow regimes in overwintering sites. SW Ontario reports increasing number of juveniles killed by flooding in recent years.
11.5	Other impacts						Warmer, drier summers, predicted in at least eastern part of the species range could reduce fungal populations, a major summer food source for Wood Turtle